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PRIORITIES FOR CONSERVING BIODIVERSITY ON EUROPEAN ISLANDS

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INTRODUCTION

Islands are special places for biodiversity. Worldwide they hold a significant proportion of global biodiversity and a high proportion of threatened species. Islands form the home of large numbers of endemic species and provide breeding areas for many pelagic species. Their extensive coastlines, varied and unique habitats and isolation make them distinct from mainland sites and enhance their value to biodiversity. Islands are also vulnerable to a range of threats, in many cases more pronounced than for mainland areas. These include invasive alien species, habitat loss, over-exploitation of their resources, climate change and pollution. Together, these unique features and threats make islands particularly vulnerable, island species form the majority of extinctions in the last century and this trend is continuing. Nevertheless, given their conservation risks, smaller land areas, and high levels of endemic richness, islands offer particularly high returns for species conservation efforts and therefore warrant a high priority in global biodiversity conservation in this century. (Kier et al 2009)

Even though islands only make up around 5% of world land area, 15% of all mammal, bird and amphibian species are island endemics. Islands contain 20% of vascular plant diversity, 25% of priority ecosystems, 29% of terrestrial biodiversity hotspots, 33% of threatened mammals, birds and amphibians, 48% of endemic bird areas and 70% of coral reef hotspots. (Roberts, et al 2002, Birdlife, Conservation International 2006, Fonesca, Mittermeier and Mittermeier 2006). Clearly they contain biological resources far beyond that expected from their size. The rates of extinctions are similarly high for islands worldwide, accounting for 35% of recent plant species losses, 45% for insects, 61% for mammals, 81% for birds and 95% of reptile extinctions. (Baillie, Stuart and Hilton-Taylor 2004, Sax and Gaines 2008).

Islands are recognised as needing especial attention if their biodiversity is to be conserved. The conservation and sustainable use of marine and terrestrial biodiversity in and around European islands is recognised within the Bern Convention and in a wide array of national and international instruments, policies and initiatives, most notably the Convention on Biological Diversity with its Programme of Work on Island Biodiversity and the closely linked Global Island Partnership (GLISPA).

The Bern Convention's Programme of Work on Island Biodiversity has created an Expert Group on European Island Biological Diversity. This has a number of objectives:

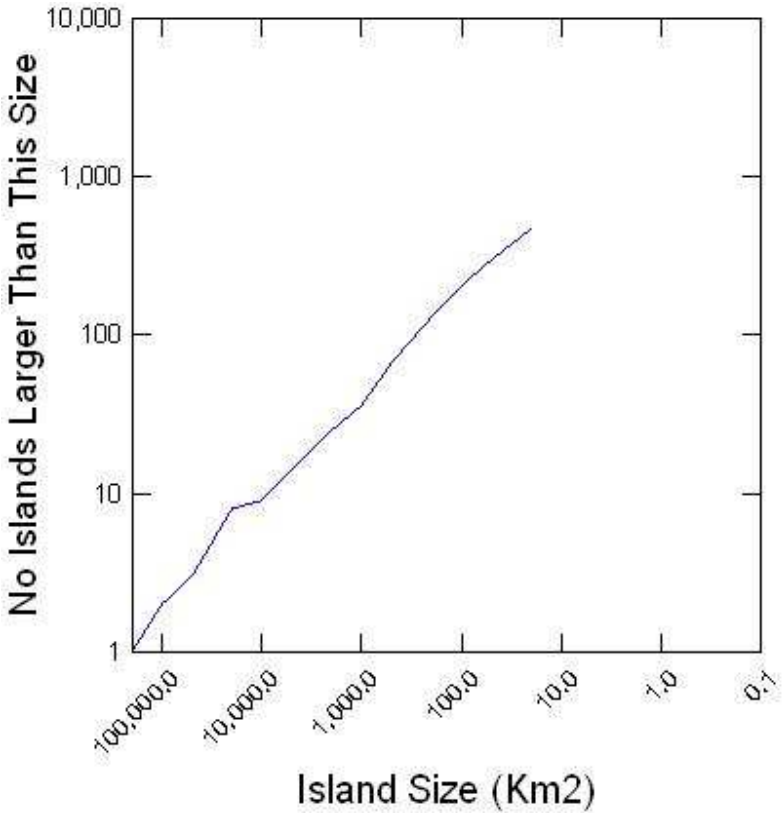
- To improve Network conservation work in European islands.
- To contribute positively to the island programme of work of the Convention on Biological Diversity by bringing the views, expertise and problems of European islands.
- To assist Bern Convention governments on specific conservation issues of European islands.
- To propose common guidelines and tools that may be used to improve conservation of European islands.
- To analyse threats to biodiversity that may present greater challenges in islands than in the continent.
- To foster national conservation work on islands.

This group supported the preparation and subsequent adoption of a Charter on the Conservation and Sustainable Use of Biological Diversity in European Islands (de Soye 2011). The Charter establishes the principles on which strategy and actions should be based. This paper should be read in conjunction with the draft Charter and explores the detail that underpins these principles and the actions that flow from this. It focuses on those aspects of biodiversity that are unique or especially prominent on European islands compared to the continental mainland. It reviews the nature and extent of these unique features and considers how these are specifically impacted by current threats to island ecosystems. From this it identifies priorities and actions which might therefore require special attention, not otherwise explicit in Europe wide biodiversity legislation or current activities.

THE EUROPEAN ISLAND RESOURCE

The marine islands of Europe include those located in the Baltic, North and Mediterranean Seas, as well as in the northern and eastern Atlantic Ocean. Islands in rivers or inland water bodies are beyond the scope of this work. Europe covers a large geographical area spread over 35° of latitude and including many bio-geographical and climatic zones. Within this, islands form entire countries, extensive and interconnected archipelagos or feature as small isolated fragments of land, valuable by nature of their isolation. The islands of Europe range from Svalbard and the northern Russian islands within the Arctic Circle, to Iceland, the Faroes and the northern coast of Scandinavia. Great Britain and Ireland form the largest European island complex by area, with significant subsidiary archipelagos such as the Hebrides, Orkney and Shetland. The North Sea and Baltic contain a wide range of islands, while the western Atlantic coast contains modest numbers of small coastal islands. Further west, the Azores and Canary islands in the Atlantic provide particularly isolated groups. The largest number of islands sit within the Mediterranean basin, including major islands such as Corsica, Sardinia, Sicily, Malta, Cyprus and Crete, together with large numbers of smaller Greek and Adriatic islands.

Europe includes around 500 islands larger than 20 km² and altogether they represent more than 7% (700,000 km²) of Europe's land area. Data on the total number of smaller islands is hard to obtain, but examination of the distribution of islands for those over 20 km² in size suggests a predictable increase in island number as size decreases. Extrapolation from this suggests there may be as many as 2000 islands of at least 1 km^2 in size, or possibly 10,000 with an area of over 100 ha.



The relationship between number of European islands and their size, based on those of over 20 km² in area. Data from http://en.wikipedia.org/wiki/List_of_European_islands_by_area.

The islands of Europe include a range of distinct types. Those in the Mediterranean together with the Macaronesian islands in the Atlantic have a long history of isolation from the mainland, and have developed a rich endemic fauna and flora as a consequence. Meditteranean islands have been inhabited for at least 8,000 years and their habitats have been largely influenced by agriculture and development.

More recently, tourism has placed significant pressure on the region's coastal ecosystems. The shores of the Mediterranean are the biggest large-scale tourist attraction in the world, with 110 million visitors arriving per year, a figure that is expected to double in the next two decades. As a consequence these islands have experienced significant habitat loss and increased resource use in recent decades. Their typically dry climates and increasing needs for water resources also place particular pressures on wetland habitats, and this trend is likely to increase in the face of climate change.

By contrast islands in Northern European have undergone glaciation in the last 10,000 years. As a consequence they demonstrate low rates of endemism and reduced species diversity due to sporadic recolonisation from the European mainland. For example, mainland Britain contains fewer mammal and bird species compared to similar latitudes in mainland Europe, and Ireland continues this trend with fewer species again (Costello and Kelly 1993). This trend continues for smaller islands and archipelagos, with many islands containing greatly reduced faunas. These can include the absence of major predatory species such as mustelids, canids or rodents, resulting in communities with limited predator guilds. In turn, these can often be associated with high densities of species vulnerable to predation, such as concentrations of ground nesting birds that can be of international importance. Many of these islands, especially in the northern Atlantic and Arctic, represent globally relevant feeding and breeding areas for birds and marine mammals, providing key refuges for threatened species, and in addition are home to important marine living resources (EEA 2002-2008). These unique if impoverished species assemblages are particularly vulnerable to the introduction of new species, either invasive aliens or species native to the neighbouring mainland but which failed to colonise naturally after glaciation.

WHAT IS UNIQUE ABOUT BIODIVERSITY ON ISLANDS?

The value of islands for biodiversity differs from mainland or continental areas in a number of important ways. These are features that are either unique to islands, or over-represented on them, such that they may require special treatment or consideration to protect them. While there are a range of policies and structures in place to protect or enhance biodiversity throughout Europe, for example the protected area networks, the special characteristics of islands may require additional actions.

The special features of islands can be considered under five headings.

- Endemism
- Breeding Colonies
- Refugia
- Migration Points
- Special Habitats

Endemism.

Islands are by their nature isolated, separated from other land masses by stretches of water. Populations with low dispersal abilities can therefore become reproductively isolated with little exchange of genetic material between neighbouring islands or mainland areas. This isolation can lead to high rates of endemism, or more specifically neoendemism, on islands. This is where a species has become reproductively isolated and diverged from the original stock to form a new species. When compared to mainland areas, islands in general are known for their high percentage of endemic species but only moderate levels of species richness, prompting the question of their relative conservation value.

Endemism is particularly common in plants, reptiles and mammals, less so for insects and relatively uncommon in birds, reflecting the different dispersal abilities of the types. Nevertheless, islands that are rich in endemics for one group tend to also be rich in other types. For example endemism richness of plants and vertebrates is strongly related, and values on islands exceed those of mainland regions by a factor of 9.5 and 8.1 for plants and vertebrates, respectively. (Kier et al 2009).

In the European context, endemism is particularly pronounced in the Mediterranean and Macaronesian regions where a long history of isolation and the absence of recent glaciation has led to

large numbers of endemics. In the Canary Islands up to 70% of some taxa (e.g.beetles) are known to be endemic. On the Mediterranean islands of Corsica, Crete and Cyprus, endemic plants make up 12%, 10% and 7% of the respective floras. (Machado 1998, Orueta 2009). Amongst Mediterranean islands, Malta contains the highest number of endemic species, including 24 plant, two butterflies, a land snail together with four reptiles and amphibians (Conservation International 2006).

Of the 22,500 species of vascular plants in the Mediterranean basin, approximately 11,700 (52 percent) are found nowhere else in the world. The endemics are mainly concentrated on islands, peninsulas, rocky cliffs, and mountain peaks. Endemism at the higher level is very reduced, with only two endemic families, both represented by single species (Conservation International 2006). Montmollin and Strahm (2005) list the 50 Mediterranean endemic plants in greatest need of conservation efforts, many of which are restricted to islands.

The Mediterranean basin also harbours a high degree of tree richness and endemism (290 indigenous tree species with 201 endemics). The only palm native to the Mediterranean, *Phoenix theophrasti*, is found in a tiny part of Crete and on Turkey's Datca Peninsula, two areas of the Mediterranean Basin experiencing substantial tourism development. Of the 440 butterfly species in Europe, 45 are endemics confined to islands (Dennis et al 2008).

There are more than 225 reptile species in the Mediterranean basin, nearly 80 (34 percent) of which are endemic. There are also four endemic genera, namely *Algyroides, Trogonophis, Macroscincus,* and *Gallotia (*the last being a genus of lizard unique to the Canary Islands). (Conservation International 2006)

European islands also appear as priorities in BirdLife International's global analysis of Endemic Bird Areas (EBAs), namely Cyprus, Madeira, and the Canary and Cape Verde Islands. Endemic birds include the Raso Island lark (*Alauda razae*) in the Cape Verdes; the Balearic shearwater (*Puffinus mauretanicus*), and the Madeira or Zino's petrel (*Pterodroma madeira*), which has an estimated breeding population of only 20-30 pairs in the central mountain massif of that island. The Canary Islands and Madeira are home to eight endemic species, including three endemic laurel pigeons (Conservation International 2006)

A range of island endemic mammals have been lost since the Pleistocene, although whether these were due to human activities or climate change remains uncertain. These have included a series of dwarf hippopotami (*Hippopotamus*) native to Crete, Cyprus, Malta and Sicily together with dwarf elephants (*Palaeoloxodon*) from a similar range of islands. Other Pleistocene losses include the Sardinian dhole (*Cynotherium sardous)* and Tenerife giant rat (*Canariomys bravoi).*

Mediterranean islands have also suffered a number of notable extinctions more closely associated with human settlement during the Holocene. These have included endemic giant shrews in the Balearics (*Nesiotites hidalgo)* and Sardinia *(N. similis);* a Balearic cave goat (*Myotragus balearicus*); giant dormice in Majorca *(Hypnomys morphaeus)* and Minorca *(H. Mahonensis);* a Cretan dwarf megacerine (*Candiacervus cretensis);* the Irish elk (*Megaloceros giganteus);* Majorcan hare (*Lepus granatensis solis);* Sardinian lynx (*Lynx lynx sardinia);* Sardinian pika *(Prolagus sardus)* and St Kilda house mouse (*Mus musculus murali).* Three island birds have become extinct in Europe, the Great Auk, (*Pinguinus impennis)* last seen in Iceland, together with the Ibiza rail, (*Rallus eivissensis)* and Faroe Island pied raven, (*Corvus corax varius morpha leucophaeus).* Two endemic reptile species, the Ratas Island lizard, (*Podarcis lilfordi rodriquezi)* and the Santo Stefano lizard, *(Podarcis sicula sanctistephani)* have also been lost. (Baillie, Stuart and Hilton-Taylor 2004, Fontaine et al 2007)

Breeding Colonies.

Islands provide the main sites for breeding congregations and colonies of certain species, particularly seabirds and turtles. These are species that feed at sea but need to nest on land, and large numbers can therefore concentrate in a few small sites. The presence of such colonies is more than just a consequence of the high proportion of coastline; islands offer unique resources for these species, including low levels

of disturbance and predation. Although it is difficult to quantify, it is clear that the majority of European populations of pelagic seabirds breed on islands.

The waters off the coast of Norway and in the Barents Sea are among the most productive in the world and are reputed to support c. 7.7 million pairs of breeding seabirds , about 2.7 million pairs breed along the mainland coast of Norway north of the Arctic Circle and the remaining 5 million breed on Svalbard, Franz Josef Land, Novaya Zemlya and the Russian mainland coast. (Barrett, Lorentsen and Anker-Nilssen 2006)

Britain and Ireland host around 2-2.5m breeding auks and 2.5-3m pairs of other seabird species totalling 14 species that breed regularly. In terms of international status, the seabird community of these islands is of considerable importance (Lloyd, Tasker and Partridge 1991)

In the Azores, the five breeding seabird species that once bred on the main islands, are now restricted to small islets and large population declines have been inferred from historic levels. Current threats to the Azores seabirds range from predation by introduced mammals, human disturbance and exploitation, habitat loss due to invasive alien plants and overgrazing by rabbits, and, potentially, competition with fisheries. (Monteiro, Ramos, and Furness 1996).

The total marine bird biomass, and species diversity are lower in the Mediterranean than in the near Atlantic. The eastern Mediterranean, with lowest primary productivity, contains fewer marine bird taxa than the more productive western part (Zotier, Bretagnolle, and Thibault 1999).

Islands also provide nesting sites for marine turtles, particularly along undisturbed sandy beaches. Broderick et al (2002) estimate that there are 2,280–2,787 logger-head and 339–360 green turtles nesting annually at sites in the Mediterranean, predominantly on islands. This highlights the critically endangered status of this population of green turtles.

Refugia.

The isolation of islands enables them to act as refugia for species that were once widespread but are now excluded from many parts of their previous range. This effect, known as paleoendemism, is less common in Europe than neoendemism, but is still an important effect. This is particularly true as species are excluded from the European mainland by agricultural intensification or the introduction of invasive alien species. As a consequence, the importance of islands as refugia is likely to increase through time. For example, the Corncrake (*Crex crex*), once widespread in Britain, underwent dramatic declines following the intensification of grassland management systems (Green and Stowe 1993). They are now only found in numbers on the islands off the north and west of Scotland, the Hebrides and the far north-west mainland where more traditional grassland management still remains. The Corncrake, at least within Britain, has virtually become an island paleoendemic. The same is likely to become true for the red squirrel (*Sciurus vulgaris*) which is being displaced on mainland Britain by the North American grey squirrel (*Sciurus carolensis*) (Gurnell et al 2004). Although efforts are underway to slow the spread of the invader and to preserve mainland populations of the red, it is conceivable that the red squirrel may become restricted to island refugia in Britain. Geoendemic populations of red squirrels now exist on Brownsea Island on the English south coast while efforts are underway to keep Anglesey in North Wales free of grey squirrels to act as a refugia for the reds. The introduction and subsequent spread within mainland Europe of *S. carolensis* from sites in northern Italy threatens the same pattern of native species loss on the continent (Bertolini and Genovesi 2003). As a consequence, European islands may also become increasingly important as refuges for native squirrels and other species excluded from mainland areas.

Migration Points.

Islands provide stopping points for migrating animals, including birds, butterflies and sea mammals. In the expanses of the sea they provide resting areas, feeding points and protected areas from storms or weather. The importance of migration points has long been recognised, bird observatories have typically been built on islands or headlands where migrating birds first touch-down after their passage. The Bern

Convention also requires parties to *'ensure the conservation of the habitats of wild flora and fauna species as well as of endangered natural habitats; and give particular attention to the protection of areas of importance for migratory species.'*

A total of nearly 500 bird species are found in the Mediterranean Basin, and many more migrate through the region, crossing the Mediterranean at Gibraltar, Sicily, the Balearic Islands, Corsica, Sardinia, Crete, and Cyprus. The populations of some migratory birds may be limited by conditions encountered on migration. This could occur at stopover sites where competition for restricted food supplies can reduce subsequent survival or breeding success. When preparing for migration, birds must normally obtain more food per day than usual, in order to accumulate the body reserves that fuel their flights. Birds often concentrate in large numbers at particular stopover sites, where food can become scarce, thus affecting migratory performance. Rates of weight gain, departure weights, and stopover durations often correlate with food supplies at stopover sites, sometimes influencing the subsequent survival and reproductive success of individuals, which can in turn affect subsequent breeding numbers. In some bird species, migration-related events can at times have substantial effects on the year-to-year changes in breeding population levels. However, the difficulties involved in studying migrating birds at different points on their migration routes have so far limited the number of studies on the influence of events during migration periods on population levels (Newton 2006). Although direct evidence is scarce, is seems likely that islands and the foraging opportunities they provide can help sustain migratory bird populations.

Butterflies and moths also migrate across Europe and from North Africa, making use of the same island stop-over points as birds. Some such as the red admiral, painted lady, clouded yellow butterflies together with the humming-bird hawk moth and silver-y moth recolonise Britain and Ireland every year from Southern Europe or even North Africa. They breed in northern regions in summer, raising generations which then return south or typically perish when winter begins (Pollard et al 1998). Although unquantified, it is likely that islands also play a role in assisting their migration.

Cetaceans can also rely on islands for certain elements of their ecology. They can provide shallow sheltered seas for breeding, while oceanic islands are also often associated with water upwellings, increasing water nutrient content and the local value as foraging grounds. These can be features contributing towards the selection of island waters as marine protected areas. (Notarbartolo-di-Sciara 2008).

Special Habitats.

Islands can contain unique habitats absent or under-represented on mainland areas. They can also contain a high diversity of habitats in a very small area. For example, islands contain a high proportion of the total length of the European coastline. No figures are available on total coastline length, which is a fractal so difficult to measure in absolute terms, but estimates be derived for the proportion of coastline in Britain derived from the British mainland or major offshore islands. This suggests major islands provide 11% of the coastline of England, 22% for Wales and 64% for Scotland. http://www.cartography.org.uk.

Within coastal areas there are typically a wide variety of habitats with known high species

diversity such as sea grass beds , coastal sedimentary habitats, mangal and coral reefs. Losses of marine diversity are also highest in coastal areas largely as a result of conflicting uses of coastal habitats. These threats are: habitat loss; global climate change; overexploitation and other effects of fishing; pollution (including direct and indirect effects of inorganic and organic chemicals; eutrophication and related problems such as pathogenic bacteria and algal toxins; radionuclides); species introductions/invasions; water-shed alteration and physical alterations of coasts; tourism; marine litter; and the fact that humans have little perception of the oceans and their marine life. The threats are frequently interlinked. (Gray 1997)

Islands can also contain habitats rare on the mainland. For example machair is a fertile low-lying grassy plain habitat found on some of the north-west coastlines of Ireland and Scotland, but particularly on the islands of the Outer Hebrides, only 6% of machair is found on the Scottish mainland, the remainder

is confined to islands. Machair is a former beach left higher in elevation than the current adjacent coast, the high seashell content of their soils leading to their high fertility. Machair has a high value for biodiversity, housing rare carpet flowers such as Irish Lady's Tresses, orchids and Yellow Rattle along with a diverse array of bird species including the corncrake, twite, dunlin, redshank and ringed plover, as well as rare insects such as the northern colletes bee (Angus 1997).

Islands contain unique habitats of their own, for example the Laurel-leaved forests of Macaronesia which once covered most of the Azores, Madeira, and parts of the Canaries between 400–1200 m in altitude. These are now threatened but contain a range of tree genera once more widespread through the Mediteranean basin before the last ice age.

WHAT ARE THE THREATS TO ISLAND BIODIVERSITY?

Islands may have high value for biodiversity, but they are also particularly vulnerable to a wide range of threats. These may be common to all habitats and ecosystems, but the nature of islands can make them particularly prone to damage. The threats to biodiversity can be considered under five broad headings:

- invasive alien species
- habitat loss
- climate change
- over-exploitation
- pollution

Invasive Alien Species

These are species introduced by human activity. They have some of the most dramatic effects on isolated ecosystems such as islands and are a leading cause of species extinctions. Islands are more prone to invasion by alien species because of the lack of natural competitors and predators that control populations in their native ecosystems. In addition, islands often have ecological niches that have not been filled because of the distance from colonizing populations, also increasing the probability of successful invasions.

The arrival of humans on oceanic islands has precipitated a wave of extinctions among the native birds of the world's islands. Blackburn et al (2004) show that the probability that a bird species has been extirpated from an island is positively correlated with the number of exotic predatory mammal species present. They also show that the effect is greater on island endemic species. In contrast, the proportions of currently threatened species are independent of the numbers of exotic mammalian predator species, suggesting that the principal threat to island birds has changed through time as species susceptible to exotic predators have been driven extinct.

Amongst Mediterranean islands, the presence of introduced ship rats has been shown to be a limiting factor in the abundance of the storm petrel (*Hydrobates pelagicus*) (Ruffino et al 2009). Within the Mediterranean and Canaries, introduced rats are known to predate the seeds of endemic plants and their presence can lead to changes in the native flora and vegetation composition of the islands (Traveset et al 2009).

Genovesi (2005) identified 37 eradications of invasive alien species in Europe, of which 33 were carried out on islands. Amongst these, 67% were targeted at rats (Rattus spp.). In many cases, these eradications produced a significant recovery of native biodiversity. No eradications of alien invertebrates and marine organisms were recorded; while for invasive alien plants, the only examples were localised removals.

The removal of an invasive predator from an island can often have dramatic effects. Nordstrom et al (2003) removed introduced American Mink (*Mustela vison*) from small islands in the Baltic and found increases in breeding seabirds, waders and passerines.

Invasive plants and grazing species have both also had profound effects on island habitats, with the two often operating in a synergistic manner to produce large scale and long-term changes in native vegetation (Schofield 1989). These invasive species effects can be a major factor threatening endemic plants on Mediterranean islands (Montmollin and Strahm 2005)

Eradications of invasive species often have striking positive effects on native biota. However, species removal in isolation can also result in unexpected changes to other ecosystem components. These secondary effects become more likely as the numbers of interacting invaders increase in ecosystems, and as alien species in the late stages of invasion eliminate native species and replace their functional roles. Food web and functional role frameworks can be used to identify ecological conditions that forecast the potential for unwanted secondary impacts. Integration of eradication into a holistic process of assessment and restoration will help safeguard against accidental, adverse effects on native ecosystems. (Zavaleta, Hobbs and Mooney 2001)

Habitat Loss

The Mediterranean Basin has experienced intensive human development and impact on its ecosystems for thousands of years, significantly longer than any other biodiversity hotspot. Human settlements of various forms have existed in the area for at least 8,000 years. The greatest impacts of human civilization have been deforestation, intensive grazing and fires, and infrastructure development, especially on the coast. Historically, Mediterranean forests were burned to create agricultural lands and intensification has especially affected European countries. The agricultural lands, evergreen woodlands and maquis habitats that dominate the area today are the result of these anthropogenic disturbances over several millennia. Paradoxically, grazing and fire can maintain species richness, while in their absence, closed forests are often less diverse. However, only five percent of the original extent of the hotspot contains relatively intact native vegetation, placing the Mediterranean Basin among the four most significantly altered biodiversity hotspots on Earth (Conservation International 2006)

Tourism development has placed significant pressure on the region's coastal ecosystems. The shores of the Mediterranean are a major tourist destination and their numbers are expected to double in the next two decades. The construction of infrastructure and the direct impacts of people are a major cause of habitat, For example, trampling of sensitive dune ecosystems remains a key threat to coastal areas including Cyprus the Balearics, Corsica, Sardinia, Sicily, Crete, and the Canary and Madeira Islands. (Conservation international 2006)

The destruction and degradation of Mediterranean wetlands threaten widespread species such as the Dalmatian pelican (*Pelecanus crispus*), which winters in the eastern parts of the hotspot, marbled teal (*Marmaronetta angustirostris*) and ferruginous duck (*Aythya nyroca*). These wetlands are also important for wintering and migrating species like the slender-billed curlew (*Numenius tenuirostris*), which travels between Africa and its Siberian breeding grounds each year.

Kier et al (2009) found that, while island and mainland regions suffered equally from past habitat loss, their measure of human impact, a measure of current threat, was significantly higher on islands. Projected land-cover changes for the year 2100 indicate that land-use-driven changes on islands might strongly increase in the future. Given their conservation risks, smaller land areas, and high levels of endemism richness, islands may offer particularly high returns for species conservation efforts and therefore warrant a high priority in global biodiversity conservation in this century.

Climate Change

Climate change is widely expected to become the greatest threat to global biodiversity in the course of the 21st century and deserves special attention on islands. Island biotas, both inside and outside Europe, are highly sensitive to climate changes due to their isolation and ecological characteristics. While some changes may be mitigated by the buffer effect of the surrounding seas, others are prone to cause severe impacts. In this context it is worth highlighting that biodiversity may be impacted both directly and indirectly from climate change.

Climate change may lead directly to changes in the physical and living natural environment. These include changes in average and extreme air and sea temperatures; precipitation; wind and weather patterns, including extreme events such as storms, floods and droughts. These changes may have consequences such as changing the availability and seasonality of freshwater resources; land and polar sea ice melting, sea level rise and greater surge power, coastal erosion; ocean currents; fire frequencies; ecosystems and ecological communities and interactions; spread and abundance of IAS and ocean acidification

There are also indirect consequences through societal response measures, most notably those undertaken in the context of climate change adaptation and mitigation. These include building of water dams and changes in water regimes; building of coastal protections; eradication of human pathogens by pesticides and draining of wetlands; changes in agricultural practices such as irrigation and livestock grazing; relocation of coastal tourism infrastructures; new transport infrastructures; increase in onshore and offshore energy infrastructures and marine geo-engineering.

Climate change also has the potential to decrease the niches available to some species (Thomas et al 2004). For example plants are by their nature relatively immobile, in the face of climate change they will find it difficult to change altitude if the species relies on specific ecological conditions. Island floras also have limited scope to migrate horizontally, especially on small islands, greatly increasing the possibility of species extinctions (Montmollin and Strahm 2005).

The evidence for direct impacts of climate change on European island biodiversity is still relatively small and there remains significant uncertainty regarding the vulnerability of European islands to climate change. Projecting climatic changes for specific islands contains large uncertainties, due to the small scale of islands and island ecosystems, their often complex microclimates, and the fact that they are surrounded by large water bodies, all of which are difficult to capture in standard climate models with their low spatial resolutions. Despite these uncertainties, climate change is likely to be one of the major factors faced by islands in the coming century.

Over-Exploitation

Islands can host high densities of human population, for example, Malta has 1300 people per km2, a level increasing at 0.9% per year. This makes it one of the most heavily populated countries in Europe with all of the corresponding pressures that humans bring.

Water is one of the most valuable resources on many European islands, particularly in the Mediterranean and Macaronesian regions with their high levels of endemism. However, water resources on these islands are at risk due to losses of forests and wetlands, pollution and, most importantly, inadequate water management resulting in the over-exploitation of local resources. The island of Cyprus, for instance, at the height of a 4-year century-drought in 2008, was forced to ship freshwater in tankers from Greece; now a pipeline is envisaged bringing water from Turkey. This situation gives reason for special concern given that freshwater biodiversity is already amongst the most threatened in Europe.

The anticipated impacts from climate change provide additional reason for concern as they are expected to affect the freshwater regimes on European islands, with those in northern Europe experiencing an increase in annual precipitation but those in southern Europe suffering significant decreases. The widespread damming of rivers and creeks for domestic and agricultural use adds to the picture as it profoundly affects natural freshwater ecosystems, and is also prone to increase under a drier climate.

Islands and their surrounding waters provide attractive sites for alternative energy developments, such as those based on wind generation or wave action. The isolation of island communities, and the added costs of importing conventional energy sources, make such renewable sources attractive. However, these developments carry their own risks. An emerging threat to birds, and one with particular relevance to migration points, is the impact of wind turbines. These have the potential to impact on bird populations in a number of ways, through collision, displacement due to disturbance, barrier effects and habitat loss (Drewitt and Langston 2006). The rates of bird collision vary greatly and appear to be site specific, but

can be significant, for example adding 3-4.4% to annual mortality for common terns near a development (Everaert and Stienen 2007). However, a number of large developments in areas where birds are concentrated during migration may have significant impacts, particularly on larger species where the rates of loss have the potential to impact at a population level. These include the Altamount Pass in California, a bird migration route that now houses a very large wind farm development and where impacts on large raptors is a cause for concern (Smallwood and Thelander 2008), although a similar study at migration points around the Strait of Gibraltar did not find significant mortality (de Lucas, Janss and Ferrer 2004).

The interest from island communities in local and renewable energy sources is likely to increase the use of wind farms in these areas, and some islands in the north Atlantic are particularly rich in wind resource. Drewitt and Langston (2006) suggest a range a mitigation measures including avoidance of particularly sensitive areas, careful mast placement to avoid barrier effects, minimising the total area of developments to avoid habitat loss and fragmentation, avoiding overhead cabling and reducing disturbance during maintenance. Site specific environmental impact assessments to agreed international standards before approving new developments provides the most effective process to avoid conflicts.

Increasing levels of human population can also be associated with over-use of natural resources, such as increased hunting pressure or unsustainable use of coastal fisheries. Over-harvesting of fisheries can alter community structure and reduce the foods available for other marine species, such as pelagic seabirds.

Pollution

Pollution risks are recognised as a major threat to international biodiversity, though the presence of damaging chemicals in the environment, destructive events such as oil spills, and increases in effluents from humans and agriculture. Islands face many of the same challenges as mainland areas, but through their increased reliance on the sea are more vulnerable in a number of ways. For instance, the Mediterranean Sea represents only 0.7% of the global surface area of seas and oceans but 27% of world's sea borne oil traffic transits this sea (Patruno, 2008). In addition the Mediterranean receives 20% of the world's leisure cruise traffic and 30% of the world's international tourists.

Oil spills provide a recurrent threat to marine and coastal habitats and can have dramatic effects on pelagic birds. Following a major spill in Alaska an island colony of over 100,000 auks was reported as 'devastated' and the total death toll of all species may have been three times this number. (Piatt et al 1990).

IDENTIFYING PRIORITIES FOR CONSERVING ISLAND BIODIVERSITY

The review above has identified five features of islands that are of particular value, and classified threats under five further headings. These can then be arranged into a matrix to consider the priorities for action to conserve biodiversity in these areas. It is worth emphasising that this analysis focuses on those aspects that are unique or particularly pronounced on islands, not on pressures that are shared equally with mainland areas. From this it is possible to identify a series of conflicts that should be the priorities for the conservation of island biodiversity.

Invasive alien species offer particular threats to island endemics, breeding colonies and refugia. The impact of these is well documented, has led to numerous species extinctions and widespread colony loss, and significant alterations to native habitats, all of which are particularly pronounced on islands. Islands also offer special opportunities to limit or remove IAS, either through preventing introductions in the first place, or removing them once they have become established. Where these have been successful there have often been significant recoveries of native biodiversity although these methods are currently underutilised. The threat to island biodiversity is current, real and practical methods are available to significantly reduce the impact. However, the legislation, expertise and funding mechanisms necessary to make action effective are still under-developed.

Habitat loss, either through developments or degradation of semi-natural habitats is the greatest threat to biodiversity worldwide and this is equally true on islands. Islands are particularly sensitive as endemics often have small ranges such that a local change can threaten a species with extinction. The protected area network is a well developed system which can effectively preserve valuable habitats and the species they contain. However, the scale and complexity of island biodiversity, and relative emphasis that should be given to areas containing low species diversity but high endemicity needs special attention (Fontaine et al 2007). Islands also have an intimate mix of human impacts and native biodiversity that may require more active management to achieve co-existance than provided by the protected area approach, for example the management of water resources or other ecosystem services on an island wide basis.

Climate change provides the greatest emergent threat, with islands particularly vulnerable to changes in sea level and rainfall, and an increased frequency of unpredictable weather. Island endemics are also particularly vulnerable to changes in local environmental conditions, by definition they typically have reduced dispersal abilities and islands provide little scope for altitudinal or latitudinal shifts in distribution (Thomas 2004). The extent of climate induced changes remains uncertain and the best strategies for adaptation and mitigation are still under development. Some, such as the concept of assisted migration of endemics, remain controversial and of unknown effectiveness.

These three broad headings provide the suggested high level priorities. This is not to diminish the potential impact of other threats, but rather to focus on those that are likely to have the greatest effect and where coordinated actions can be best focused.

Key issues	Invasive alien species:	Habitat Loss	Increasing Resource Use	Climate change	Pollution
Endemism	IAS pose a major threat to island endemism, for example grazing species impacting on endemic plants, predators impacting on endemic vertebrates, introduced species hybridising with endemics	The high number of endemics and their often small ranges makes them vulnerable to habitat loss, eg tourist developments along coastal habitats	Decreasing value of habitats for endemics, eg low water availability following increased abstraction or increases in grazing pressure. Increased disturbance, eg trampling of dune habitats	Changing climate and expected shifts in species distribution threatens species with limited geographic range or abilities to migrate, including many island endemics	Few direct impacts that are specific to islands
Breeding Colonies	IAS pose a major threat to many colonial island breeding bird species, through predation of eggs and of breeding animals both reducing populations and leading to colony abandonment	The loss of habitats for colonial nesting species, eg loss of turtle nesting beaches to tourist developments	Intensive grassland management may reducing value to breeding waders. Increasing disturbance of breeding colonies, eg tourism affecting turtle breeding beaches, wind farm developments affecting bird colonies. Increased fishing may reduce food availability for pelagic birds	Climate change may alter food availability or alter habitats to their detriment	Coastal breeding colonies are at significant risk from pollution events at sea, such as oil spills.
Migration points	Few direct impacts	Loss of habitat oases for migrating species	Loss of semi-natural habitats to agricultural intensification, Potential risks to migrating birds from wind farm developments	Potential loss of key habitats used as migration staging posts	Few direct impacts that are specific to islands
Species refugia	IAS threaten species already excluded from mainland habitats by their presence	Development increases risk of introduction of IAS, zoonoses or increased predation pressures from domestic species	Increased agricultural intensification leading to loss of semi-natural habitats	Changing climate and expected shifts in species distribution threatens species with limited geographic range or abilities to migrate, including species using islands as refugia	Few direct impacts that are specific to islands
Special habitats	Loss of key habitats to IAS - eg dune systems invaded by non-native plants.IAS simplify natural habitats, eg through increased grazing pressure or by smothering native vegetation	Large pressures from tourism on coastal areas, loss of coastal habitats to development	Loss of wetland habitats through water extraction or increased irrigation, increase agricultural intensification leading to loss of semi-natural habitats. Effects of renewable energy developments on coastal habitats	Raised sea levels threaten coastline habitats, including coral reefs, salt marshes and risk increased erosion. Changing climate will alter the nature and species composition of habitats	Few direct impacts that are specific to islands

SUGGESTED ACTIONS TO CONSERVE ISLAND BIODIVERSITY

Existing initiatives and commitments

The Bern Convention recognises the need to conserve marine and terrestrial biodiversity in and around European islands. This is complemented by the Convention on Biological Diversity's Programme of Work on Island Biodiversity and the closely linked Global Island Partnership (GLISPA).

Linked to these there are already specific instruments and agreements that have direct relevance to islands within Europe or its regions. These include the Helsinki Commission on Baltic Marine Environment Protection (HELCOM); the OSPAR Commission on the Protection and Conservation of the North-East Atlantic and its Resources; the Barcelona Convention with its Mediterranean Action Plan; the Convention and Action Plan for the Sustainable Development of the Smaller Islands of the Mediterranean; the North European and Baltic Network on Invasive Alien Species (NOBANIS); the European Small Island Network; and the European Islands Network on Energy and Environment (ISLENET) convened under the Islands Commission of the Conference of Peripheral and Maritime Regions.

Worldwide there are significant networks and initiatives to propose and support actions to conserve island biodiversity. These include The Message from Reunion Island (IUCN 2008) and initiatives such as the The Cooperative Initiative on Invasive Alien Species on Islands ("The Cooperative Islands Initiative" or CII). This is a global initiative within IUCN that was launched in 2002 following calls from island countries and countries with islands for more efforts to manage invasive species. CII aims to facilitate cooperation and enhance capacity to prevent and manage invasive species on islands. There is a specific Pacific Islands Initiative that supports action in that region, but no similar initiative within Europe.

These are in addition to a wide range of other legislation and agreements to conserve wider biodiversity within Europe, in particular the Convention on Migratory Species; the Convention on International Trade of Endangered Species; the World Heritage Convention; the Ramsar Convention on Wetlands of International Importance; the UN Convention on the Law of the Sea; the EU Birds and Habitats Directives; the EU Water Framework Directive; the EU Common Agricultural Policy; the EU White Paper "Adapting to climate change: Towards a European framework for action"; the EU Marine Strategy Directive; the EU Common Fisheries Policy including the various Regional Fisheries Management Organisations. The EU are also considering options for the management of Invasive Alien Species, which will have significant impacts on islands (Shine et al 2010)

Protecting endemic island species and breeding colonies from the impact of Invasive Alien Species

Invasive Alien Species are, arguably, the greatest immediate threat to European island biodiversity in both the terrestrial and marine realms. In addition, IAS cause significant damage to economic activities and human health. Tackling the impact of IAS is thus fundamental for safeguarding the biological diversity on European islands. Important opportunities exist because both prevention and eradication are feasible on islands, where they are often very difficult in continental situations.

There is a considerable body of work proposing actions and initiatives to strengthen Europe's response to the challenges posed by IAS, many of which apply equally to islands as they do to mainland areas. Shine et al (2010) suggest four strategic goals to protect EU biodiversity and ecosystem services against present and future impacts of invasive alien species and genotypes. These also aim to minimise damage to our economy, human health and wellbeing, without limiting our use of species that do not threaten such interests.

- Development of risk-based prioritisation protocols for EU-level action and capacity building
- A structured framework to manage pathways into, within and from the EU, focused on prevention and rapid response at the appropriate biogeographic scale
- Integrated IAS management linked to ecological restoration and ecosystem resilience, taking account of climate change as a future driver of IAS spread.

- EU-wide awareness, responsibility and incentives adapted to target audiences and key stakeholders, based on a partnership approach

These strategic goals, and their underpinning actions, are proposed for operation at the European level, but equally apply to the protection of island biodiversity against the specific threats posed by Invasive Alien Species. Within these, there are specific needs for islands.

In addition to the continental issues of prioiritisation, the nature of individual islands needs to be incorporated. This should identify those islands or species most in need of protection and action, as has already been attempted for threatened Mediterranean endemic plants (Montmollin and Strahm 2005). A range of studies have proposed methods of prioritising islands in term of value for endemism (Dennis 2008). However, the value of islands to biodiversity is multifaceted and unlikely to be adequately captured with a single metric. For example the islands identified as priorities for endemism will be quite different from those housing the greatest assemblages of colonial nesting seabirds. However, it would seem that protecting endemism in the Mediterranean and Macaronesian regions should be one priority with actions required at an island level. Protecting and enhancing island breeding populations, particularly of pelagic species , is a further priority, but one best considered at a species population level, rather than by individual island. This requires coordination of action across a species range.

The pathways for the introduction of new IAS to islands need especial attention. As currently applied, taxonomic coverage of EU instruments is weakest for alien animals and

for alien plants that do not qualify as diseases or pests. It also has gaps for captive-bred specimens and is not explicit at the level of sub-species and genotypes. Major pathways for the introduction to vulnerable ecosystems, in particular isolated islands, are not addressed (Shine et al 2010).

Islands offer particular opportunities for effective management, most European eradications have taken place on islands, but this tool is underutilised (Genovesi 2005). Too often new IAS are allowed to establish when rapid reaction when first identified would allow their removal. The capacity of islands to undertake eradications is also often limited, both financially and in terms of expertise. While funding instruments such as LIFE and now LIFE+ have been used to co-finance numerous IAS projects, the scale of the problem is larger than the current levels of support. The grant application process is also time consuming and focused on larger projects with matched funding needs, this is not a good model to support rapid reaction which requires a quick and flexible response. Mechanisms are needed to make prevention and action against IAS on islands more rapid, more frequent and more effective.

Given the disparate nature of current domestic legislation regarding IAS in Europe and the potential for an EU wide strategy or legislation, it is important that the specific needs of islands and island biodiversity are incorporated at the heart of any dedicated, overarching and coherent legislative framework on IAS prevention and response in the EU.

- Support a European Information System on Invasive Alien Species in European Islands, in collaboration with appropriate partner organisations to comprise a European islands inventory; an inventory of presence/absence on European islands of both key IAS and native species affected by these IAS; a compilation and assessment of eradication or containment projects on European islands. (Carnevali and Genovesi 2009).
- Complete the identification of IAS threats to priority species and sites, as well as of priority actions (eradication, trade prohibition, etc.), and develop specific action plans for species and islands.
- Given the limited actions that have been taken to date to manage or eradicate IAS from European islands, the high effectiveness of eradications as a tool to conserve island biodiversity, the restricted capabilities to support eradications within many islands, and the high biodiversity value of European islands. Provide support to make prioritised action against IAS on islands more rapid, more frequent and more effective. In particular support projects to safeguard Mediterranean and Macaronesian endemic species from IAS and projects to enhance seabird colonies and populations along the Atlantic seaboard in a coordinated manner.

- There are already coordinating and network groups in place to support European island biodiversity, cooperation and action; while there are further international models, such as the Cooperative Islands Initiative. However, the conservation needs of island biodiversity far outweigh the current level of action. Additional work to identify and establish projects that would best develop action against IAS to promote biodiversity on European islands is clearly required . A European Island Initiative based on the existing international model could support these needs but should focus strongly on actions.

Protected area and species networks

These structures and networks are well developed within Europe compared to other regions and there are mature systems and legislation in place to support them. However, many European habitats are already significantly altered by human intervention and these pressures continue to rise. There are ongoing debates on the relative priorities for European conservation action, and the role of endemic rich, but species poor areas in this context.

Island endemics are under-represented in the indicators used to measure high level biodiversity. Most European species listed as threatened in the IUCN Red List are narrow-range species. Conversely there are as many wide-range species as narrow range endemics in the list of protected species in Europe (Bird and Habitats Directive). The subset of biodiversity captured by the 2010 target indicators should be representative of the whole biodiversity in terms of distribution and abundance. Indicators should not overlook the large number of narrow range endemic species and their intrinsic vulnerability. Without adequate representation in high level targets, the extinction of narrow range endemics may go unnoticed (Fontaine et al 2007).

Montmollin and Strahm (2005) list the greatest threats facing Mediterranean endemic plants in order of importance. For this group, the first four threats, urbanisation, tourism, fires and agricultural change, are all ones best remedied through the use of protected areas. These authors propose conservation actions that match these, with legal protection, species and habitat management plans and the creation and management of protected areas as prioirities. Clearly there is an ongoing need for protected areas and species networks to protect island endemics.

The identification of protected areas is typically also based on current biodiversity value. The role of islands as refugia is set to increase, and will be enhanced by protecting sites and habitats by virtue of their potential to act in this way. Prime sites might include those with a high diversity of habitats, increasing their probability of acting as a future refuge; their defensibility, the prospect of avoiding colonisation by a species widespread on the mainland; and size, whereby islands sufficiently large to maintain refuge populations should be considered. Such islands should then be prioritised for rapid response action in the event of a new IAS incursion and control on neighbouring land masses may be needed to reduce colonisation pressure.

Mitigating the effects of climate change on islands

There are already a large number of initiatives to assess and mitigate the effects of climate change on biodiversity at a European level, reviewed in Harley and Hodgson (2008). The recommendations can be summarised under five headings of shared vision; mitigation; adaptation; technology transfer and capacity-building; and finance. For island biodiversity, their increased vulnerability to climate change suggests a series of actions. These include:

- Refine the analysis identifying island biotas most threatened from direct climate change impacts and the according priority actions
- For critically endangered taxa exposed to severe climate impacts, targeted translocations to other islands might be envisaged although this concept raises conflicts with the strategy on Invasive Alien Species that need to be carefully managed.
- In view of the limited capacity in many European islands, and the increasing demand for integrated solutions, for example in relation to renewable energy or water management, consider the establishment or designation of one or several centres of excellence on minimising the effects of

direct and indirect climate change impacts on biodiversity and natural resources, to offer quality guidance and a coordinating platform to interested stakeholders.

- Promote voluntary coastal-zone management programmes for adaptation to climate change as a tool to build ecosystem resilience, protect ecosystem services and secure local livelihoods.
- Place greater and more numerous areas (including more environmentally diverse protected areas and altitudinal gradients) under conservation regimes to achieve the same level of biodiversity conservation over the long term; apply the ecosystem approach outside protected areas and reduce the degree of threat from other direct drivers.

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