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CLIMATE CHANGE AND THE BIODIVERSITY OF EUROPEAN ISLANDS

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EXECUTIVE SUMMARY

European islands are home to many species and habitats of conservation concern, including endemic as well as threatened biodiversity. Endemism is largely concentrated on islands in the Mediterranean and Macaronesian regions. There are significant knowledge gaps concerning current and potential future impacts of climate change on European island biodiversity. However, there is enough evidence to demonstrate that impacts already take place and are likely to increase in future. Processes related to climate change which are particularly relevant in the island context include sea level rise and the possibility of increasing incidence of invasive alien species. Measures available to support the adaptation of biodiversity to climate change for its long-term preservation are similar to those recommended for other areas. However, opportunities for enhancing connectivity beyond individual islands are limited. Ex situ and translocation measures might be considered for endemic island taxa where no other options exist. Priority attention should be given to islands in the Mediterranean and Macaronesian region both because of their high endemism and because of expected changes in precipitation patterns, and within these islands to endemic species which are already considered threatened. Further efforts in monitoring and research are recommended.

1. INTRODUCTION

The specific environmental and socio-economic conditions of islands provide both challenges and opportunities for nature conservation. A targeted approach to biodiversity issues which takes these characteristic features into account has recently been promoted through the adoption of the Programme of Work on Island Biodiversity under the Convention on Biological Diversity (CBD) in 2006, as well as the formation of the Global Islands Partnership (GLISPA)[1].

In the CBD Programme of Work, climate change is pointed out as one of the important threats to island biodiversity and all Parties are encouraged to implement adaptation measures and strategies to strengthen the resilience of species and ecosystems, and to carry out research and monitoring to improve the knowledge base for such activities.

The available literature on climate change impacts on ecosystems frequently mentions islands as an area of high concern (e.g. Berry 2008). Reasons for this include the high ratio of coastline to overall land area and the ensuing threat of habitat loss through sea level rise as well as the fact that for many island populations of plant and animal species it will be even more difficult than for mainland populations to adapt to climate change by dispersing into newly suitable areas.

Because of the large number and diversity of Europe's islands, these findings should be reflected in any regional efforts to conserve biodiversity in the face of rapid global change.

The present study was prepared on behalf of the Council of Europe for consideration by the Group of Experts on Biodiversity and Climate Change established under the Bern Convention in 2006. It aims to outline the state of knowledge concerning island biodiversity in Europe and the likely impacts of climate change on its components, and to provide a starting point for discussion on actions to be taken by Parties. It builds upon previous reports reviewed by this Group of Experts which have dealt with other aspects of the link between climate change and the conservation of European species and habitats[2] as well as the guidance provided to Parties on the issue of biodiversity and climate change in Recommendations No. 135 (2008) and No. 143 (2009), and is intended to complement the ongoing work of the Groups of Experts on European Island Biological Diversity and Invasive Alien Species.

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[1] see http://www.cbd.int/island/glispa.shtml

[2] Huntley (2007, Doc. T-PVS/Inf (2007) 3), Ferrer et al. (2008, Doc. T-PVS/Inf (2008) 1 rev), Capdevila-Arguelles & Zilletti (2008, Doc. T-PVS/Inf (2008) 5 rev.), Berry (2008, Doc. T-PVS/Inf (2008)6 rev.), Henle et al. (2008, Doc. T-PVS/Inf (2008) 11 rev.), Harley (2008, Doc. T-PVS/Inf (2008) 12 rev.), Wilson (2009, Doc. T-PVS/Inf (2009) 8), Heywood & Culham (2009, Doc. T-PVS/Inf (2009) 9), Araujo & Garcia (2009, Doc. T-PVS/Inf (2009) 10)

In line with the agreement made by the Group of Experts on Island Biological Diversity, the scope of this report has been set to include the Macaronesian islands, but not the Outermost Regions and Overseas Countries and Territories of European countries in the Pacific and Indian Oceans or the Caribbean Sea. Moreover, only marine islands have been considered.

2. ISLAND BIODIVERSITY IN EUROPE

a. General features of island biodiversity

The characteristics of the species assemblages found on islands are determined by many factors, including size, age, climatic history, current climate, latitude, relief and geology, as well as, importantly, the distance to other islands and the mainland and the diversity and composition of their species communities. Thus, although as a general rule islands are poorer in terrestrial species than comparable mainland areas (Whittaker and Palacios 2007), their biodiversity often exhibits unique features and a high degree of endemism, from the genetic to the ecosystem level.

A useful distinction can be made between remote islands for which evolution has in the past been a faster process than immigration – termed “oceanic” islands by Whittaker and Palacios (2007, with reference to Williamson 1981) because many areas which fit this description are located off the continental shelf – and islands in relative proximity to the mainland, which are characterised by higher immigration rates and may be called “continental”. At the same time, since both the evolution and immigration rates vary between different groups of organisms, there is a continuous range of intermediate forms between these two types. For example, many insular locations may have bird populations which are closely connected to those of the nearby continent, while their terrestrial mammal populations are effectively isolated.

The significance of islands for global biodiversity conservation has been highlighted by many authors, for instance Fonseca et al. (2006). Although islands make up only some 5 % of the global land area, their endemic biota are estimated to include about 20 % of the world’s vascular plant species and 15 % of all mammal, bird and amphibian species. Endemism is often correlated with vulnerability to various factors of threat, and island endemics account for around one third of the mammal, bird and amphibian species which have been classified as threatened on a global scale.

Endemism is, however, not the only factor which contributes to the high conservation value of many islands. The array of threats or pressures acting on a species in a given location is likely to differ from the mainland, and elements such as land use intensity or predator pressure may be either more or less pronounced in each individual island’s setting. Thus, vulnerable species which have been lost from much of their former distribution area may find refugial niches and persist in significant numbers on islands with suitable circumstances. For instance, ground-breeding bird and reptile species often form large colonies on inaccessible or predator-free islands.

Islands are also important for marine biodiversity, even if colonisation is more easily achieved and highly restricted marine endemics therefore harder to find than in the terrestrial realm. But a range of marine species and habitats, such as warm and cold water corals or sea-grass beds, while not essentially different from those of the mainland coast, can have important strongholds around islands beyond the easy reach of humans. Islands located along migration pathways may also provide important stopover and resting sites for both marine and terrestrial animals.

Threatening factors which often have more severe effects in island ecosystems both because of the existing space limitations and the specialised nature of island biota include habitat destruction, uncontrolled tourism development and invasive alien species. Examples of invasive alien species causing serious problems on islands in Europe include wild boar (*Sus scrofa*) introduced as game animals on some Croatian islands, rats (*Rattus rattus*) and exogenous fish parasites on Corsica, *Opuntia ficus-indica* on the Italian Ponziane islands, mink (*Mustela vison*) and raccoon dog (*Nyctereutes procyonoides*) on Swedish Baltic Sea islands and the macroalga *Gracilaria vermiculophylla* in the intertidal zone of the Gothenburg archipelago, and *Rhododendron ponticum* in Ireland (Source: national reports to the Bern Convention on activities related to Biological Diversity on European islands[3]) (Orueta 2009, Carnevali & Genovesi 2009). Climate change is expected to interact with already existing stressors in a mutually reinforcing way, and thus enhance the particular vulnerability of island biota.

In line with the above-mentioned facts, many of the lists of priority sites for conservation which have been developed by different international organisations (e.g. Global 200 Ecoregions (WWF), Endemic Bird Areas (BirdLife International), Biodiversity Hotspots (Conservation International) and AZE sites (Alliance for Zero Extinction)) include a high proportion of sites situated entirely on islands (one quarter to about half of the sites for the listings cited above) as well as numerous sites comprising mainland areas as well as islands (Fonseca et al. 2006).

b. Geographic overview of European islands and their main characteristics

Islands are a prominent feature of the European continent with its long and irregular coastline. Several European countries are entirely situated on islands, and except for a small number of landlocked states almost all countries have islands within their territories. As stated by Carnevali and Genovesi (2009), although an inventory of European islands has not been completed yet, the Global Island Database (http://gid.unep-wcmc.org/)[4] holds information about more than 50,000 islands belonging to Europe. Of these, around 500 are larger than 20 km^2, and their total area (excluding Greenland) is more than 700,000 km^2, or more than 7 % of the surface of Europe (Orueta 2009).

There is an enormous diversity among the European islands as regards their size, geology, morphology and climate, such that any kind of general statement about their characteristics would be impossible. Europe comprises islands located from the Arctic in the far north to subtropical regions off the North-West African coast. Typical ‘island phenomena’ such as a strong maritime influence, resource limitations and a high share of specialized biota and communities are more prevalent on smaller and more isolated territories, while the bigger islands such as Great Britain have more commonalities with coastal states on the mainland. Table 1 gives an overview of major islands and archipelagos in the biogeographical regions of Europe and some of their characteristic features, referring to the delineation of biogeographical regions as defined by the European Commission and the Council of Europe for the purpose of evaluation and reporting on nature conservation (EEA 2002-2008).

[3] Doc. T-PVS/Inf(2009)12 and T-PVS (2009) 13

[4] The Global Island Database was initiated within the framework of the Global Island Partnership and is being developed in a multilateral partnership project led by UNEP-WCMC.

Table 1: Major islands and archipelagos in the biogeographical regions of Europe and some of their characteristic features (Sources: Global Island Database[5], UNEP Island Directory[6], EEA 2002-2008, Wikipedia)

Biogeographic region	Name of island or archipelago[7]	Country or countries[8]	Characteristics
Arctic	Svalbard	Norway	Largest island Spitsbergen; total land area of archipelago 61,022 km2; distance to mainland (Norway) 660 km; highest elevation 1,713 m asl
	Iceland	Iceland	Land area 101,794 km2; distance to mainland (Norway) 970 km; main vegetation type tundra; highest elevation 2,110 m asl; coasts consisting mainly of rock and sand with open fjords
	Coastal archipelago of Northern Norway	Norway	Largest island Hinnoya, with an area of 2,204 km2; large number of islands of different sizes at short distance from mainland
Boreal	Aland islands and islands of the Finnish Archipelago Sea	Finland	Largest island Fasta Aland, with an area of 879 km2; large number of islands of different sizes at short distance from mainland, total area about 2,000 km2; more than 90 % of the territory less than 30 m asl; geology characterised by bedrock
	Hiiumaa	Estonia	Land area 1,026 km2; highest elevation 68 m; distance to mainland 22 km; includes calcareous soils
	Saaremaa	Estonia	Land area 2,680 km2; highest elevation 54 m; distance to mainland 8 km; includes calcareous soils
	Gotland	Sweden	Land area 3,015 km2; highest elevation 82 m; distance to mainland 90 km; includes calcareous soils
	Swedish coastal archipelago on the Baltic Sea[9]	Sweden	Largest island group Stockholm archipelago, with an area of about 530 km2; large number of islands

[5] http://gid.unep-wcmc.org
[6] http://islands.unep.ch/
[7] Note that the designations used in this report are not meant to express any opinion concerning the legal status of any country or island territory.
[8] Several island territories have some form of political autonomy within their countries, thus the information in this column should not be taken as a description of political status
[9] with the exception of the small area south of Oland which belongs to the Continental region

			of different sizes at short distance from mainland; more than 90 % of the territory less than 30 m asl; geology characterised by bedrock
	Swedish and Norwegian coastal archipelagos on the Skagerrak Sea	Sweden / Norway	Numerous small islands at short distance from mainland; more than 90 % of the territory less than 30 m asl
	Norwegian archipelago on the western coast south of the Polar Circle	Norway	Large number of islands of different sizes at short distance from mainland; partly steep terrain
Atlantic	Faroe Islands	Denmark	Total land area 1,393 km2; highest elevation 882 m asl; highest sea cliffs in Europe; distance to mainland (Scotland) 310 km; coasts mainly composed of vertical cliffs as a result of intensive erosion
	Atlantic Archipelago of Britain and Ireland	United Kingdom, Ireland, the Channel Islands and the Isle of Man	Total land area 315,134 km2; over 6000 islands altogether; largest island Great Britain with land area of 218,571 km2; highest elevation 1,344 m; distance to mainland 16 km (Alderney to France)
	Frisian Islands	Denmark, Germany, Netherlands	Total land area 1,048 km2; chain of islands at short distance from mainland; more than 90 % of the territory less than 20 m asl; coasts characterised by sandy beaches and marshland as well as extensive mudflats
Continental	Danish Islands in the Kattegat and Baltic Sea (incl. Zealand, Fyn, Bornholm)	Denmark	Largest island Zealand with a land area of 7,031 km2; highest elevation 162 m; distance to mainland less than 1 km
	Swedish coastal archipelago in the Kattegat and Southern Baltic Sea up to Oland	Sweden	Largest island Sturko with a land area of 19 km2; numerous low lying small islands at short distance from mainland
	Oland	Sweden	Land area 1,366 km2; highest elevation 55 m; distance to mainland 6 km; includes calcareous soils
	Islands on the Pomeranian Bay (incl. Rugen, Usedom, Wolin)	Germany, Poland	Largest island Rugen with a land area of 968 km2; highest elevation 161 m; distance to mainland less than 1 km
Mediterranean	Balearic Islands	Spain	Total land area 4,992 km2; largest island Mallorca; highest elevation 1,432 m asl; distance to mainland 79 km

	Corsica	France	Land area 8,741 km2; highest elevation 2,706 m; distance to mainland 90 km
	Sardinia	Italy	Land area 23,962 km2; highest elevation 1,834 m; distance to mainland 200 km
	Sicily	Italy	Land area 25,531 km2; highest elevation 3,320 m; distance to mainland 3 km
	Malta	Malta	Total land area of archipelago 316 km2; highest elevation 253 m; distance to mainland 220 km
	Adriatic islands	Croatia, Montenegro, Albania, Italy	Largest island Cres with a total land area of 406 km2; highest elevation 778 m; large number of islands at short distance from mainland
	Ionian islands	Greece	Total land area 2,307 km2; highest elevation 1,630 m; distance to mainland less than 1 km
	Aegean islands (incl. Crete)	Greece, Turkey	Largest island Crete with a total land area of 8,336 km2; highest elevation 1,611 m; large number of islands at varying distance to mainland
	Cyprus	Cyprus	Land area 9,317 km2; highest elevation 1,952 m; distance to mainland 75 km
Macaronesian	Azores	Portugal	Total land area 2,346 km2; nine main islands, highest elevation 2,351 m; distance to mainland 1,390 km; volcanic origin
	Madeira	Portugal	Total land area 828 km2; two main islands; highest elevation 1,826 m; distance to mainland 520 km; volcanic origin
	Canary Islands	Spain	Total land area 7,447 km2; seven main islands; highest elevation 3,718 m; distance to mainland 97 km; volcanic origin

c. Importance of islands for biodiversity in Europe

The conservation assets of European islands are as diverse as their physio-geographic and socio-economic characteristics. Many islands especially in those regions which are easily accessible and attractive for tourism or leisure activities are suffering from overexploitation of scarce resources and destruction of coastal habitats, whereas others still hold a large extent of relatively unimpacted ecosystems.

Because of their high ratio of coastline to interior, islands are hosting a significant share of the total area of coastal, littoral and shallow water marine habitats in Europe. For example, although islands make up only 5.8 % of the territory of Croatia, they account for about 70 % of the Croatian coastline (source: Croatian national report to the Bern Convention on activities related to Biological Diversity on European islands[10]). For the whole of the Mediterranean Sea, according to the European Environment Agency (EEA 2002-2008), island coasts make up about 40 % of the total coastline. Coastal and halophytic communities represent a large share of the Bern Convention habitats as listed in Resolution 4 (96). The machair, a specific type of coastal grassland with a long history of extensive agricultural use, is only found on the Hebrides as well as the northwest coasts of Ireland and Scotland. Although marine habitats such as seagrass meadows or mussel beds around islands are not generally distinct from those of the mainland coast, they may be better preserved in many areas due to a lower degree of disturbance.

As stated above, one of the main reasons for paying particular attention to islands in biodiversity conservation is their high level of endemism. Although many endemic species have been lost from European islands as a consequence of human settlement (Orueta 2009), the number of species confined to one or several islands is still significant. For example, according to Delanoe et al. (1996), the proportion of endemic species among vascular plants on the larger Mediterranean islands is on average around 10 %. Even higher levels of endemism are reached in the Macaronesian islands with their unique blend of North Atlantic, African and Mediterranean biogeographic influences and special vegetation types such as the humid evergreen laurel forest and the dry Canary pine forests.

In addition to the species level, endemism should also be considered at the level of sub-species and varieties.

There is currently no complete inventory of endemic species on European islands (Orueta 2009), and new taxa are still being discovered. However, some of the available information on well-researched taxonomic groups has been compiled in annexes 1 and 2. These tables clearly demonstrate the concentration of endemic species in the Mediterranean and Macaronesian regions. The near complete absence of species-level endemism from northern European islands is believed to be largely a consequence of their recent glaciation history (EEA 2002-2008).

Another prominent feature from a conservation point of view is the importance of many islands for breeding and migrating birds as well as marine mammals and sea turtles. Both the United Kingdom and Ireland hold a large number of internationally important wintering, stopover and breeding sites for birds of conservation concern on the main islands as well as the numerous smaller islands. 31 of the Special Protection Areas classified under the EU Birds Directive in the United Kingdom are situated on offshore islands, accounting for some 3,788,000 breeding seabirds [11]. As noted in the French national report on island biodiversity, islands are hosting the main part of the national population of several seabird species, e.g. Cory's Shearwater (*Calonectris diomedea)*, Storm Petrel (*Hydrobates pelagicus)* and the subspecies of the European Shag *Phalacrocorax aristotelis* subsp. *desmarestii*.

The importance of Arctic islands as one of the world's most important reproduction areas for seabirds is pointed out in EEA (2002-2008), highlighting also the role of seabird populations in the region's ecosystem. In the same publication, the role of the archipelagos along the Swedish and Finnish

[10] Doc. T-PVS/Inf(2009)12
[11] Doc. T-PVS/Inf(2009)12

Baltic coasts as breeding sites for large numbers of ducks and waders is also emphasized. For example, the small islands and skerries are reported to contain an estimated 600,000 pairs of Eider Ducks. Also, all three species of seal found in the Baltic - the Grey Seal (*Halichoerus grypus*), the Harbour (Common) Seal (*Phoca vitulina*) and the Baltic Ringed Seal (*Phoca hispida botnica*) **-** live mainly in the archipelagos. Migratory waterbirds are increasingly wintering in the lagoons and shallow waters of the Southern Baltic, and the extensive mudflats and shallow waters of the Wadden Sea area are used as stopover or wintering sites by more than 12 million birds per year, while also hosting marine mammals such as the Harbour Seal (*Phoca vitulina*), the Grey Seal (*Halichoerus grypus*) and the Bottle-nose Dolphin (*Tursiops truncatus*) (EEA 2002-2008).

Several Mediterranean islands play an important role as nesting sites for marine turtles. The beaches of Laganas Bay on the Greek island of Zakynthos hold the highest known concentration of nests of the Loggerhead Turtle (*Caretta caretta*) in the whole of the Mediterranean basin and their protection has been an issue of concern over many years (cf. Bern Convention Recommendation 9 (1987), Margaritoulis 2005).

In addition to coastal communities, several other Bern Convention habitats, e.g. European wet heaths and Mediterranean shrub formations, are commonly found on islands, and a few are endemic to specific islands or island groups (e.g. Macaronesian heaths and certain types of Aleppo pine woods). Orueta (2009) has proposed a more thorough assessment of the distribution of habitats on European islands and their conservation status as a potential line of work for the Bern Convention Group of Experts on Island Biological Diversity.

d. State of conservation efforts on European islands

Efforts to conserve European island biodiversity are being undertaken by a variety of governmental and non-governmental actors at the sub-national, national and regional level, with the respective roles and level of involvement varying between countries.

At the national level, the designation of protected areas, notably including the sites of the Natura 2000 and Emerald networks, has been one of the focal areas of conservation work in the past decades. In many cases, the share of protected areas is higher on the island part of a country's territory than on the mainland. For example, more than 85 % of the Croatian island area and 40 % of the area of the Canary Islands has been included in the Natura 2000 network (national reports to the Bern Convention on activities related to Biological Diversity on European islands[12]). More than half of the area of the Svalbard archipelago is included in protected areas under Norwegian law (EEA 2002-2008). According to Orueta (2009), about 10 % of the European Biosphere Reserves are situated on islands.

However, like elsewhere, the designation of protected areas on islands needs to be complemented by measures to ensure effective management and sufficient financing, if conservation targets are to be met (see for example EC 2009). Besides, island protected areas often face particular logistic constraints as compared to the mainland, which need to be addressed in the further development of protected area networks.

Because of the importance of the Mediterranean as a biodiversity hotspot, several international research and conservation efforts have focussed on islands in this region, for example the work of the Mediterranean Island Plant Specialist Group of IUCN[13]. High levels of human impact over much of the area give reason for continued concern over the conservation status of its unique array of species and habitats. A similar situation exists in the Macaronesian region.

[12] Doc. T-PVS/Inf(2009)12 and T-PVS (2009) 13

[13] http://www.iucn.org/about/work/programmes/species/about_ssc/specialist_groups/directory_specialist_groups/directory_sg_plants/ssc_mediterranean_island_plant/

Two global conservation initiatives focussing on islands are particularly relevant in the European context, i.e. the Convention on Biological Diversity's Programme of Work on Island Biodiversity and the Global Island Partnership, which provides support to the implementation of the Programme of Work. Although the work of the Global Island Partnership has in the past focussed mainly on tropical areas, some activities have been undertaken in the European region as well. For example, Croatia has made a commitment to work towards an improvement of the network of Marine Protected Areas in the Mediterranean by 2012.

3. IMPACTS OF CLIMATE CHANGE ON THE BIODIVERSITY OF EUROPEAN ISLANDS

Changes in the climate system and their impacts on the physical environment can be described through a wide range of statistical measures related to the state of, and processes in, the atmosphere and hydrosphere. These measures include mean values and average seasonal patterns of air and water temperature as well as precipitation and the direction and intensity of wind and ocean currents, the extent of ice and snow cover, and the frequency and severity of extreme events related to any of these parameters. In the marine and coastal realm, sea level and water salinity are further key variables, as is the water pH value which is decreasing on a global scale as a direct consequence of rising atmospheric carbon dioxide concentrations (WBGU 2006, Orr et al. 2009).

All of these factors play a role in determining the impacts of climate change on biodiversity, including island biodiversity, although their relative importance varies depending on the organisms and ecosystems present in an area (Usher 2005, Fischlin et al. 2007). A further aspect that needs to be taken into account are climatically induced changes in species interactions and ecological processes, such as increases in the occurrence of invasive alien species or wildfires (Capdevila-Arguelles & Zilletti 2008, Moreno 2010).

While there is ample evidence from ecological science to demonstrate the existence of causal relationships between these climate-related environmental factors and the condition and future prospects of individual organisms, species and ecosystems, significant challenges remain in quantifying and projecting the nature and scale of the impacts (see for example Heywood & Culham 2009, Kuhn et al. 2009). The following chapters provide an overview of existing observations and projections of the impacts of climate change on island biodiversity in Europe as well as a discussion of knowledge gaps.

a. Observed impacts

Observations of climate change impacts on the biodiversity of European islands are largely anecdotal in nature, as most of the available information has originally been collected for other purposes and relates to well-studied groups of species and larger, densely populated islands with a tradition of species monitoring. Knowledge on species occurrence and trends is generally poor on smaller islands due to logistical barriers. Many of the existing studies also suffer from the fact that although the observed changes in biodiversity can be shown to be in line with what would be expected as a consequence of climate change, the data are not sufficient to prove a causal relationship.

Based on a comprehensive review of evidence for the impacts of climate change on biodiversity in the European Union, Hodgson et al. (2009) concluded that there is a marked imbalance of information coverage both within and across the European biogeographical regions. At the same time, it seems reasonable to assume that a considerable amount of observational evidence is held at the sub-national level (e.g. by protected area managers) and remains to be made more widely available.

The types of changes which have been most frequently recorded and analysed include phenological changes and expansions in distribution of conspicuous and common species from taxonomic groups such as birds or butterflies. However, from a practical conservation point of view, information on overall population trends and changes in distribution areas especially for rare or declining species is more urgently needed.

Hodgson et al. (2009) cite a large number of studies demonstrating shifts in phenology and distribution ranges of birds, butterflies and other terrestrial and littoral invertebrates in Great Britain, while stating that for other parts of the Atlantic biogeographical region, literature is more scarce.

In the Arctic region, monitoring data on moths in Iceland (time series beginning in 1995) show a trend towards earlier spring adult appearance (Nordic Council of Ministers 2009).

Observations of the reproductive success, survival rates and population numbers of seabirds breeding on islands around the North Sea and the North Atlantic Ocean have shown large-scale decreases in recent decades. These are attributed to a combination of factors, notably overfishing and climate change both leading to a decline in food sources. For example, a decrease in the population of the Thick-billed Murre (*Uria lomvia*) and Fulmar (*Fulmarus glacialis*) has been observed in Iceland for the period from the 1980s to 2005 (Nordic Council of Ministers 2009).

Changes in the behaviour of migratory birds have been recorded for several species since the last century. These include not only changes in timing, but also changes to migratory routes and destinations, which means that the relative importance of islands for the survival of certain species may increase or decline. Ferrer et al. (2008) have reviewed the evidence for climate change effects on migration routes of European birds. One of the most well known examples of recent changes in migratory direction is that of the Blackcap (*Sylvia atricapilla*), whose winter distribution has now largely shifted from southern Europe to the British Islands.

Petit and Prudent (2008) compiled a range of observations from the Macaronesian region which seem to indicate that climate change is already having an impact on the biodiversity of the Canary Islands, Madeira and the Azores. These include first sightings of more than 30 species of Saharan birds on the Canary islands, as well as the unprecedented appearance of several species of tropical fish in the surrounding waters. An immigration of tropical fish species has also been documented from the waters of the Azores. On Madeira, changes in the migratory habits of some bird species have been observed. As a further example from the Macaronesian region, del Arco (2006, as cited in Hodgson et al. 2009) found evidence for decreased plant productivity linked to reduced rainfall in the Canary Islands.

Due to the obvious bias in literature coverage, no comparisons can be made about the degree of already observed climate change impacts on the biodiversity of different island regions.

b. Projected impacts

One of the challenges with regard to determining potential climate change impacts on islands lies in the fact that the coarse spatial resolution of many currently available projections of future changes in climatic parameters makes it difficult to derive valid statements for many of the smaller islands. The need for downscaled projections to support assessments of potential climatic changes on small islands has also been noted by Christensen et al. (2007) in the IPCC 4th Assessment Report.

A further layer of complexity is added by the fact that many island biota depend on marine as well as terrestrial resources for their survival, and are thus affected by changes in both spheres. Although sea surface temperatures are generally captured reasonably well by current versions of Global Circulation Models, the methods needed for downscaling are different from those employed for terrestrial settings, and the projection of small-scale changes in hydrography and circulation is particularly difficult in areas that are close to the continents (Donner et al. 2005, Lowe et al. 2009).

Finally, smaller-scale factors influencing local climatic conditions, such as wind, exposure or albedo, may lead to greater variations in temperature changes in some island locations than would be predicted even by regionalized climate models.

In spite of these limitations, some basic assumptions can be drawn from available data on projected climatic developments at the European scale as well as from regional models that have been developed for certain areas. Generally, increases in temperature are expected to be attenuated on islands as compared to continental areas due to the buffering effect of the ocean. In line with this, according to an analysis of the temperature changes which might affect Natura 2000 sites in Europe (Bertzky et al. 2009, based on data derived from the HadCM3 model), even under the higher A2 scenario most Natura 2000 sites situated on islands in the Mediterranean, Atlantic and Continental biogeographical regions would only experience a warming of 1-2° C during the second half of the century, while the largest share of the mainland part of the European Union would see temperatures rise by 2-3° C. In the north-western part of the Atlantic Archipelago of Britain and Ireland, the increase in mean annual temperature is even projected to remain below 1° C. However, it has to be noted that the scale of the oceanic effect might have been overestimated in this study due to a low data resolution, as the climatic data retrieved from the IPCC Data Distribution Centre was used without further regionalisation.

With regard to precipitation, the data presented by EEA (2007, with reference to Schroter et al. 2005) suggests more variation among the biogeographical regions. The projections for changes in annual precipitation during the 21st century (again for the A2 scenario and based on the HadCM3 model) show an increase of 10-15 % for all parts of the Norwegian archipelago (both within the Arctic as well as the Atlantic and Continental regions), as well as for most islands within the Boreal and Continental regions. In the Atlantic region, only for Ireland and Great Britain more differentiated shifts in rainfall are projected, ranging from an increase of 0-5% in the Southeast of Great Britain to increases of up to 15-20% on the eastern coast of Scotland. Only some of the islands in the Mediterranean region would experience an overall decrease in annual rainfall over parts of their area, with reductions of up to 10-15% for Sardinia and Sicily. Because of the shift of precipitation towards the winter months which is expected for all of Europe (Christensen et al. 2007), these average values imply a significantly drier summer climate in the Mediterranean region. Consequences would include not only prolonged periods of low soil moisture affecting vegetation, but also an increasing risk of wildfires, which are already an issue of serious concern in many Mediterranean islands. As stated in the IPCC 4th Assessment Report, the Mediterranean region as a whole is likely to be seriously impacted by climate change as a consequence of increasing drought and heat stress. Projections of precipitation derived from the IPCC models are less clear for the Macaronesian region. However, changes in the distribution and seasonality of rainfall are expected as a consequence of shifts in the dominating wind patterns (Petit & Prudent 2008).

More detailed regional projections of climatic changes are available mostly for larger island countries rather than single islands within a country's territory.

In order to gain further insights into the likely impacts of future climate change on species and habitats, various approaches can be used. In recent years, a number of studies have used climate envelope models in order to analyze how the potentially suitable climate space of species from different taxonomic groups might shift geographically as a consequence of climate change (e.g. Berry et al. 2005; Berry et al. 2007; Araujo et al. 2006; Thuiller et al. 2005; Huntley et al. 2007, Settele et al. 2008).

However, these approaches can only be applied to species for which a minimum amount of distribution and ecological data is available. This is often not the case for rare species and species of less well researched taxonomic groups. Another important limitation with regard to application in an island context lies in the fact that climate envelope modelling is based on the assumption that species are currently filling the whole of their suitable climatic niche. For narrowly endemic species, whose distribution is likely to be largely determined by historical factors and dispersal barriers (both to the species itself and to potential predators and competitors), this might justify special caution when interpreting the results[14].

Finally, the problem of scale which was referred to above with regard to available climate projections also applies to climate envelope modelling. Even where finer scale data are available for projections of climate parameters, their application in simulations of the potential future ranges of species may be limited by the resolution of available data on current species distributions (cp. Thuiller et al. 2005,

[14] For a more detailed discussion of the methodological limitations of climate envelope modelling, see also Heywood & Culham (2009).

Huntley et al. 2008). Climatic niches which are only realized on small areas would not be captured by these models.

In order to assess the vulnerability[15] of island taxa to climatic change, other approaches including expert opinion based on biological and ecological information and a structured analysis of species' life history and ecological traits should therefore be considered. Work on identifying biological traits which could indicate high susceptibility to climate change and a trait-based assessment of species vulnerabilities to climate change for a large number of bird, amphibian and reef-building warm water corals have been carried out in a study led by IUCN (Foden et al. 2008). The final outcomes of this assessment are yet to be published, but could provide guidance for future work.

Sajwaj et al. (2009) have combined data derived from climate envelope modelling with information on species characteristics that can be used to gauge adaptive capacity in order to develop a framework for assessing the vulnerability of species which are protected under the Habitats and Birds Directives of the European Union. Vulnerability scores could be produced for a total of 212 (~ 24.4%) out of 869 species listed in the Birds and Habitats Directives. Of these, 149 were bird species, 12 amphibian species, 12 reptile species, 13 butterfly species and 26 plant species. For the remaining 657 (869 minus 212) species of Community Interest no suitable modelling data was available.

135 species (64 %) were assessed in the study as showing a high, very high, critical or extremely critical vulnerability under at least one of the examined climate scenarios and time horizons, leaving only 77 species (36 %) with moderate to low vulnerability. The authors attribute this to the fact that most species protected under the EU Nature Directives are already threatened or rare and have specific habitat requirements. They point out that constraints to species' ability to move to and colonise new areas with suitable climate (e.g. because of limited dispersal abilities, lack of suitable habitat, or low levels of emigration due to small population sizes etc) are the main factor contributing to vulnerability.

Although very few of the species assessed in the study are endemic to islands (which may be explained by the lack of data for use in modelling), a significant number also occur on islands and could be given special attention in efforts to protect island biodiversity against negative impacts of climate change. Annex 3 of the present document contains a list of the 122 Bern Convention species which have been identified by Sajwaj et al. (2009) as being at least highly vulnerable.

In contrast to the large body of literature concerning climate change impacts on individual species or species groups, relatively few authors have attempted to address the potential impacts at the level of habitats and ecosystems. Since models for the projection of ecological interactions between species (such as competition between different plant functional types) are highly complex and currently only applicable to very limited sets of species or species groups (Kuhn et al. 2009), it is hardly possible to model the future species assemblages that would determine the characteristics of the ecosystems present in a certain location. The vulnerability of habitats and ecosystems has therefore often been considered through alternative approaches, including expert judgment and the use of information on the vulnerability of characteristic plant and animal species as a surrogate (Sajwaj et al. 2009). Berry et al. (2007) in their study assessed the climate change vulnerability of a subset of coastal habitats in Europe including saltmarshes and mudflats, of relevance also to islands. Moreover, the European Topic Centre on Biodiversity is currently leading a project that is developing and applying a comprehensive vulnerability assessment framework for European habitats (M. Harley *in litt*., 2010).

Along the above lines, also no comprehensive analyses on the vulnerability of Bern Convention habitats to climate change have so far been carried out, and the amount of research and consultations that would be necessary for such a study is far beyond the scope of this paper. Therefore only some specific considerations which appear relevant to the context of European islands can be presented here.

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[15] The term vulnerability is used here (in line with the definition provided in the IPCC 4th Assessment Report) to describe the degree to which a species is likely to be adversely impacted by climate change when its de facto exposure to changes in climatic parameters, its sensitivity and its adaptive capacity are all taken into account.

As can be seen in Table 2, the largest proportion of vulnerable Bern Convention species, as adapted from the assessment of a subset of European species by Sajwaj et al. (2009), occurs on islands in the Mediterranean region. There are several possible reasons for this, including a correlative effect of the higher species richness of the Mediterranean region as compared to other parts of Europe, and the projected severe impacts of climate change in the Mediterranean region as a whole. It must therefore not necessarily indicate a particularly high vulnerability of Mediterranean island species or ecosystems.

On the other hand, the high degree of endemism on the islands of the Mediterranean and Macaronesian regions asks for further investigations of their vulnerability.

Table 2: Bern Convention species occurring on islands in the different biogeographical regions of Europe, assessed as being at least highly vulnerable to climate change (adapted from the subset of species assessed by Sajwaj et al. (2009) through an analysis of the underlying atlas data; the small number for Macaronesia likely results from the fact that too few model projections for species from the region could be included in Sajwaj's study).

Biogeographical region	**Number of species**
Arctic	15
Atlantic	34
Boreal	30
Continental	20
Mediterranean	58
Macaronesian	2

An important factor to be kept in mind when thinking about the prioritization of conservation efforts is the likelihood that as species distributions shift with climate change, the relative importance of certain island regions for biodiversity conservation may change. For example, if the projected shifts in suitable climate space as presented in the Climatic Atlas of European Breeding Birds (Huntley et al. 2008) are considered for the vulnerable species listed in Annex 3, the number of species which could potentially occur on islands in the Arctic region would double from 14 to 28 by the end of this century.

One specific factor associated with climate change that is likely to have a significant impact on islands is the expected continuation of global sea level rise. In many areas, this will add to the already high pressure on coastal and littoral habitats due to settlement and infrastructure construction. Intuitively, one can assume that the greatest impact of increased sea levels would be felt on islands where coasts are flat and human pressure is high (e.g. parts of the British isles, the Frisian and southern Baltic islands, and the eastern islands of the Canaries). In contrast, impacts on coastal species and habitats may be less severe where human pressure is low and space remains for these species and habitats to move higher (e.g. in Arctic islands); or where the coasts are steep and rocky (e.g. many Mediterranean islands, many Atlantic islands including the Azores, Madeira and the western Canaries). However, Berry et al. (2007) in their study (which did not consider Macaronesia) concluded that the vulnerability of European coastal mudflats and saltmarshes to sea level rise was greatest in islands in the Baltic Sea and, particularly, the Mediterranean Sea; this is explained by the fact that these have low tidal ranges making coastal ecosystems more sensitive to sea level rise.

Naturally, the projected magnitude of sea level rise can be expected to have no or rather limited effects on terrestrial communities away from the coast, and on many components of marine biodiversity (excluding, for example slow-growing sessile organisms adapted to shallow waters). Moreover, for some parts of Scandinavia, sea level rise is expected to be counteracted by the ongoing process of postglacial land uplift (HELCOM 2007).

As noted by Orueta (2009), impacts will also be caused by changes in the frequency of extreme events such as storm surges. According to the IPCC 4th Assessment Report, several studies have projected climate-driven increases in extreme water levels in the European shelf region, although Christensen et al. (2007) state that estimates of future coastal flooding still hold substantial uncertainty. Soft substrate islands, e.g. the islands lining the coasts of the Wadden Sea and the southern Baltic Sea which are largely made up of glacial sediments, are facing a particular risk of high losses in land area due to increased coastal erosion.

Climate change is also expected to increase the likelihood of threats to native island biota caused by invasive alien species Already now, invasive species are having particularly detrimental effects on island biodiversity in Europe as well as other regions of the world, despite significant efforts at control and eradication (Genovesi & Shine 2003; Carnevali & Genovesi 2009). New IAS threats will come from two sources: (a) an influx of new species facilitated by changing climatic parameters; and (b) increased invasiveness of already introduced taxa that are currently “dormant” such as grass species commonly used in gardening (V. Heywood pers. comm. 2009).

When talking about invasive alien species in the context of climate change, it is important to note that according to the CBD definition of invasive alien species as interpreted by the Standing Committee to the Bern Convention, native species naturally extending their range in response to climate change should not be considered as “alien” (Rec. No. 142 (2009)).

Many island communities are susceptible to invasion because they have developed under conditions of reduced competition and predation. Climate change is expected to trigger a significant rise in the number of alien species becoming invasive as well as to favour the spread of many invasive alien species that are already established (Capdevila-Arguelles & Zilletti 2008). Invasive species may be more able than native ones to benefit from the changing environmental conditions including higher temperatures, decreasing numbers of frost days and elevated levels of carbon dioxide. However, predictions about invasion success at species level are difficult to make.

More frequent extreme events such as storms, floods, droughts or fire may also increase the susceptibility of ecosystems to invasion. Gritti et al. (2006, as cited by Heywood & Culham 2009) have studied the vulnerability of ecosystems in five Mediterranean islands (Mallorca, Corsica, Sardinia, Crete and Lesvos) to climate change and invasion by exotic plants. Their simulations predict that while climate change on its own would not have any severe impacts, as an effect of habitat disturbance in the longer term almost all the ecosystems would be dominated by invasive aliens.

Some work on identifying priority areas for efforts to control the impacts of invasive alien species on European islands, including the development of a European Invasive Alien Species Island Information System, has been initiated under the Bern Convention (Carnevali & Genovesi 2009)[16].

Finally, climate change may also lead to significant indirect impacts on biodiversity, for example due to inappropriate land and water management measures adopted in the context of adaptation, or due to mitigation activities such as the increased use of renewable energies. With regard to the latter, the development of ill-placed wind farms has in recent decades been an issue of concern for conservationists on many islands, and further expansion is to be expected. Renewable energy infrastructures with even greater biodiversity impacts are tidal barrages and hydropower dams; whereas well-placed onshore and offshore wind farms as well as infrastructures harnessing tidal stream and wave energies are, in relative terms, considered lesser threats to biodiversity (Keder & McIntyre Galt 2009).

In a similar manner, inappropriate new water management measures deployed in the context of climate change adaptation, particularly on Mediterranean and Macaronesian islands, could further increase pressure on freshwater ecosystems, which are already now amongst the most threatened.

Going beyond the European-scale analyses outlined above, island-specific projections or expert opinions on impacts are available only for certain regions and taxa, again with a heavy bias towards the British Isles. One of the earliest and most comprehensive studies examining potential climate change impacts was the MONARCH project, which focussed on Britain and Ireland. Among other results,

[16] Note also Bern Convention Recommendation 91 (2002) on invasive species that threaten biological diversity on islands and evolutionary isolated ecosystems

montane heaths, native pine woodland and peat bogs in areas becoming drier were identified as potentially vulnerable habitats. Hodgson et al. (2009) also cite several other modelling studies focussing on Britain and examining potential impacts on butterfly and bird species.

According to Heywood & Culham (2009), the islands of Macaronesia should be considered as a particularly vulnerable region due to the potential effects of an eastwardly shift of the Azorean anticyclone that would diminish the frequency and intensity of the northwest trade winds with consequential effects on the unique Laurel forest zone. Indeed, changes in the trade winds might upset the current distribution of microclimates and habitat niches. Citing an assessment of climate change impacts on the flora and vegetation of the Canary Islands by Del Arco (2008), Heywood & Culham (2009) further point out risks to high altitude ecosystems and species due to their inability to migrate.

Hodgson et al. (2009) note a very limited amount of available research on the vulnerability of island biota in the Mediterranean region, but assume a high vulnerability of their endemic species due to the geographic restrictions. Heywood & Culham (2009) also suggest that Mediterranean islands are at high risk of facing species extinctions both because of the presence of a large number of narrowly endemic and threatened plant species, many of which are confined to mountain areas making successful dispersal into new areas even more unlikely, and the significant climatic changes expected. The generally high vulnerability of Mediterranean ecosystems due to an increase in already now severe drought stress and fire risk has been observed in several studies (Berry 2008).

For instance, based on expert judgment it is assumed that rising temperatures and a decrease in days with precipitation could threaten the endemic Corsican gastropod *Tyrrhenaria ceratina* as well as several endemic species of Corsican mountain aquatic invertebrates (French national report to the Bern Convention).

The expected impacts of climate change in the Arctic biogeographical region, including thawing of permafrost and a major reduction in the area of tundra (EEA 2002-2008, Zockler and Lysenko 2000), are likely to affect island ecosystems in the region.

4. IMPLICATIONS OF CLIMATE CHANGE FOR CONSERVATION EFFORTS ON EUROPEAN ISLANDS AND OPTIONS FOR ACTION

Climate change adds to the existing pressures on island biodiversity and is likely to affect those species most that are often already threatened - species with specialized habitat requirements, small population numbers, limited distribution areas and low dispersal ability. Therefore, many conservation strategies and measures that have been put in place will remain useful under conditions of climate change.

However, the increasing dynamics of environmental conditions and the possibility of unexpected effects (triggered for example by impacts of climate change on species interactions) have to be taken into account, both by stepping up monitoring efforts with a particular focus on islands and by ensuring a certain amount of flexibility (and willingness) to adapt strategies if needed.

In addition, targeted measures to reduce the negative direct and indirect impacts of climate change should be taken. Thorough reviews of approaches supporting the adaptation of biodiversity to climate change have been provided by Huntley (2007), Harley (2008) and Hodgson et al. (2009). However, not all of these approaches can be applied equally well to islands. While measures such as filling the gaps in protected area networks, maintaining and restoring ecosystem function, conserving genetic diversity, reducing non-climatic stresses, introducing elements of adaptive management, establishing buffer zones, integrating biodiversity considerations into sectoral and cross-sectoral strategies for climate change adaptation and mitigation and making use of ecosystem-based approaches to adaptation and mitigation (cf. CBD Secretariat 2009) are relevant on islands as much as anywhere else, at least for terrestrial biota the insular setting effectively limits the applicability of those strategies which aim to facilitate natural adaptation by shifts in species distributions. Measures to increase the connectivity of terrestrial habitats by the creation of corridors or stepping stones and by strengthening landscape permeability in general are feasible only within islands and would thus seem irrelevant to many of the smaller island territories. With regard to marine and coastal biodiversity, however, conservation efforts based on islands can provide wide-ranging connectivity benefits to the surrounding seascape.

Given the above-mentioned constraints related to the small size of islands and their isolation, due consideration should be given to the question of ex situ conservation and translocation for those terrestrial species which are threatened with extinction in their current habitat and unlikely to be able to reach other suitable habitat by natural dispersal. Although both ex situ and translocation measures are resource-intensive strategies and not always feasible in practice, and translocation also carries a significant amount of risk to biota in the target area (see also discussion in Heywood & Culham 2009 and CBD Secretariat 2009), they may in some cases be the only way to ensure the survival of threatened island taxa.

The specific threats to coastal habitats from sea-level rise should be addressed by providing space for natural retreat towards higher areas wherever feasible, and by avoiding further habitat destruction for the construction of settlement and transport infrastructure.

Finally, preventive measures against the establishment of further invasive species and containment measures where invasive alien species have already been introduced should be considered a priority in island ecosystems.

5. RESEARCH NEEDS

In addition to research needs already identified in previous reports (including improving the information base on the vulnerability of Bern Convention species and habitats, and strengthening monitoring schemes) and by other Expert Groups (including the identification of knowledge gaps in European island threatened biodiversity and on invasive alien species on European islands), the following specific research needs should be addressed:

- improving knowledge about island endemic species and sub-species in less well researched groups,
- monitoring both direct and indirect climate change impacts on island biota (including marine and migratory species),
- further developing appropriate approaches to assess the vulnerability of rare and endemic species to climate change, including through traits-based assessment frameworks
- including the combined effects of changes in the terrestrial and marine environment in assessments of the vulnerability of island biota to climate change
- improving climate projections at a resolution which is appropriate for consideration of climate change effects on islands

6. CONCLUSIONS AND RECOMMENDATIONS

Many recommendations which are relevant to the conservation of island biodiversity under climate change have already been approved by the Standing Committee and should be applied in the island context.

These include:

- Bern Convention Recommendation 135 (2008) on addressing the impacts of climate change on biodiversity, and in particular the points of guidance on taking an integrated approach to climate change response activities, addressing non-climatic threats to vulnerable species, taking early action on the protection of island-endemic amphibian and reptile species, maintaining and restoring large intact habitats as well as ecosystem structure and function, establishing networks of interconnected protected areas, increasing protected area coverage where necessary to ensure that vulnerable species groups and habitats are included, establishing buffer zones around conservation areas, avoiding development in coastal areas, considering the role of species translocation and ex situ conservation, ensuring policy integration, using adaptive management and addressing invasive species issues.

- Bern Convention Recommendation 143 (2009) on further guidance for Parties on biodiversity and climate change, and in particular the points of guidance on minimising threats to vulnerable invertebrates, including in Atlantic and Mediterranean islands, implementing appropriate protected area management to increase resilience and considering mechanisms for implementation of off-protected areas management.
- Bern Convention Recommendation 91 (2002) on invasive species that threaten biological diversity on islands and evolutionary isolated ecosystems
- The European Strategy on invasive species

When developing measures supporting the adaptation of biodiversity to climate change, special consideration should be given to islands of the Mediterranean and Macaronesian regions because of their high rates of endemism and expected serious changes in their climatic regimes; and within these regions particularly to those sites hosting vulnerable or threatened endemic taxa (the lists provided in annexes 1 and 2 can serve as a starting point for this). However, islands in other regions also contain highly sensitive biota which require attention, as exemplified by the observed drastic declines in seabird populations of the North East Atlantic region. For all islands, the marine environment and its interactions with the terrestrial sphere need to be considered appropriately both in research and in the design and implementation of practical measures.

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Annex 1:
Endemic animal species in various taxonomic groups, Bern Convention species marked (data extracted from IUCN Red Lists, IUCN Species Database, BirdLife fact sheets and WCMC Species Database)

Species name	Distribution	IUCN Red List Status	Listed in Appendix II of the Bern Convention
Mammals			
Nyctalus azoreum	Azores	EN	Yes
Pipistrellus maderensis	Madeira, Canary Islands	EN	Yes
Plecotus sardus	Sardinia	VU	Yes
Plecotus teneriffae	Canary Islands	EN	Yes
Acomys minous	Crete	DD	--
Crocidura canariensis	Canary Islands	EN	Yes
Crocidura sicula	Sicily and surrounding islands	LC	--
Crocidura zimmermanni	Crete	VU	--
Birds			
Loxia scotica	Great Britain	DD	Yes
Serinus canaria	Azores, Madeira, Canary Islands	LC	--
Pterodroma madeira	Madeira	EN	Yes
Columba trocaz	Madeira	NT	--
Columba bollii	Canary Islands	NT	Yes
Columba junoniae	Canary Islands	EN	Yes
Apus unicolor	Madeira, Canary Islands	LC	Yes
Saxicola dacotiae	Canary Islands	EN	Yes
Anthus berthelotii	Madeira, Canary Islands	LC	Yes
Fringilla teydea	Canary Islands	NT	Yes
Sylvia melanothorax	Cyprus	LC	Yes
Oenanthe cypriaca	Cyprus	LC	Yes
Puffinus mauretanicus	Balearic Islands	CR	--
Sitta whiteheadi	Corsica	LC	Yes
Regulus madeirensis	Madeira	LC	Yes
Reptiles			
Hierophis cypriensis (Coluber cypriensis)	Cyprus	EN	Yes
Tarentola angustimentalis	Canary Islands	LC	Yes
Tarentola boettgeri	Canary Islands	LC	Yes
Tarentola delalandii	Canary Islands	LC	Yes
Tarentola gomerensis	Canary Islands	LC	Yes
Algyroides fitzingeri	Corsica, Sardinia and some surrounding islets	LC	Yes
Archaeolacerta bedriagae	Corsica, Sardinia and several smaller islands	NT	Yes
Gallotia atlantica	Canary Islands	LC	--
Gallotia auaritae	Canary Islands (possibly extinct)	CR	Yes (as part of *Gallotia simonyi*)

Gallotia bravoana	Canary Islands	CR	Yes (as part of *Gallotia simonyi*)
Gallotia caesaris	Canary Islands	LC	Yes (as part of *Gallotia galloti*)
Gallotia galloti	Canary Islands	LC	Yes
Gallotia intermedia	Canary Islands	CR	--
Gallotia simonyi	Canary Islands	CR	Yes
Gallotia stehlini	Canary Islands	LC	Yes
Phoenicolacerta troodica	Cyprus	LC	--
Podarcis cretensis	Crete and satellite islands	EN	Yes (as part of *Podarcis erhardii*)
Podarcis filfolensis	Malta, Linosa and Lampione (Italy)	LC	Yes
Podarcis gaigeae	Aegean Islands	VU	--
Podarcis levendis	Aegean Islands	VU	--
Podarcis lilfordi	Balearic Islands	EN	Yes
Podarcis milensis	Aegean islands	VU	Yes
Podarcis pityusensis	Balearic Islands	NT	Yes
Podarcis raffonei	Aeolian Islands (Italy)	CR	--
Podarcis tiliguerta	Corsica, Sardinia and adjacent islets	LC	Yes
Podarcis waglerianus	Sicily, adjacent islands	LC	Yes
Teira dugesii	Native to Madeira, introduced to the Azores Islands	LC	Yes
Chalcides sexlineatus	Canary Islands	LC	Yes
Chalcides simonyi (Chalcides occidentalis)	Canary Islands	EN	Yes
Chalcides viridanus	Canary Islands	LC	Yes
Macrovipera schweizeri (Vipera schweizeri)	Aegean Islands	EN	Yes
Emys trinacris	Sicily	DD	Yes (as part of *Emys orbicularis*)
Amphibians			
Speleomantes imperialis	Sardinia	NT	Yes
Euproctus platycephalus	Sardinia	EN	Yes
Lyciasalamandra helverseni	Aegean Islands	VU	--
Atylodes (Hydromantes / Speleomantes) genei	Sardinia	VU	Yes
Alytes muletensis	Balearic Islands	VU	Yes
Salamandra corsica	Corsica	LC	--
Pseudepidalea sicula	Sicily, adjacent islands	LC	Yes (as part of *Bufo viridis*)
Euproctus montanus	Corsica	LC	Yes
Speleomantes (Hydromantes) flavus	Sardinia	VU	Yes
Speleomantes supramontis	Sardinia	EN	Yes
Pelophylax cretensis	Crete	EN	--

Pelophylax cerigensis	Aegean Islands	CR	--
Discoglossus montalentii	Corsica	NT	Yes
Hyla sarda	Corsica, Sardinia, adjacent islands	LC	Yes
Speleomantes sarrabusensis	Sardinia	VU	Yes (as part of *Hydromantes / Speleomantes imperialis*)
Butterflies			
Plebejus psyloritus	Crete	LC	--
Plebejus bellieri	Corsica, Sardinia	LC	--
Cyclyrius webbianus	Canary Islands	LC	--
Glaucopsyche paphos	Cyprus	LC	--
Pseudophilotes barbagiae	Sardinia	LC	--
Papilio hospiton	Corsica, Sardinia	LC	Yes
Zerynthia cretica	Crete	LC	--
Thymelicus christi	Canary Islands	LC	--
Spialia therapne	Corsica and Sardinia	LC	--
Hipparchia maderensis	Madeira	LC	--
Hipparchia azorina	Azores	LC	--
Hipparchia tilosi	Canary Islands	VU	--
Hipparchia aristaeus	Corsica, Sardinia, adjacent islands	LC	--
Hipparchia gomera	Canary Islands	LC	--
Hipparchia neomiris	Corsica, Sardinia, adjacent islands	LC	--
Hipparchia sbordonii	Ponza Islands, Italy	NT	--
Hipparchia miguelensis	Azores	LC	--
Hipparchia leighebi	Aeolian Islands, Italy	NT	--
Hipparchia cypriensis	Cyprus	LC	--
Hipparchia cretica	Crete	LC	--
Hipparchia bacchus	Canary Islands	VU	--
Hipparchia tamadabae	Canary Islands	LC	--
Hipparchia christenseni	Aegean islands	LC	--
Hipparchia wyssii	Canary Islands	LC	--
Coenonympha thyrsis	Crete	LC	--
Coenonympha corinna	Corsica, Sardinia and adjacent islands	LC	--
Pararge xiphia	Madeira	EN	--
Pararge xiphioides	Canary Islands	LC	--
Melanargia pherusa	Sicily	LC	--
Vanessa vulcania	Madeira, Canary Islands	LC	--
Argynnis elisa (Fabriciana elisa)	Corsica, Sardinia	LC	Yes
Maniola nurag	Sardinia	LC	--
Maniola chia	Aegean islands	LC	--
Maniola cypricola	Cyprus	LC	--
Lasiommata paramegaera	Corsica, Sardinia and adjacent islands	LC	--
Aglais ichnusa	Corsica, Sardinia	LC	--
Gonepteryx maderensis	Madeira	EN	--
Gonepteryx cleobule	Canary Islands	VU	--
Euchloe insularis	Corsica, Sardinia	LC	--
Euchloe grancanariensis	Canary Islands	LC	--

Euchloe hesperidum	Canary Islands	LC	--
Euchloe eversi	Canary Islands	LC	--
Pieris cheiranthi	Canary Islands	EN	--
Pieris wollastoni	Madeira	CR	--
Dragonflies			
Boyeria cretensis	Crete	EN	--
Sympetrum nigrifemur	Canary Islands, Madeira	LC	--
Coenagrion intermedium	Crete	VU	--
Ischnura genei	Corsica, Sardinia, Sicily, Malta and adjacent islands	LC	--
Saproxylic Beetles			
Trichoferus bergeri	Crete	EN	--
Axinopalpis barbarae	Cyprus	DD	--
Delagrangeus schurmanni	Canary Islands	VU	--
Crotchiella brachyptera	Azores	EN	--
Stenopterus creticus	Crete	EN	--
Blabinotus spinicollis	Canary Islands, Madeira	NT	--
Glaphyra bassettii	Cyprus	CR	--
Pseudosphegesthes bergeri	Crete	EN	--
Anaglyptus praecellens	Crete	EN	--
Purpuricenus nicocles	Cyprus	NT	--
Isotomus jarmilae	Crete	EN	--
Clytus clavicornis	Sicily	VU	--
Pediacus tabellatus	Canary Islands	DD	--
Scobicia barbifrons	Canary Islands	LC	--
Scobicia ficicola	Canary Islands	LC	--
Stephanopachys brunneus	Canary Islands	NT	--
Procraerus cretensis	Crete	DD	--
Stenagostus sardiniensis	Sardinia, possibly Corsica	DD	--
Ampedus minos	Crete	DD	--
Ampedus assingi	Cyprus	EN	--
Ampedus corsicus	Corsica	NT	--
Alestrus dolosus	Azores	DD	--
Haterumelater schembrii	Malta	DD	--
Gnorimus decempunctatus	Sicily	VU	--
Protaetia sardea	Sardinia and Corsica	DD	--
Osmoderma cristinae	Sicily	EN	Yes (as part of *Osmoderma eremita*)
Leipaspis pinicola	Canary Islands	VU	--
Leipaspis lauricola	Canary Islands	VU	--
Propomacrus cypriacus	Cyprus	CR	--
Dorcus musimon	Corsica, Sardinia	LC	--
Dorcus alexisi	Cyprus	EN	--

Annex 2:
Plant species protected under the Bern Convention which are endemic to a single island or archipelago in Europe according to the Euro+Med Plantbase. Endemic species of the Macaronesian region were purposely omitted from this table as they are already listed separately in Appendix I of the Convention.

Species name	**Distribution**
Primula egaliksensis	Iceland
Bromus interruptus	Great Britain
Gentianella anglica	Great Britain
Anthyllis hystrix	Balearic islands
Centaurea balearica	Balearic islands
Daphne rodriguezii	Balearic islands
Diplotaxis ibicensis	Balearic islands
Euphorbia margalidiana	Balearic islands
Genista dorycnifolia	Balearic islands
Lysimachia minoricensis	Balearic islands
Paeonia cambessedesii	Balearic islands
Ranunculus weyleri	Balearic islands
Viola jaubertiana	Balearic islands
Aconitum corsicum	Corsica
Astragalus maritimus	Sardinia
Centaurea horrida	Sardinia
Lamyropsis microcephala	Sardinia
Ribes sardoum	Sardinia
Abies nebrodensis	Sicily
Brassica macrocarpa	Sicily
Bupleurum dianthifolium	Sicily
Cytisus aeolicus	Sicily
Petagnaea saniculifolia	Sicily
Cremnophyton lanfrancoi	Malta
Helichrysum melitense	Malta
Palaeocyanus crassifolius	Malta
Asyneuma giganteum	Aegean islands
Consolida samia	Aegean islands
Androcymbium rechingeri	Crete
Anthemis glaberrima	Crete
Arum purpureospathum	Crete
Bupleurum kakiskalae	Crete
Carlina diae	Crete
Cephalanthera cucullata	Crete
Colchicum cousturieri	Crete
Convolvulus argyrothamnos	Crete
Hypericum aciferum	Crete
Origanum dictamnus	Crete
Wagenitzia lancifolia	Crete
Zelkova abelicea	Crete
Alyssum akamasicum	Cyprus
Arabis kennedyae	Cyprus
Brassica hilarionis	Cyprus
Centaurea akamantis	Cyprus

Chionodoxa lochiae	Cyprus
Crocus cyprius	Cyprus
Crocus hartmannianus	Cyprus
Delphinium caseyi	Cyprus
Onosma troodi	Cyprus
Ophrys kotschyi	Cyprus
Origanum cordifolium	Cyprus
Phlomis brevibracteata	Cyprus
Phlomis cypria	Cyprus
Ranunculus kykkoensis	Cyprus
Salvia veneris	Cyprus
Scilla morrisii	Cyprus
Sideritis cypria	Cyprus
Tulipa cypria	Cyprus

Annex 3:

Species protected under Appendix I or II of the Bern Convention which are assessed by Sajwaj et al. (2009) as being at least highly vulnerable to climate change.

Accipiter brevipes
Acrocephalus melanopogon
Acrocephalus paludicola
Aegypius monachus
Anser erythropus
Anthus campestris
Apus caffer
Aquila adalberti
Aquila chrysaetos
Aquila clanga
Aquila heliaca
Aquila pomarina
Ardea purpurea
Ardeola ralloides
Asio flammeus
Botaurus stellaris
Botrychium simplex
Branta leucopsis
Bubo bubo
Burhinus oedicnemus
Buteo rufinus
Calonectris diomedea (Procellaria diomedea)
Charadrius morinellus (Eudromias morinellus)
Chersophilus duponti
Chioglossa lusitannica
Chlidonias hybridus
Chlidonias niger
Ciconia nigra
Circaetus gallicus
Circus cyaneus
Circus macrourus
Circus pygargus
Coracias garrulus
Crex crex
Cygnus bewickii (Cygnus columbianus bewickii)
Cygnus cygnus
Dendrocopos leucotos
Dendrocopos medius
Discoglossus galganoi
Egretta alba (Ardea alba) (Casmerodius albus)
Egretta garzetta
Elanus caeruleus
Emberiza cineracea
Falco biarmicus
Falco cherrug
Nycticorax nycticorax
Oceanodroma leucorhoa
Oenanthe leucura
Oenanthe pleschanka
Otis tarda
Oxyura leucocephala
Pandion haliaetus
Phalacrocorax pygmeus
Phengaris nausithous (Maculinea nausithous)
Phoenicopterus ruber
Picoides tridactylus
Picus canus
Platalea leucorodia
Plegadis falcinellus
Podiceps auritus
Porphyrio porphyrio
Porzana parva
Porzana pusilla
Pterocles alchata
Pterocles orientalis
Puffinus yelkouan
Pulsatilla patens
Pyrrhocorax pyrrhocorax
Rana latastei
Recurvirostra avosetta
Rumex rupestris
Salamandrina terdigitata
Sitta krueperi
Sterna albifrons
Sterna caspia (Hydroprogne caspia)
Sterna dougallii
Sterna paradisaea
Sterna sandvicensis
Strix nebulosa
Strix uralensis
Surnia ulula
Sylvia rueppelli
Sylvia sarda
Sylvia undata
Tadorna ferruginea
Tetrax tetrax
Triturus montandoni
Vipera ursinii
Xenus cinereus (Tringa cinerea)

Falco columbarius
Falco eleonorae
Falco rusticolus
Falco vespertinus
Ficedula albicollis
Ficedula semitorquata
Fulica cristata
Galerida theklae
Gallinago media
Gelochelidon nilotica (Sterna nilotica)
Glareola pratincola
Grus grus
Gypaetus barbatus
Gyps fulvus
Haliaeetus albicilla
Hieraaetus fasciatus
Hieraaetus pennatus
Himantopus himantopus
Hydrobates pelagicus
Lacerta monticola (Archaeolacerta monticola)
Lacerta schreiberi
Lanius nubicus
Larus audouinii
Larus melanocephalus
Loxia scotica
Luscinia svecica
Lycaena dispar
Marmaronetta angustirostris
Melanargia arge
Mergus albellus (Mergellus albellus)
Milvus milvus
Neophron percnopterus
Nyctea scandiaca