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CONVENTION ON THE CONSERVATION OF EUROPEAN WILDLIFE
AND NATURAL HABITATS

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REPORT

CLIMATE CHANGE AND THE VULNERABILITY OF BERN CONVENTION SPECIES AND HABITATS

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1. CLIMATE CHANGE IMPACTS ON BIODIVERSITY

1.1 Introduction

The Intergovernmental Panel on Climate Change (IPCC) suggest that warming of the climate system is unequivocal, as shown by observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, rising global average sea level and changing patterns and frequencies of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones (Chaps 3-5, IPCC, 2007a). For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios. The best estimate for the low greenhouse gas emission scenario (B1) is 1.8°C (*likely* range is 1.1°C to 2.9°C), and the best estimate for the high scenario (A1FI) is 4.0°C (*likely* range is 2.4°C to 6.4°C) (Chap 10 Table 10.7, IPCC, 2007a). The greatest temperature increase is projected to occur over land and at high latitudes in the northern hemisphere and snow cover and sea ice are projected to decrease (Chap 10.3, IPCC, 2007a). It is *very likely* that hot extremes, heat waves and heavy precipitation events will continue to become more frequent and it is *likely* that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperature (Chap 10.3, IPCC, 2007a). Increases in the amount of precipitation are *very likely* in high latitudes, while decreases are *likely* in most subtropical land regions (Chaps 3.3, 10.3, 11.2 to 11.9 IPCC, 2007a).

Observations from all continents and oceans show that many natural ecosystems are responding to regional climate changes, especially increases in temperature (Chapter 1.3.4-1.3.5, Rosenweig *et al.*, 2007, IPCC, 2007b). The responses include poleward and altitudinal range shifts of biota, phenological changes (such as the earlier onset of spring events, migration (see Climate Research Special issue on effects of climate change on bird migration, 35, 5-180, 2007)), and lengthening of the growing season), changes in species' abundance and in community composition (Chapter 1.3.5 IPCC, 2007b), as well as changes in form and physiology (Reading and Clarke, 1999), reproduction (Crick and Sparks, 1999) and productivity. In Europe, of the observed changes in biological systems (terrestrial, marine and freshwater) 90% of significant changes are consistent with warming (Rosenweig *et al.*, 2008)

This shows that some species are already adapting autonomously to current climate change, but it is also projected that the resilience of many species and ecosystems will be exceeded in the 21st century. These species may become vulnerable[1] if their adaptive capacity[2] is exceeded. This may be as a result of climate change or through a combination of this and associated disturbances or other drivers of global change. In this case, human intervention, through various adaptation strategies, will be needed in order to reduce species loss and the various options have been recently reviewed for the Council of Europe (Huntley, 2007).

This review will examine the direct and indirect impacts of climate change on biodiversity (focusing on the Bern Convention's species and habitats) at the global, European, EU and country-level and will identify the most vulnerable species and habitats in the context of climate change, based on both the direct impacts of climate change and the adaptation and mitigation measures taken to combat climate change. The report also builds on the previous report to the Standing Committee which provides more detail on past, present and future changes, and adaptation possibilities (Huntley, 2007).

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[1] Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of *climate change*, including *climate variability* and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its *sensitivity*, and its adaptive capacity (Appendix 1 IPCC, 2007b).

[2] Adaptive capacity is the ability of a system to adjust to *climate change* (including *climate variability* and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences(Appendix 1 IPCC, 2007b).

1.2 Vulnerability

Vulnerability, as defined by the IPPC, incorporates the concepts of exposure[3], sensitivity[4] and adaptation[5] and it is usually a combination of these that lead to vulnerability. Species are already vulnerable to decreases in their abundance and range, which could lead to extinction, as a result of human activities, such as land use/land cover change, habitat fragmentation and exotic invasive species. On the short-time scale (1-10 years) many of these other pressures are likely to have a greater local impact on vulnerability, but climate change will increasingly contribute to longer-term stresses on plants and ecosystems (Parmesan and Yohe, 2003). Climate change, therefore, is not an isolated factor and an integrated approach is needed in order to understand how these contribute to vulnerability.

Climate change poses a risk to human and natural systems. The risk is often considered as the probability of occurrence times the consequence(s) and thus it includes an element of vulnerability and uncertainty (IPCC, 2007b). In the case of biodiversity, a vulnerability assessment could identify where the consequences could be greatest. and in order to reduce the risk both adaptation and mitigation are necessary (Klein *et al.*, 2007).

1.2.1 Exposure

Exposure can come from any of the climatic elements, but those expected to be of most concern are:

- High level of change in temperature
- High level of change in precipitation
- High level of sea level rise
- Increased frequency and/or magnitude of extreme events
- Changed disturbance regimes, e.g. fire

While species have adapted to such changes in the past, the speed and magnitude of projected climate changes will affect the success of species, population, and community adaptation and the rate of projected changes may exceed the rate of movement in certain species' ranges and their ability to adapt (Huntley, 2007; and see below).

1.2.2 Sensitivity

Species sensitive to climate change are those that are near a climatic tolerance threshold; many corals, for example, are near their thermal limit as shown by the bleaching episodes associated with warmer sea temperatures. Also, populations in the warmest part of a species' range (e.g. southern populations in the northern hemisphere) are likely to be more sensitive to climate change, as they are nearest to their upper thermal limit. Where populations at this rear edge of a shifting range are isolated, relatively poor intra-population diversity will reduce the evolutionary potential in the face of rapid environmental change and local extinctions are likely (Davis and Shaw, 2001; Parmesan, 2006; Willi *et al.*, 2006). Sensitive species may have a small niche breadth and thus be more readily affected by changes. The observed changes in response to climate change over the last few decades may indicate the sensitivity of species to future climate change and this may aid taxonomic experts in identifying some vulnerable species. An alternative approach to identifying sensitivity is to use knowledge of the species' current European distribution to model changes in their potential climate

[3] Exposure is the nature and degree to which a system is exposed to significant climatic variations (Glossary, IPCC, 2001).

[4] Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate change (Glossary, IPCC, 2007b).

[5] Adaptation is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (Glossary, IPCC, 2007b).

space. This involves a number of assumptions, including that climate is the prime factor affecting the distribution of the species at this scale, that the species is equilibrium with current climate and that species will continue in their current relationship with climate. Also there are various sources of uncertainty and so the results should be treated with caution. For a fuller discussion of such modelling issues see Pearson and Dawson, 2003; Araújo and Guisan,

1.2.3 Adaptation

Adaptation is vital to avoiding unwanted impacts of climate change, especially in sectors, such as ecosystems, vulnerable to even moderate levels of warming, (Stern, 2006; IPCC, 2007a). It is also seen as a means maintaining or restoring of ecosystem resilience to single or multiple stresses (Convention on Biological Diversity, 2005). The IPCC (Volume II Glossary, 2007) recognises two types of adaptation: autonomous (or spontaneous) adaptation and planned (or societal) adaptation. The former occurs at the level of species and habitats (see below) and includes the various responses to climate change and the latter includes human management and policy actions aimed at facilitating autonomous adaptation. The range of adaptation strategies reviewed by Huntley (2007) will not be discussed in any detail here, but various situations where a lack of adaptive capacity, particularly autonomous adaptive capacity, will be highlighted in order to provide an indication for the need for planned adaptation.

Autonomous adaptation responses include *in situ* genetic adaptation, phenological and physiological adjustments and dispersal (polewards or upwards). A number of factors can hinder this adaptation and contribute to vulnerability, including:

- Lack of opportunity for poleward migration
- Lack of opportunity for altitudinal migration
- Lack of opportunity for inland migration
- Limited dispersal capacity
- Barriers to dispersal e.g. oceans, urban areas
- Rarity/small population numbers
- Low genetic diversity

Other factors which may affect the success of adaptation include:

- Little or no overlap between present and potential future distributions
- Endemism
- Restricted range – current and/or projected future range
- Loss of critical associated species – those with monospecific relationships are most likely to be affected
- Disruption of the synchrony in the timing of life cycle events (phenology) or of species' interactions e.g. great tits and caterpillars.
- Increase competition from invading species (both natives and exotics)
- Increase in pathogens

The IPCC identified seven criteria that may be used to identify key vulnerabilities: magnitude of impacts, timing of impacts, persistence and reversibility of impacts, likelihood (estimates of uncertainty) of impacts and vulnerabilities, and confidence in those estimates, potential for adaptation, distributional aspects of impacts and vulnerabilities, and the importance of the system(s) at risk (Schneider *et al.*, 2007). These include many of the elements identified above, but the list has been refined and expanded to make it more specific to biodiversity. The exposure, sensitivity and adaptation potential components can act individually or in any combination to give rise to vulnerability. Species in alpine regions, for example, which are often endemic and of high importance for plant diversity, are vulnerable to climate warming, most probably because often they have restricted climatic ranges, small isolated populations, and the absence of suitable areas at higher elevations to migrate to (Pauli *et al*., 2003). The three elements and their components can be used to provide a framework for assessing vulnerability and this report will use these to try and identify the vulnerability of Bern Convention species and habitats to climate change.

The IUCN held a "Species Vulnerability Traits" workshop[6] and the participant experts identified a list of traits generally indicative of species' vulnerability to extinction. This has been refined to a list of the most important traits for assessing species' climate change vulnerability. This is currently being refined and appropriate data collected for selected taxonomic groups, including birds and amphibians. The traits associated with vulnerability to climate change map on to those identified in this report, such as specialised habitat requirements, narrow environmental tolerances (i.e. sensitive species), poor dispersal ability and dependence on specific interactions. This trait-based framework is in its early stages of development and testing and so it cannot be used at present for Bern Convention species, but in the longer-term it could provide a good framework for assessing species' vulnerability to climate change and provide a globally applicable, consistent approach.

2. Vulnerability of biodiversity to climate change

2.1 Global

The vulnerability of ecosystems and species is partly a function of the rate of climate change (exposure) relative to the resilience of such systems (sensitivity and adaptive capacity). The contribution of each to the vulnerability of global ecosystems is summarised in Table 1. However, this does not take into account other stressors which may be significant, in that humans have already substantially reduced the resilience of many ecosystems and made them more vulnerable, for example through habitat fragmentation and degradation, reduced populations, introduction of alien species and pollution.

Table 1: Global vulnerability of ecosystems (adapted from Berry, 2004)

Ecosystem	**Reason for climate change vulnerability**[1]
Terrestrial	
Polar (e.g. tundra)	experience highest changes in temperature (E) changes in precipitation amount and type (E), change in ice and permafrost regimes (S) lack of opportunity for poleward migration (A)
High mountain	lack of opportunity for altitudinal migration (A)
Islands	sea level rise (on small islands) (E), barriers to dispersal (A)
Wetlands	increased drought (E)
Karoo (S. Africa)	increased frequency of drought (E), changing fire regimes (E), loss of specialist pollinators (A)
Cape Floral Kingdom	increased frequency of drought (E), changing fire
(Fynbos, S. Africa)	regimes (E), lack of space for altitudinal or latitudinal migration (A)
Coastal and marine	
Mangroves	sea-level rise (E), changing sediment flux (E), lack of opportunity for inland/poleward migration (A)
Sea grass beds	sea-level rise (E), changing sediment flux (E)
Coral reefs	CO_2 (E), temperature increases (S)

[1] (E) exposure to direct and indirect climate change factors (S) high sensitivity to projected climate changes (A) barrier to adaptation

6 www.iucn.org/themes/ssc/news/2007_articles/Climate%20Change%20workshop.pdf

The warming is projected to be greatest in high northern latitudes, leading to reduced snow cover, increased thawing of permafrost and decreased ice extent (Chapter 3.2.2, IPCC, 2007a). It is very likely that precipitation will increase at high latitudes and is projected to decrease in most subtropical land regions. Thus there is potential for biodiversity vulnerability in these areas. Greater storminess and higher returns of extreme events will also alter disturbance regimes in coastal ecosystems, leading to changes in diversity and hence ecosystem functioning (Chapter 4, IPCC, 2007b). Saltmarshes, mangroves and coral reefs are likely to be particularly vulnerable (Bertness and Ewanchuk, 2002; Hughes *et al.*, 2003).

The IPCC review of projected impacts (Table 4.1, Fischlin *et al.*, 2007) suggests that the most sensitive (those which could be affected by less than a 1°C increase in temperature above pre-industrial levels) ecosystems and species are coral reefs in the Caribbean, Indian Ocean and the Great Barrier Reef (Hoegh-Guldberg, 1999), amphibians on mountains in Costa Rica, Spain and Australia (Pounds *et al.*, 2006; Bosch *et al.*, 2006), reduction in krill in Antarctic Ocean possibly affecting Adelie penguins (Forcada et al., 2006) and some Arctic ecosystems, such as those that overlie permafrost, and ice-edge ecosystems that provide habitat for polar bears and penguins (Zockler and Lysenko, 2000; Symon *et al.*, 2005). An ecosystem-specific, multiscale spatial model to synthesize 17 global data sets of anthropogenic drivers of ecological change for 20 marine ecosystems showed that no area is unaffected by human influence and that a large fraction (41%) is strongly affected by multiple drivers (Halpern *et al.*, 2008). However, large areas of relatively little human impact remain, particularly near the poles, but anthropogenic drivers associated with global climate change (acidification, ultra violet light and sea temperatures) are distributed widely and are an important component of global cumulative impact scores, particularly for offshore ecosystems.

An analysis using several niche-based models for a selection of regions covering 20% of the earth's terrestrial surface showed that, based on a middle of the range warming scenario, by 2050 15-37% of the species in these regions would be "committed to extinction" (Thomas *et al.*, 2004). The level of extinction would depend on the level of warming and whether species were able to disperse in response to climate change. More recently, the IPCC (Chapter 4, Fischlin *et al.*, 2007) has concluded that 20-30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperatures exceed 1.5 to 2.5°C.

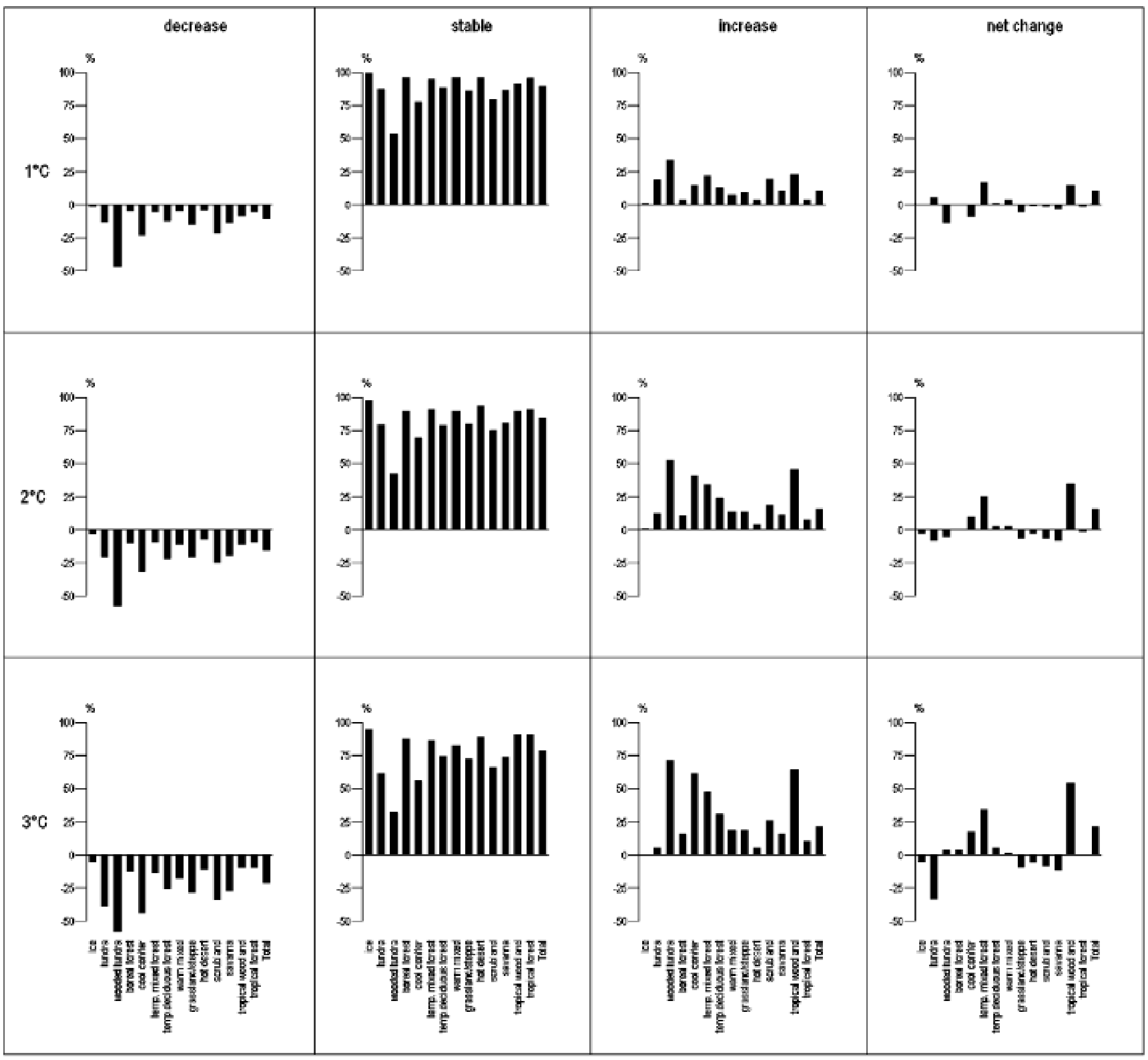
An integrated assessment model IMAGE which incorporates terrestrial vegetation, land-use and carbon models driven by different GCMs and climate scenarios showed that most species, ecosystems and landscapes will be impacted by increases in global mean temperatures of 1°C to 2°C and that adaptive capacity will become limited (Leemans and Eickhout, 2004). A 1°C warming led to a global average range change of all ecosystems of more than 10% (Figure 1), although there were large differences between specific ecosystems, with the greatest changes in the wooded tundra regions which were only 53% stable, with temperate forests replacing boreal forests and boreal forests invading the tundra. Cool conifer forests (e.g. Black Forest in Germany; Hemlock forests in the Pacific Northwest) were only 77% stable. At 2°C and 3°C the largest regional differences were in the tundra, wooded tundra and cool conifer forests. In years of more extreme variation in precipitation, such as are associated with El Ninõ, forests are more vulnerable. The severe El Ninõ in 1997, for example, led to reduced precipitation over large parts of Indonesia and Africa, resulting in many forest fires (Page *et al.*, 2002). Such extremes and associated disturbances could have important impacts on the vulnerability of species.

2.2 Europe and the EU

This section will examine vulnerability in Europe and the EU together, as studies vary in the countries included in their work and, as far as possible, results will be disaggregated to the regional or national scale. Also, much of the modelling work on the impacts of climate change which helps understanding of possible sensitivity and adaptive capacity is focused on identifying vulnerable regions and ecosystems and aspects of biodiversity, such as species richness and turnover, for these areas. Thus it can be difficult to establish the vulnerability of Bern Convention habitats and species, nevertheless by establishing these broader geographical patterns of vulnerability it is possible to combine them with knowledge of both the causes of vulnerability (Section 1.2) and the ecology of the habitats and species to provide guidelines, at least at the European and the EU level on their overall vulnerability to climate change.

In Europe, by the end of the century climate change could lead to an increase in annual mean temperatures, of between 2.5 to 5.5°C under a high greenhouse gas emissions scenario and between 1.0 to 4.0°C under a low greenhouse gas emissions scenario (IPCC, 2007a), although in the Russian Federation and other EECCA and SEE countries it could be more than 6°C (Table 3.1, EEA, 2007). This warming would be greatest in winter in Eastern Europe and in summer in western

Figure 1: Different changes in area of specific ecosystems for a global mean temperature increase of 1°C (top), 2°C (middle) and 3°C (bottom). Notes: From left to right is the decrease in area, the area that is stable (i.e. no impact), the increase in area, and the net change in area, based on the climate-change patterns of the HADCM-GCM (Leemans and Eickhout, 2004).



and southern Europe (Giorgi *et al.*, 2004). Projected precipitation changes are more variable, but most scenarios suggest an increase in mean annual precipitation in northern Europe and decreases further south, but with seasonal variations, although Turkey is projected to have up to a 50% increase by 2080/2100 (Table 3.1, EEA, 2007). Winter precipitation, for example, could increase in northern and central Europe, but decrease in Mediterranean Europe, while summer precipitation could decrease almost everywhere (Giorgi *et al.*, 2004; Räisänen *et al.*, 2004). Sea-level rise could be as much as 88 cm under a high greenhouse gas emissions scenario, and as low as 9 cm under a low greenhouse gas emissions scenario. Regional departures from these global rises could be ±50%, and additionally uplift/subsidence needs to be considered to develop relative sea-level rise scenarios (Hulme *et al.*, 2002). Thus there is geographic variability in the exposure to climate change. Projections of temperature and precipitation extremes are highly uncertain, but warm periods, including heat waves, are expected to be more intense, more frequent and longer-lasting (Christensen and Christensen, 2007). These changes are projected to occur especially in the Mediterranean and eastern Europe, while cold winters are projected to disappear almost entirely from Europe by the end of the century. The probability of extreme precipitation events is projected to increase in western and northern Europe (Palmer and Raisanen, 2002), while many parts of Mediterranean Europe may experience further reduced rainfall and longer periods of drought (Good *et al*, 2006).

The key vulnerabilities (both direct and indirect) of these changes for European biogeographical regions are given in Table 2. The WGBU (2003) identified four regions in Europe with highly vulnerable ecosystems: the Arctic, including parts of Scandinavia and Greenland, mountain regions, various coastal zones including the Baltic and parts of the Mediterranean. These tie in with

Table 2: Key biotic vulnerabilities of European biogeographic regions - based on EEA, 2004a (http://www.eea.europa.eu) and EU Green paper on Adapting to Climate Change in Europe (http://ec.europa.eu/environment/climat/adaptation/index_en.htm)

Region	Vulnerability
Tundra/Arctic	Higher temperature increases. Thawing of permafrost, decreased tundra area and sea ice, increased coastal erosion and flooding.
Boreal	Waterlogging, eutrophication of lakes and wetlands, increased coastal flooding and erosion, increased storm risk
Atlantic	Increased coastal flooding and erosion, stressing of marine bio-systems and habitat loss, greater winter storm risk
Central (including Pannonian region)	Increased magnitude and frequency of winter floods, severe fires in drained peatlands
Mountains	Reduced glacier ice and snow cover, upward shift of tree-line, high species loss
Mediterranean (including Black Sea region)	High temperatures, increased drought, forest fires, high species loss, land loss in estuaries and deltas, increased salinity and eutrophication of coastal waters.
Steppe	Increased soil erosion, salinity of inland seas and sea level rise with positive North Atlantic Oscillation.
Coastal zones	Sea level rise combined with increase storm risk

the terrestrial ecosystems in the IPCC report especially affected by climate change (and found in Europe): tundra, boreal forest, mountain and Mediterranean-type ecosystems, as well as salt marshes and sea-ice biomes and the Arctic region (Alcamo *et al.*, 2007).

One of the most comprehensive modelling studies for Europe used four representative emissions scenarios (A1, A2, B1, B2) and three different climate models (HadCM3, CGCM2, and CSIRO2), and a range of niche-based models, to project the potential impacts of climate change for the period 2051 to 2080 compared with baseline climate (averaged from 1961 to 1990) for 1,350 plant species in Europe (Thuiller *et al.*, 2005a). It discarded species with fewer than 20 records, thus many of the rare Bern Convention species were not included. Also, as with almost all such modelling studies it does not include land use changes, population dynamics or biotic interactions nor the lags in spatial range shifts associated with processes of dispersal, establishment, and local extinction and assumes instantaneous range changes.

Species extinction risks were estimated by summing for each species the number of pixels lost, potentially gained (under full migration into new suitable climate space), or stable for the different climate change scenarios. Each species was assigned to an International Union for Conservation of Nature and Natural Resources (IUCN) threat category (IUCN, 2001). Those that were not listed were classified as lower risk, depending on the projected reduction in range size from present to 2080. Present and future range sizes were estimated from the number of pixels where species occurred. Loss in range size was calculated by subtracting future potential range size from present potential range size. In line with IUCN Red List criterion A3(c), the following thresholds were then used to assign a species to a threat category (Table 3).

Table 3: Projected range and IUCN threat category

IUCN threat category	Projected range loss (%)
Extinct	100
Critically endangered	>80
Endangered	>50
Vulnerable	>30
Lower risk	30 or less

Under the assumption of no migration, more than half of the species would become vulnerable or committed to extinction by 2080, with 22% of the species becoming critically endangered and 2% extinct by 2080 under the most severe (A1) scenario (Figure 1 in Thuiller *et al.*, 2005a). These numbers decrease for the other scenarios and climate models, such that under the universal migration assumption and A1HadCM3 scenario, 67% of species would be classified as low risk. The percentage of species lost if these changes in suitable climate space were realised could exceed 80% in some areas, such as north central Spain and the Cevennes and Massif Central in France.

Mapping of projections of the residuals from a multiple regression of species loss against growing-degree days and moisture availability showed some regions of particularly high or low species vulnerability, because of the ecological and historical characteristics of the flora, and/or specific environmental conditions (Figure 2). Several mountain areas (mid-altitude Alps, mid-altitude Pyrenees, central Spain, French Cevennes, Balkans, Carpathians) have an excess of species loss over that expected. This supports other work which also has highlighted the vulnerability of European mountain regions (Schröter *et al.*, 2005a; Thuiller *et al.*, 2005b; Berry *et al.*, 2007a; Chapter 12.4.3, IPCC, 2007b).

By contrast, the southern Mediterranean and parts of the Pannonian region have lower than expected species loss, possibly because the species are already adapted to drought and high temperatures. This contrasts with work done in the BRANCH project which showed that for the 386 species modelled, which included proportionally many more rare species, these two regions were more sensitive in terms of changes in total number of species over time (Berry *et al.*, 2007a).

The mean percentages of species loss and turnover by environmental zones under the A1HadCM3 scenario showed that the northern Mediterranean (52%), Lusitanian (60%) and Mediterranean mountain (62%) regions are the most sensitive regions; the Boreal (29%), northern Alpine (25%), and Atlantic (31%) regions are consistently less sensitive (Figure 3). Species turnover shows a different pattern, with the Boreal region potentially gaining many species from further south, leading to a high species turnover (66%). The Pannonian region could also theoretically gain eastern Mediterranean species and has a calculated turnover of 66%. Thus, these regions stand to lose a substantial part of their plant species diversity, and (in time) to show major changes in floristic composition. Projected species turnover peaks at the transition between the Mediterranean and continental regions with the extirpation of Euro-Siberian species and expansion for Mediterranean or

Atlantic species. Southern Fennoscandia is also an area of high potential turnover with the loss of boreal species and gain of Euro-Siberian species.

Figure 2: Regional projections of the residuals from the multiple regression of species loss against growing-degree days and moisture availability. Red colours indicate an excess of species loss; grey colours indicate a deficit (Figure 4 from Thuiller *et al.*, 2005a).

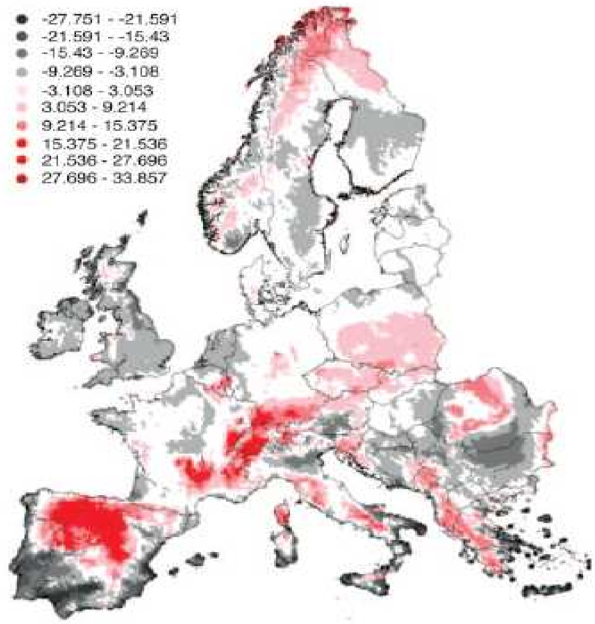
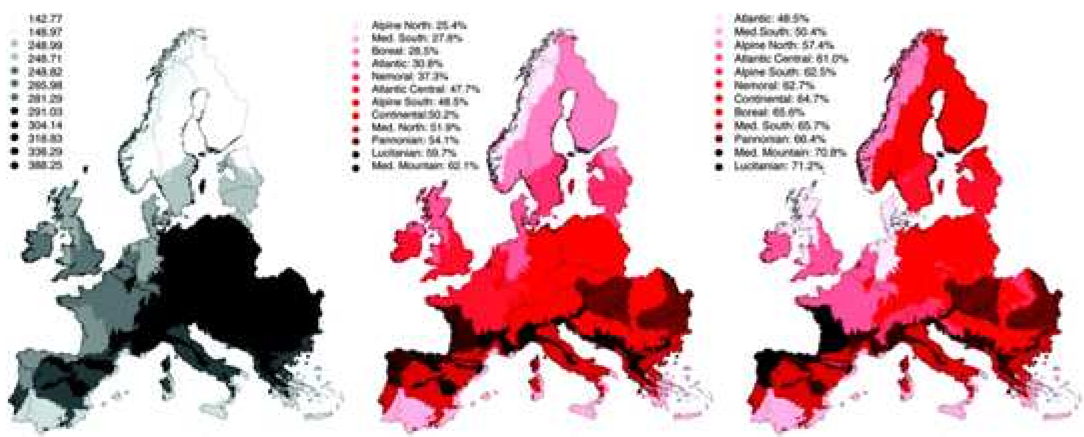


Figure 3: Spatial sensitivity of plant diversity in Europe ranked by biogeographical regions. Mean percentage of current species richness (*Left*) and species loss (*Centre*) and turnover (*Right*) by environmental zones under the A1-HadCM3 scenario (Figure 5 from Thuiller *et al.*, 2005a).



Thuiller *et al.* (2005b) also projected the future potential distributions of 1200 European higher plants using the HadCM3 model with a high (A1F1) emissions scenario, having defined 10 classes of chorology based on the phytogeographical and biogeographical properties of the species. This showed that despite the large interspecific variability within types, chorotypes susceptible to lose the largest amount of habitat were Atlantic, Alpine and Boreo-alpine species (median loss = 55%), whereas Mediterranean species were projected to lose the smallest amount of habitat (Figure 4 in Thuiller *et al.,* 2005b) . Conversely, Mediterranean species were projected to gain potentially the highest proportion of habitat (median = 80%), whereas Boreo-alpine species should gain the least (median = 8%). This is because Boreo-alpine species, being marginal at the cold end of the temperature gradient, with a narrow niche breadth are predicted to be highly sensitive as they have a high exposure given the projected climate warming. They suggest that Alpine species by contrast, which are also marginal at the cold end of the temperature gradient, have larger niche breadth and are under pressure from climate change, but they could also gain suitable habitat by upslope migration, a feature that was not captured due to the resolution of the models. Mediterranean species, which are at the warm end of the temperature gradient, with medium niche breadth and medium range size, were predicted to lose proportionally less suitable habitat as their exposure to climate warming is lower and they could gain a substantial amount of new habitats.

A selection of these vulnerable regions will be examined in more detail.

2.2.1 Arctic

Climate models show that projected temperature increases in the range of 4–7 °C are likely by the end of the 21st century (Symon *et al.*, 2005). Ecosystems in Arctic regions are highly vulnerable to climate change because of this high exposure, although in terms of geological time scales, such changes have been experienced in the past, it is the rate of change that is important now. Also, in many cases the adaptive capacity is relatively low as a number of plant species are clonal, but also there is limited possible northwards migration. The combination of high temperatures and drought seem to be very problematic for terrestrial invertebrates (Strathdee and Bale, 1998). Arctic mammals are possibly sensitive to global temperature increases of 1.7–2.2°C, but impacts may be a consequence of intensified interspecific interactions, such as parasitism, predation, and competition (Callaghan *et al.*, 2005).

Substantial areas of tundra ecosystems (up to 50 %) might be replaced by boreal forests under a 1.3–3.8 °C rise in global average temperature (EEA, 2005). Palsa mires, for example, have already started disappearing in parts of Lapland and while their vascular plants and bryophytes, and possibly butterfly species are also found in other types of mires, they may be essential for birds (Luoto *et al.*, 2004). Again none of the bird species identified occur exclusively in palsa mires, but many seem to prefer palsa mires (or at least the palsa mire zone) . These birds include waders such as *Calidris alpina* subsp. *alpina*, *Phalaropus lobatus* and, particularly, *Limosa lapponica*, and passerines, such as *Calcarius lapponicus* and *Anthus cervinus* (Järvinen and Sammalisto, 1976; Järvinen and Väisänen, 1976; 1978; Mjelstad and Sæterdal, 1986).

Modelled vegetation changes across the whole of the Arctic, combined with maps of water-bird distributions, show a large variation in the impacts on the 25 selected species (Zöckler and Lysenko, 2000). In Europe, the few areas of high tundra loss are in part of Iceland, the southern part of Novaya Zemlya and parts of northern Russia and while some of the birds are not found in Europe they do indicate the sensitivity of this group to climate change. For example, 76% of tundra bean goose (*Anser fabalis rossicus/serrirostris*) habitat could be lost. For two of the three water-bird species that are considered globally threatened, namely the red-breasted goose (*Branta ruficollis*) and the spoon-billed sandpiper (*Eurynorhynchus pygmaeus*), 67 and 57% respectively of their current breeding range is projected to change from tundra to forest. This additional loss of habitat is likely to place these two species at a higher risk of extinction. The emperor goose (*Anser canagicus*) is already in decline and with 54% of its small range projected to be affected, it is highlighted as needing further conservation attention.

In freshwater ecosystems, a combination of high magnitude events and rapid rates of change will probably exceed the ability of biodiversity to adapt and thus they are very vulnerable.

Possible sources of vulnerability for fish in Arctic freshwater are:

- local excedance of the thermal optimum e.g. for algae, plankton, and benthic invertebrates in shallow lakes. Vulnerable cold water fish include Arctic char (*Salvelinus alpinus*) and broad whitefish (*Coregonus nasus*) – all *Coregonus spp* are part of the Bern Convention.
- reduced ice-cover duration on Arctic lakes especially in northern Arctic areas, increased and more rapid stratification, earlier and increased primary production, and decreased oxygenation at depth will possibly result in a reduction in the quality and quantity of habitat for species such as lake trout,

- decrease or local loss of native fish as southern Arctic and sub Arctic fish species migrate northwards. The broad whitefish, Arctic char complex, and the Arctic cisco are particularly vulnerable to displacement.
- decreased water flow in summer is likely to decrease habitat availability and possibly deny or shift access for migrating fish.

Based on Wrona *et al.*, 2005 and Anisimov *et al.*, 2007

An increase in sea temperatures, with a decrease in the Greenland Ice sheet and sea ice extent. could have devastating consequences for marine mammals. *Ursus maritimus (*Polar bear), *Balaena mysticetus* (Bowhead whale) and *Odobenus rosmarus* (Narwhal), for example, are vulnerable to loss of sea ice and they are Strictly Protected Bern Convention species. The former has recently been upgraded by the IUCN from Least Concern to Vulnerable and projections of sea ice lost suggest that polar bears could face a high risk of extinction with increases in temperature of 2.8^{o}C above the pre-industrial average (Fischlin *et al.*, 2007, Box 4.3).

2.2.2 Mountains

A study of the the potential impact of climate change on mountains, used the UNEP-WCMC mountain map, such that Europe was divided into mid-latitude and high-latitude mountains (Nogués-Bravo *et al.*, 2007) and a range of GCMs and emission scenarios were used to project changes in temperature. These showed that in 2055 high-latitude mountains in Asia, then North America could be the most exposed to climate change, followed by those in Europe (2.8 to 3.6^{o}C projected increase in temperature). In 2085, European high-latitude mountains, with an increase between 3.7 and 5.9^{o}C, were fourth after high-latitude mountains in Asia and North America and mid-latitude mountains in Asia. Sætersdahl *et al.* (1998), however, suggest that the north-south trend of the Fennoscandian chain may make dispersal easier, as was seen with the Rockies in North America at the end of last glacial. Nevertheless, mountains are sensitive to climate change and a 40-60% loss of mountain habitat was projected for Scandinavia under early climate change scenarios (Holten and Carey, 1992) and vegetation in snow beds is known to be highly vulnerable to changes in temperature (Beniston, 2003). A reduction in snow cover also could increase erosion on Alpine grassland (EEA, 2002).

The Alpine region forms a case study in the EEA report (Section A1.2, EEA, 2005) and in terms of biodiversity it suggested that Alpine species are in danger of being out-competed either by other grassland species or by trees and shrubs migrating upwards under increasing temperature, atmospheric CO_2 concentration and land-use change (reforestation of pastures) (Bader and Kunz, 1998; Beniston, 2004; EEA, 2004b). The number of forest fires is increasing due to temperature increases, reforestation and immigration of species from warmer climates. In Armenia, it has been projected that, based on an IPCC 2^{o}C increase in temperature and a 10% decrease in precipitation, there could be a 22% reduction in the Alpine belt, which will particularly affect Alpine meadows while vegetation in rocky areas, stone screes and placers on the highest ridges and peaks will be less affected (Box 4.4, EEA, 2007 and http://unfccc.int/resource/docs/natc/armnc1e.pdf). This illustrates the differential effect even within sensitive regions and ecosystems. The study also showed that endemic and rare species (e.g. Komarov's caraway, Pallace's immortelle, Caucasian rhododendron (*Physoptichis* caspica)) growing on lower mountain ridges are more vulnerable.

Montane ecosystems are also vulnerable because of their low productivity and the slow response rates of organisms to climate change. In the Alps, about one third of the approximately 5500 vascular plants are considered extinct, endangered, vulnerable or rare, with about 15% of the 2,500 plants growing above the tree line being endemic (Grabherr, 1998). Often though climate change is not the most immediate threat (EEA, 2003). Modelling has projected that a 1^{o}C warming could result in the loss of 40% of the potential range of 62 endemic mountain plants in the Alps, and a a 90-97% loss for a 4-5^{o}C warming (Pauli *et al.*, 2001; Hare in EEA, 2005). Endemics are particularly vulnerable as they are probably less able to adapt to the changes in environment and have limited migration potential. Bulgaria's alpine habitats and their associated rare and endemic species are also thought to be threatened by global change (Meine, 2007).

2.2.3 Coastal zones

It is estimated that 9 % of all European coastal zones (12 % for EU Member States), which can be

defined as a 10 km strip, lie below a 5 m elevation, so are potentially vulnerable to sea level rise and related inundations. The most vulnerable areas are in the Netherlands and Belgium, where more than 85 % of the coast is under a 5 m elevation. Germany and Romania have 50 % of their coasts below 5 m, Poland 30 % and Denmark 22 % (EEA, 2006).

The most threatened coastal environments are deltas, low-lying coastal plains, islands and barrier islands, beaches, coastal wetlands, and estuaries (Nicholls and Klein, 2005). A number of studies have suggested that the Mediterranean and Baltic coastal wetlands are more vulnerable because they have low tidal ranges and are more sensitive to sea level rise; a warming of 2-3°C could result in about a 50% habitat loss for these coastal wetlands (Hare, 2003). Storms and surges could lead to losses of 84-98% and 31-100% respectively in the Mediterranean region (Kundzewicz *et al.*, 2001; Gitay *et al.*, 2002). Deltaic areas often are particularly threatened because they naturally subside and may be sediment starved by dam construction (EEA, 2005). The deltas of the Ebro, Nile, Po are thought to be particularly vulnerable climate change and sea-level rise (EEA, 2003).

The BRANCH project undertook an assessment of the vulnerability of selected coastal habitats in the EU to a range of sea-level rise scenarios over the next 100 years (Richards *et al.*, 2007). A new Dynamic and Interactive Vulnerability Assessment (DIVA) tool was used to examine the vulnerability of saltmarsh and low unvegetated wetlands. This showed projected higher relative losses around the northern Mediterranean and Baltic Seas compared to the Atlantic and North Sea coasts. Figures 4 and 5 show the very high losses of saltmarshes and mudflat under the IPCC high sea-level rise scenario, resulting in losses of up to 100% along the coasts of the Baltic and northern Mediterranean by the 2080s. However, it should be realised that representing the results at the administrative level across Europe can be misleading, and only gives an indicative result. In reality the losses would be more localised, as is the current distribution of saltmarsh and unvegetated tidal flats.

Also in the BRANCH project a coastal habitat vulnerability index (CHVI), based on the relative sea-level rise, weighted by tidal range, the process environment, accommodation space, including the effects of defences, and sediment supply, was used to examine the vulnerability of saltmarsh and mudflats in North West Europe to similar sea level rise scenarios (Zhang *et al.*, 2007). Tables X and Y show the projected vulnerabilities on a country basis with Ireland followed by France having the greatest percentages in the high/very high categories.

Figure 4: Indicative map of the relative loss of saltmarsh area by the 2080s under the IPCC high sea-level rise scenario as a percentage loss from the 2000 baseline, showing the large losses in the Baltic and Mediterranean regions (from Richards *et al.*, 2007)

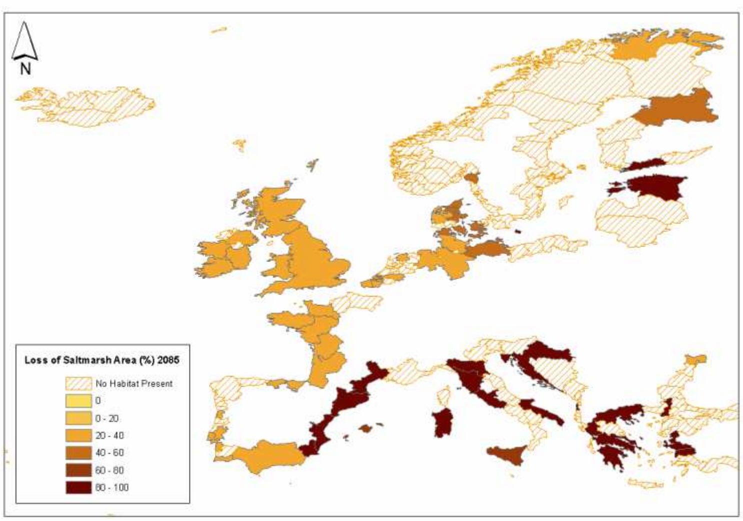


Figure 5: Indicative map of the relative loss of low unvegetated wetland (mudflat) area by the 2080s under the IPCC high sea-level rise scenario, as a percentage loss from the 2000 baseline (from Richards *et al.*, 2007).

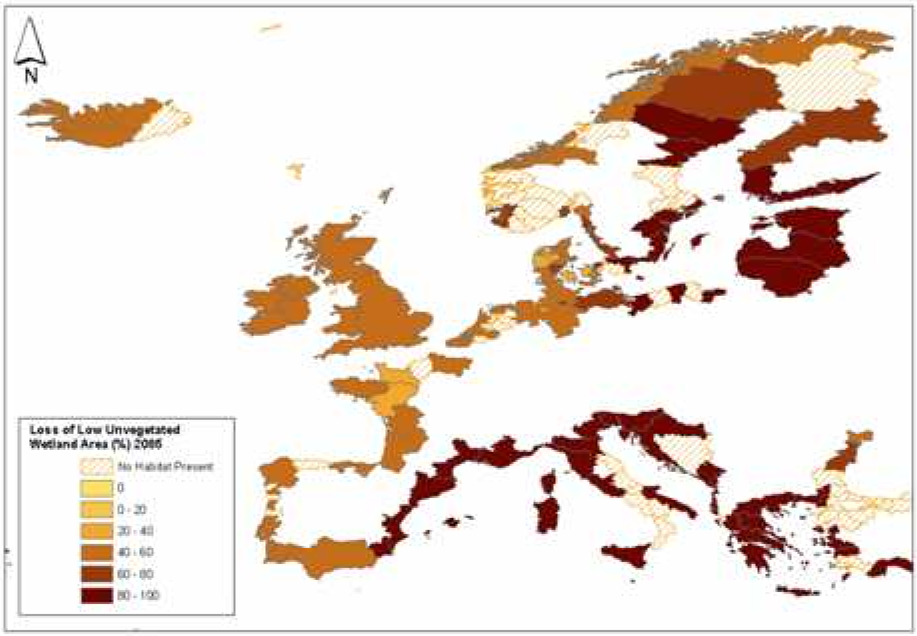


Table 4: Percentage of saltmarsh in different vulnerability categories under natural conditions in 2080 under a low and high sea-level rise scenario, where 1 = low, 2 = moderate, 3 = high, 4 = very high (from Zhang *et al.*, 2007).

Country	Current			2080 Low			2080 High		
	1	2	3	1	2	3	2	3	4
Belgium	0	100	0	0	100	0	0	100	0
France	0	66	34	0	66	34	0	80	20
Ireland	0	52	48	0	52	48	0	0	100
Netherlands	0	75	25	0	75	25	15	86	0
UK	6	88	6	6	88	6	0	76	24

Table 5: Percentage of mudflats in different vulnerability categories under natural conditions in 2080 under a low and high sea-level rise scenario, where 1 = low, 2 = moderate, 3 = high 4 = very high (from Zhang *et al.*, 2007).

Country	Current			2080 Low			2080 High		
	1	2	3	1	2	3	2	3	4
Belgium	0	100	0	0	100	0	0	100	0
France	0	79	21	0	79	21	0	77	23
Ireland	0	50	50	0	50	50	0	11	89
Netherlands	29	15	56	0	44	56	31	69	0
UK	1	67	32	1	66	32	0	56	44
Total	1	71	28	1	71	28	1	62	37

2.2.4 Mediterranean

Mediterranean ecosystems are thought to be among the most vulnerable in Europe (EEA, 2005; Schröter *et al.*, 2005a; Berry *et al.*, 2007a) as many are close to their environmental limits, for example with respect to drought stress, with droughts projected to start earlier in the year and last longer. The regions most affected could be the southern Iberian Peninsula, the Alps, the eastern Adriatic seaboard, and southern Greece (Beniston *et al*. 2007). Relatively small warming and drying scenarios could lead to the expansion of adjacent semi-arid and arid systems. In addition, the increased frequency of fires (Pausas and Abdel Malak, 2004 - although with some exceptions Mouillot *et al.*, 2003) and land degradation due to salinity could exacerbate the situation (EEA, 2005). It is also thought that many ecosystems have a low adaptive capacity and land use pressures and habitat fragmentation will limit this further.

Projections of changes in species' ranges and composition show that between 60 and 80% of current species may not to persist in the southern European Mediterranean under a global mean temperature increase of 1.8°C (Bakkenes *et al*., 2002). A later paper showed that the regions most affected include countries like Romania, Bulgaria, Spain, Portugal, Former Yugoslavia, Albania, Greece, and Italy, which show a decline in stable area (no change in climate) of about 20–30% in 2050, and 40–50% in 2100 (Tables 1 and 2 in Bakkenes *et al.*, 2006). Thuiller *et al.* (2005b) also suggest that species composition change may be high under a range of scenarios in southern Europe. Endemic plants and vertebrates in the Mediterranean Basin are also particularly vulnerable to climate change (Malcolm *et al*., 2006), while if no migration is assumed then most amphibians and reptiles (e.g. *Pelobates cultripes*) in south west Europe, especially the Iberian peninsula, could experience a major loss of climate space (Araújo *et al.*, 2006). The distribution of a number of typical tree species is also likely to decrease in the Mediterranean (Schröter *et al*., 2005a).

In the Mediterranean, many ephemeral aquatic ecosystems are projected to disappear, and permanent ones to shrink (Alvarez Cobelas *et al.*, 2005) and increase in salinity. Climate change could negatively impact on a number of marine mammals (Learmonth *et al.*, 2006) and the *Monachus monachus* (Mediterranean monk seal) is discussed in Section 2.4. Increased sea temperatures may also trigger large scale disease-related mortality events of dolphins in the Mediterranean and of seals in Europe (Geraci and Lounsbury, 2002).

2.3 National

The previous section has identified the regions most exposed to climate change and the ecosystems which could be most vulnerable. These can provide a starting point for identifying potential nationally vulnerable species and habitats, although these will need modifying in the light of more local situations. A brief summary of the vulnerability in EU countries of different sectors, including ecosystems, as reported in national communications to UNFCCC or in national assessments up to 2005, is provided in EEA (2005). There are no entries for a number of countries, but those in the Mediterranean Basin and Alpine ecosystems again appear as particularly vulnerable.

There are few national studies that explicitly examine vulnerability, although again climate change impacts research can be used to infer vulnerability. This has been used in countries such as Finland, Germany and the Britain and Ireland. A study of the impacts of climate change on Spain and Portugal is about to be undertaken, which will include a vulnerability analysis (Araujo pers. comm). For this review, studies on climate change impacts in two countries will be examined, with the main focus on the Britain and Ireland, as some research has been undertaken at the regional and local level too. It should be noted again that care has to be taken in interpreting results of modelling work, especially at these finer resolutions as there is a greater degree of uncertainty in the modelling outputs (see Walmsley *et al.*, 2007).

One of the most comprehensive studies is the MONARCH project[7] (Harrison *et al*., 2001). In Phase 1, the potential impacts of climate change on 50 species from 12 habitats of conservation concern were modelled and although these included species of national conservation concern, few

[7] MONARCH (Modelling Natural Resource Responses to Climate Change) was a seven year phased programme to assess impacts of projected climate change on wildlife in Britain and Ireland, funded by a range of stakeholders, led by Natural England. www.ukcip.org/index.php?option=com_content&task=view&id=331

were Bern Convention species and habitats. The results showed that all the species modelled for montane heath could lose climate space, as could those for peat bogs in south east of Britain and Ireland (Berry *et al.*, 2001). Thus both the species and the habitats are sensitive to climate change and are potentially vulnerable. Sea level rise could lead to additional stress for some salt marsh plants, such as *Puccinellia maritima* (Common salt-marsh grass), especially in the south and east of England, where the greatest rises are projected. In Phase 3, changes in potential suitable climate space were modelled for 120 UK Biodiversity Action Plan species, with 32 being analysed further (Berry *et al.*, 2007b; Walmsley *et al.*, 2007). This showed that 15 (of the 32) species could increase their climate space and thus are not vulnerable to climate change in a national context, while 8 have losses and no significant gains (Table 6).

Table 6: Species potentially vulnerable to climate change in Britain and Ireland (based on Walmsley *et al.*, 2007).

Species	Common name	Area of loss
Alauda arvensis	Skylark	Loss from S. and E England, SE Ireland
Melanitta nigra	Common scoter	Almost total loss, except N Scotland
Tetrao tetrix	Black grouse	Almost total loss except N Scotland
Tetrao urogallus	Capercaillie	Total loss under 2050s High scenario
Turdus philomelos	Song thrush	Increasing loss from S. 2080s High most of England and ROI
Artemesia norvegica	Norwegian mugwort	Some left on W. coast of Scotland
Linnaea borealis	Twinflower	Only Cairngorms suitable 2080s Low; none 2080s High scenario
Woodsia ilvensis	Oblong woodsia	Only Cairngorms suitable 2080s Low; none 2050s and 2080s High scenario

This illustrates again that it is mostly northern and montane species at their southern range margin in Britain and Ireland that are most vulnerable. In Scotland, risks associated with this loss have been identified, and there is concern for situations where there is low adaptation potential (Watkiss *et al.*, 2005). Direct and indirect impacts of climate change on a range of habitats, largely based on MONARCH work, are reviewed in Mitchell *et al.* (2007).

Climate change (both temperature and precipitation) is projected to be greatest in the south of Britain and Ireland, and there are some species which could become vulnerable to this level of exposure, for example *Turdus philomelos* (Song thrush). These results agree with the response of British Odonata to current (and by inference projected) climate changes, which showed that northern species have either decreased their range size between two survey periods (1960-70 and 1985-95) or have retracted northwards at their southern range margin (Hickling *et al.*, 2005). Other species showed a potential increase in range, as did many in a study of 31 butterflies (Roy, *et al.*, 2001), although research into 46 butterfly species near their northern range margins in Britain, which were expected to have responded positively to warming over the last 30 years, indicated that three quarters of them had declined due to habitat loss (Warren *et al.*, 2001). Other factors, therefore, can override climate change and increase potential vulnerability .

MONARCH Phases 1 and 2 also identified the regions most sensitive to climate change (Harrison *et al.*, 2001; Berry *et al.*, 2005). Phase 2 showed that 42% of Britain and Ireland is projected to have future bioclimate unlike any currently found there. It included parts of SE England, Snowdonia, SW and Central Scotland, and Fermanagh, Connemara and Galway in Ireland. These areas could be considered climatically exposed and potentially vulnerable. Modelling in case study regions associated with these areas showed the varied response of species, depending partly on their sensitivity, and vulnerability was higher with no dispersal.

Regional studies have enabled further refinement of the issue of vulnerability. The RegIS[8] project examined integrated climate change impacts for different climate change and socio-economic scenarios on four sectors, including biodiversity, in two contrasting areas of England: East Anglia and the North west (Holman *et al.*, 2005a). The former is projected to be exposed to high increases in temperature and decreases in summer precipitation, while the latter could experience smaller changes in climate, but does include important upland areas. Upland species at their southern range margins were again seen to be vulnerable, but this depended on species sensitivity (Holman *et al.*, 2005b). Most saltmarsh plants in East Anglia were not vulnerable to climate change, but, when combined with habitat loss due to sea-level rise, then they could become vulnerable. If the habitat adapted by migrating inland then coastal grazing marsh (another conservation priority habitat) could be negatively affected. Thus there may be conflict in the adaptation needs of different habitats (and species).

In Germany, the ATEAM results have also been used to ascertain the vulnerability without further adaptation (business-as-usual scenario) of different climate-sensitive sectors, including nature conservation, separated by region/environmental zone (in Zebisch *et al.*, 2005). The highest vulnerability to climate change within the selected sectors was found in South west Germany (upper Rhine rift valley) which is projected to experience the strongest warming in Germany, the central parts of Eastern Germany where the risk of summer droughts could lead to high vulnerability in many sectors and the Alps where the sensitivity of many sectors and lack of adaptation possibilities are the main reasons for the high vulnerability (Table 2, Figure 5, in Schröter *et al.*, 2005b). Nature conservation in the Alps is very vulnerable, because the mountains are characterised by many endemic plant and animal species, with few migration alternatives.

In a "worst case" HadCM3 A1f scenario (highest greenhouse gas concentration), ATEAM results project a possible loss of species in Germany ranging from 25% (North western Germany) to over 50% (Southern and Eastern Germany) per grid cell (average loss per grid cell under the assumption of no migration) by 2080 (Schröter *et al.*, 2004; Schröter *et al.* 2005a). If arrivals are taken into account and a net balance is calculated, then the number of herbaceous species per grid cell decreases by 4-14% by 2080, depending on the emission scenario. Especially high declines (of up to –36%) are found in the Alpine region and in South western Germany. Changes by taxonomic group showed many trees, amphibians and reptiles and birds do not appear *directly* vulnerable to climate change, but land-use and other changes could have negative effects on populations.

In the medium to long-term, wetlands and moorland could also be particularly affected through decreasing summer precipitation and changes in flooding patterns (Zebisch *et al.*, 2005). This endangers not only the moisture dependent plant communities of wetlands, but also the species- rich bird communities, which inhabit, for example, large floodplain areas in Eastern Germany. Wittig and Nawrath (2000) consider wetland plant communities, such as *Carex spp.* communities, wet meadows and forests, and moors, as particularly threatened by climate change. Rising sea levels and increased storm activity could also endanger coastal freshwater marshes (Secretariat of the CBD, 2003).

National studies, such as those discussed above, help to refine the more broad-scale European analyses of vulnerability and serve to illustrate further how the various components of vulnerability and their interaction could affect the status of species and habitats.

2.4 Species

There is comparatively little direct information on the sensitivity and vulnerability of Bern Convention species, as many of the observations of current impacts of climate change and experimental studies by which vulnerability might be inferred do not involve these species, possibly due to their rarity. There is an EU project EUMon[9], which aims to bring together monitoring schemes across the EU and a number of Bern Convention species and habitats are listed as being part of monitoring schemes in particular countries e.g. certain beetles in Slovenia and wolf, lynx and bear in

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[8] RegIS (Regional Integrated Assessment of Climate Change Impacts in the North West and East Anglia. Reports can be downloaded from http://www.ukcip.org.uk

[9] EUMon – EU-wide monitoring methods and systems of surveillance for species and biathlons of Community interest. Http://eumon.ckff.si/index1.php

France. These could form an important resource for establishing species' responses to climate change and thus their vulnerability. Niche-based modelling requires accurate European distribution data for species and again often this is not available or reporting is not done at the species level. Also the models need a certain level of data for model training, so species with few occurrences are discarded. For example, Araujo *et al*., (2006) disregarded species with less than 20 occurrences in their modelling of reptiles and amphibians and Sætersdahl and Birks (1997) suggested that *Papaver lapponicum (Tolm.) Nordh.* (Arctic poppy) and *Braya purpurasceus (R.Br.) Bunge* are possibly threatened but were too rare to model. This report, therefore, has largely had to infer vulnerability of species from the conditions that can lead to vulnerability as listed in Section 2.4. The findings are reported on by taxonomic group and the maps of the projected changes in climate space for species modelled in the BRANCH project (http://www.branchproject.org) and the ALARM project for reptiles and amphibians (www.biochange-lab.eu/projects-alarm/data) are available on the web as indicated.

Where readily available (mostly from Ozinga, and Schaminée, 2005) the IUCN 2001 categories have been identified for Bern Convention species and these are summarised in Table 6. The old IUCN category Lower Risk (LR in IUCN 1994) is now replaced by Near Threatened (close to qualifying for Vulnerable) and Least Concern (evaluated but not threatened), but where the older category of lower risk had been used this has been retained. It should be noted that this table only includes a proportion of Bern Convention Species and thus it should be interpreted with care.

Climate change has not been used as a criterion for the listing of species, but if other threats are present then it is possible that the species will be vulnerable to climate change too, especially if it is in a vulnerable region or if there is other supporting evidence in the form of modelling results and/or additional components of vulnerability present. These various sources can be used to build up a picture of the potential vulnerability of species to climate change. Each taxonomic group will be examined in terms of the information available on the most vulnerable Bern Convention species and aspects of the causes of vulnerability will be illustrated.

Table 6: Summary of the IUCN categories by taxonomic group.

IUCN Category	Mammals	Sea mammals	Insects	Reptiles	Amphibians	Fish	Birds	Vascular plants
Extinct	1							5
Critically endangered		3	1	4		2	4	
Endangered	4		3	5	3	3	6	138
Vulnerable	15	3	3	4	5	2	10	105
Vulnerable/ Endangered		1						
Near threatened					7		15	
Least concern								
Rare								96
Lower risk (LR)			3					
LR/Critical		1						
LR/Endangered		1						
LR/Vulnerable	1							
LR/cd	1	4						
LR/near threatened	6	1		2				
LR/lc		1						
Data deficient		10		1		3	3	
Indeterminate								20

2.4.1 Mammals

Four mammals are categorised as endangered and there is no direct modelling work on these species. Hulme and Sheard (1999) suggest the Iberian lynx, which has declined due to loss of habitat and prey, could be adversely affected by climate change, as increased summer drought could lead to the decline of woodland and wetlands, which are important habitats for their main spring prey, ducks, and summer prey, *Lepus europaeus (*European rabbit). The modelling work of Levinsky *et al*., (2007) shows that without migration climate change could lead to the loss of all suitable climate space for species such as, *Microtus tatrus* (Tara vole) and *Myomimis roachi* (Mouse-tailed dormouse) which have an IUCN class of lower risk and vulnerable respectively. *M. tatrus*, however, occurs in Alpine rocky meadows and montane forests which are also vulnerable to climate change and this could increase its vulnerability, while most of the semi-open habitat for *M. roachii* is now intensively farmed. Unfortunately there is no climate change projections on the other endangered species. The vulnerable bats show a mixed response to projected changing climate space, with *Myotis dasycneme* (Pond bat) being particularly threatened and both the horseshoe bats have a large potential for expansion, although this will depend on their dispersal ability and the availability of suitable habitat, which may be limited (Berry *et al*., 2007a).

For the critically endangered marine mammal, *Monachus monachus* (Mediterranean monk seal), rising sea levels and increased storm frequency could eliminate already scarce haul-out sites and the small number of caves or narrow beaches used for breeding (Learmonth *et al*., 2006). The vulnerable/endangered Saimaa ringed seal *(Phoca hispida saimensis*) could also be adversely affected, as warmer winters in Finland could affect lair sites (Sipilä, 2003).

2.4.2 Birds

19 European bird species (4 %) are listed as globally threatened, while 16 species (3 %) are classified as ‘near threatened’ (IUCN 2004).and three rare species could not be reliably classified in Red List categories due to a lack of data: *Glareola nordmanii* (black-winged pratincole), *Loxia scotica* (Scottish crossbill) and *Tetrao mlokosiewiczi* (Caucasian Grouse). According to Birds in Europe 2 (BirdLife International 2004), 226 species out of 524 have an ‘unfavourable conservation status’ at a Pan European level (43 % of the European avifauna).

There is evidence that climate change is already affecting phenology in birds, including the arrival times for short and long distance migrants (Jonzen *et al.*, 2006; Tottrup *et al.*, 2006) and the laying dates of *Parus palustris* (marsh tits) (Dolenec, 2006). The impacts of these on the vulnerability of species is not yet clear and in some cases it signals appropriate adaptation to climate change, thus decreasing vulnerability, but it can also lead to asynchrony as has been shown in the classic study few *Parus major* (great tits), where advance in vegetation phenology and arthropod abundance has not been matched by an advance in egg laying timing (Visser *et al.*, 1999; Visser *et al.*, 2003). Thomas and Lennon (1999) showed that over a 20 year period in Britain the northern margins of many birds moved northwards by an average of 18.9 km, which is consistent with changing climate, although not all species had a similar response due to other factors, such as habitat changes affecting their distribution.

A comprehensive study of the modelled potential impacts of climate change on the availability of suitable climate space for breeding birds of Europe has been carried out (Huntley *et al.*, 2008) and this report will only highlight findings relating to vulnerability. The greatest reduction in bird species richness is projected to occur in southern and central Europe. There are a number of birds for which there is no potential future range extent in Europe, for example *Anthus berthelotii* (Berthelot's pipit), *Chersophilus duponti* (Dupont's lark) and (*Bucanetes* githagineus (great horned owl) or the extent is equal to or less than 10% of their present range under some scenarios, such as *Alectoris barbara* (Barbary partridge) (Table 4.3, Huntley *et al.*, 2008). A lack of overlap between a species' current distribution and projected future climate space can also lead to vulnerability and more than a quarter of species modelled fall in to this category for at least one scenario, thus are at risk of regional extinction (Table 4.4, Huntley *et al.*, 2008). 10 of these have no projected future climate space under all three scenarios, including the three birds mentioned above and species such as *Apus* caffer (white-rumped swift), *Phoenicopterus ruber* (greater falmingo) and *Calidris alba* (sanderling). The species at the greatest risk of global extinction are those which are endemic to Europe, have little or no projected future climate space and are adversely affected by other factors, such as poor dispersal capability, biotic interactions or lack of habitat,

The BRANCH project has shown that birds such as *Acrocephalus paludicola* (aquatic warbler), pintail *(Anas acuta*) and meadow pipit (*Anthus pratensis*) also could be vulnerable throughout their range, losing all suitable climate space under some/all scenarios (Berry *et al.*, 2007). Northern species again are generally vulnerable and birds such as marsh warbler (*Acrocephalus palustris*) could be vulnerable in the southern and western parts of their range.

2.4.3 Reptiles

Four of the reptiles are critically endangered: three are turtles *Lepidochelys kempii* (Kemp's Ridley Sea turtle), *Dermochelys coriacea* (Leatherhead turtle) and *Eretmochelys imbricata* (Hawksbill turtle). They have suffered from human activities and climate change is known to have already pushed the northern range margin *of D. coriacea* polewards by about 400km in the last 20 years (McMahon and Hays, 2006). The fourth, *Gallotia simonyi (*Hierro lizard) is endemic to the Mediterranean Basin (Cox, *et al.*, 2006), which has already been identified as a region vulnerable to climate change. The modelling of climate change impacts on reptiles has shown that without dispersal many of those in the Mediterranean and in particular the Iberian peninsula and southern France are projected to contract in range, possibly to the point of extinct through loss of all climate space (Araújo, *et al.*, 2006). They suggest that it is possible that reptiles in south west Europe do not fill all their fundamental niche, in which case they may be able to cope better than expected with the projected increases in temperature and dryness. Of the endangered reptiles only *Vipera ursinii* (Meadow viper) has been modelled (Araújo, *et al.*, 2006). If it is able to disperse then it could expand its range, but otherwise it could contract.

2.4.4 Amphibians

None of the endangered amphibians have been modelled, but a study on factors affecting the distribution and populations of the endemic *Euproctus platycephalus* (Sardinian newt) showed that water temperature was important in determining which pools are most likely to be inhabited (Lecis and Norris, 2003). The newts were found in pools where temperatures ranged from 12.4 up to 24.5°C during spring and summer months. This may not be a direct relationship, as water temperature could be expected to be higher in pools that dry completely during the summer months, while colder pools are likely to persist through the driest season. A colder temperature could be linked to the presence of underground flowing water connecting pools all through the summer. In 54.5% of the sites surveyed, habitat might have become less suitable for newt populations too, but previously occupied sites have significantly higher recorded water temperatures than sites that retain newt populations. Lecis and Morris (2003) suggest various possible explanations for this: in these streams water temperature has risen and the habitat is no longer optimal for newt populations, or newts are found in pools with higher water temperature only periodically, or there are some other factors correlated to water temperature which are driving newt distribution. Climate change then may not be a (direct) driver of changes in species' populations and distributions and other contributory factors should also be sought.

The modelling of the impacts of climate change on amphibians showed that while generally there is potential for range expansion, they could be susceptible to drought and, as with the reptiles, dispersal is unlikely to occur due to the rate of climate change and habitat loss and fragmentation (Araújo, *et al.*, 2006). This could make them particularly vulnerable in the Iberian peninsula. Of the species modelled both *Alytes obstetricans* (Midwife toad) and *Bufo calamita* (Natterjack toad), for example, have been shown to lose suitable climate space both with and without dispersal (Araújo, *et al.*, 2006; Berry *et al.*, 2007a) and thus they are vulnerable to climate change.

2.4.5. Insects

The European Strategy for the conservation of invertebrates identifies climate change as a present threat and risk (Haslett, 2008). Three general conclusions are made: negative responses, such as extinction are faster than positive ones such as range expansion, many of today's communities will not exist under future projected climates and specific species traits (see 1.2.3) will make some species particular sensitive to climate change. A study of 14 endemic Sardinian butterflies, including the endangered *Papilio hospiton* (Corsican swallow tail) did not view climate change as a significant short-term threat as other factors, such as collecting, are more critical (Grill *et al.*, 2002). It is thought that Southern European species may remain less affected as they are better adapted to very high temperatures as well as rapid changes in temperature (i.e. significant differences between day and night temperatures). It has been suggested, based on studies in the Czech Republic, that the vulnerable *Erebia sudetica* (Sudeten ringlet) has poor long distance dispersal capabilities and this would hinder its adaptation to climate change, especially when coupled with its montane habitat associations (*Kuras et* al., 2003).

2.4.6 Fish

One of the most vulnerable species is the critically endangered *Romanichthys valsanicola*, originally found in 1956 in the Carpathian rivers of Romania, which has been adversely affected by water management structures and is now surviving at only one locality (Bruton, 1995). Its vulnerability therefore stems from other sources and the potential impacts of climate change are unknown. Another critically endangered fish, *Acipenser sturio* (Sturgeon), along with some other sturgeons, has also been affected by dam construction, pollution and over-hunting (Bachmann, 2000), although *A.sturio* is not thought to be sensitive to climate change in Georgia (Gabunia and Kvavadze, 2003).

2.4.7 Vascular plants

No evidence of responses to current changes or sources of vulnerability have been found for vascular plants, although some may be forthcoming from the EUMon project. Using modelling to identify countries losing more than 75% of their projected climate space for a species, Berry *et al.* (2007a) suggest that species such as *Pulsatilla patens* (Pasqueflower), *Apium repens* (Creeping marshwort) and *Cypripedium calceolus* (Lady's slipper) could be vulnerable in southern parts of their range in Europe. In the Czech Republic, loss of *P. patens*, *Pulsatilla vernalis* (Spring Pasqueflower) and *Gentiana vernalis* (Spring Gentian) is attributed to the abandonment of traditional land-use (Plesník and Roudná, 2000). A comparison of national databases to analyse and compare proportional alterations in the distribution ranges of orchid species between two surveys in the UK (surveys completed in 1969 and 1999) and in Estonia (surveys completed in 1970 and 2004) showed that every species declined between the surveys in both countries, and two species may have become extinct in the UK (Kull and Hutchings, 2006). *C. calceolus* has declined by in the UK 95% and 28% in Estonia. This is thought to be due to the loss of a very high percentage of traditional sheep-grazed calcareous grasslands. These two examples serve to illustrate the importance of land use changes in over-riding the current effects of climate change.

3. MITIGATION AND ADAPTATION RESPONSES

Mitigation and adaptation are both aimed at reducing the vulnerability to climate change. For mitigation this is through a net reduction in greenhouse gas emissions, uptake of storage and avoidance of loss of storage or greenhouse gas emissions. These should lead to a reduction in the magnitude and rate of the projected climate changes and thus vulnerability through decreasing exposure. This, however, is a longer term action and thus adaptation is required in order to facilitate species' adjustment to the climate change to which we are committed and to reduce the contribution of climate change as a driver of species loss. Mitigation and adaptation are not alternatives, as adaptation alone is unlikely to be sufficient to avoid the serious impacts (Klein *et al.*, 2007). While they may be considered complementary at the global scale they may have regional or local synergistic or antagonistic interactions. The EU ADAM project (Adaptation and Mitigation Strategies: supporting European climate policy)[10] is seeking to understand the trade-offs and conflicts that exist between adaptation and mitigation policies. Another EU project, MACIS (Minimisation of and Adaptation to climate change impacts on biodiversity)[11] is reviewing the interactions between biodiversity and a range of mitigation and adaptation actions in a variety of sectors, including agriculture, forestry, built environments, river and coastal flooding. Paterson et al. (2008) have already identified some possible

[10] www.adamproject.eu

[11] www.macis-project.net

synergies and antagonisms that may exist between such actions and biodiversity. A full report on the positive and negative aspects of a range of mitigation and adaptation activities for biodiversity is being prepared and should be available by November 2008. The IPCC identifies "What combination of short and long term actions will minimise the costs of climate change and how these are distributed across mitigation, adaptation and impacts that humans are prepared to accept?" as a key question for policy (Fisher *et al*., 2007).

3.1 Mitigation

Species and habitats identified as sensitive to climate change could benefit from both mitigation and adaptation actions. There is, however, limited opportunity for the management of ecosystems to contribute to short-term mitigation, as actions such as reforestation or other land use changes have limited effect on atmospheric CO_2 as there are approximately century scale time lags in mature forest establishment and the regional warming effects of the lower albedo of poleward boreal forest expansion must be balanced against this (a fuller discussion is in Section 4.4.6 of Fischlin *et al.*, 2007). Other mitigation actions, such as the use of biofuels are generally reckoned to have a negative impacts on biodiversity, while the reduction of forest destruction is positive. Stringer *et al*. (2008), for example, show how efforts to reduce desertification and mitigate the effects of climate change could negatively impact biodiversity. Each mitigation activity, therefore, needs assessment in terms of its potential to contribute to or reduce vulnerability.

3.2 Adaptation

Adaptation is vital to avoiding unwanted impacts of climate change, especially in sectors, such as ecosystems, vulnerable to even moderate levels of warming, (Stern, 2006; IPCC, 2007a). It is also seen as a means maintaining or restoring of ecosystem resilience to single or multiple stresses (Convention on Biological Diversity, 2005). It should not be forgotten that "There are clear limits to adaptation in natural ecosystems. Even small changes in climate may be disruptive for ecosystems (e.g. coral reefs, mangrove swamps) and will be exacerbated by existing stresses, such as pollution. Beyond certain thresholds, natural systems may be unable to adapt at all, such as mountainous habitats where the species have nowhere to migrate." (Stern, 2006, Chapter 18 p10).

Adaptation needs to consider the species' dynamic and individualistic responses to climatic change (Huntley, 2007). The various adaptation strategies that have been mentioned in that report operate through reducing the exposure and sensitivity components of vulnerability and by assisting autonomous adaptation through planned adaptation. A few examples are discussed below to show further the need for adaptation.

Dispersal is an important autonomous adaptation and extinctions are projected to be greater without dispersal in all modelling results (e.g. Thomas *et al*., 2004; Bakkennes *et al*., 2006; Berry *et al.*, 2007a). Often this is thought to be limited either due to the dispersal capacity of the species and/or a lack of opportunity. For example, for reptiles and amphibians it was suggested to be likely to be due to habitat fragmentation (Araújo *et al.*, 2006). The research by Leemans and Eickhout (2004) mentioned in Section 2.1 showed that with a warming of $0.1^{o}C$ per decade 50% of all impacted ecosystems are able to adapt through range shifts within a century, but only 36% of all impacted forests. As rates of change are increased, then the adaptive capacity of ecosystems rapidly declines. At a rate of warming of $0.3^{o}C$ per decade only 30% of all impacted ecosystems can adapt and only 17% of all impacted forests. In such cases adaptation measures, such as habitat re-creation/restoration leading to the formation of more habitat patches (stepping stones) or corridors, and especially in the areas closest to the poleward range could be appropriate, although the effectiveness of such measures is still widely debated.

Bern Convention species and habitats already have a degree of vulnerability based on factors, such as the nature of their range extent, population sizes and/or other pressures, so if climate change is identified as an additional pressure then there is increased cause for concern. For those have been identified as vulnerable to climate change (Section 2.4) then consideration needs to be given to appropriate additional actions that will complement those conservation measures already in place. In some cases there may little that can be directly done *in* situ for extremely rare and/or endemic species which are sensitive and/or exposed to a high degree of climate change, but other pressures on them may be able to be addressed thus possibly increasing their resilience to climate change .

In the BRANCH assessment of the vulnerability of saltmarsh and mudflats in NW Europe (Section 2.2.3), the inclusion of population increases and coastal defences led to significant increases in the areas of both habitats in the high and very high vulnerability classes. In France and the UK, for example, these classes increase from 19% and 30% currently vulnerable to 74% and 43% for these two countries respectively, under the 2080s high sea level rise scenario because of the lack of opportunity for autonomous adaptation through inland migration (Zhang *et al*., 2007). Managed re-alignment would represent a planned adaptation action that could be positive for biodiversity, but it would pose costs for other sectors, thus illustrating the need for adaptation action to be integrated across sectors. Increasingly, this integration of nature conservation (and also adaptation) into broader social, environmental, economic and political objectives and plans for other sectors, especially agriculture, forestry, fisheries and other economic activities is being stressed (IUCN *et al.*, 2003; IPCC, 2007a; Paterson *et al*., 2008).

The EU White paper on Adapting to Climate Change in Europe should be published later this year, but currently the Green paper[12] also argues for the need for both mitigation and adaptation and provides guidelines on adaptation actions. The four pillars are: early action in the EU, integrating adaptation into EU external actions, reducing uncertainty through expanding the knowledge base through integrated climate research and involving European society, business and public sectors in the preparation of adaptation strategies. For biodiversity, emphasis is on ensuring the coherence of the Natura 2000 network, conserving and restoring biodiversity and ecosystem services in the wider countryside, making development compatible with diversity and reducing the impact of alien invasive species. The implementation of the 2006 Biodiversity Communication and its EU Action Plan to 2010 and beyond is seen as an important first step in this adaptation process.

Many countries in Europe now have and are implementing adaptation plans and some of these are outlined in the EEA report on Vulnerability and Adaptation (EEA, 2005). Finland is a prime example, where FINADAPT (Assessing the adaptive capacity of the Finnish environment and society under a changing climate)[13] has undertaken a scoping study involving a range of stakeholders and research institutions to investigate climate change in Finland and the potential for adaptation in a number of sectors, including biodiversity (Carter, 2007). For the latter, various possible adaptation measures were explored, based on a literature search and expert questionnaire. The Finland's National Strategy for Adaptation to Climate Change (FNSACC) lists a number of possible adaptation actions, some of which were earmarked to be implemented during 2005-2010, including reducing human-induced stress on nature by controlling land use and the conservation of high value traditional farmland. The list overlaps with many of the actions identified by Huntley (2007) and when they were reviewed, expert's opinion on their effectiveness and preferences was canvassed and synthesised in order to provide a guide for future adaptation actions for biodiversity conservation in Finland (Pöyry and Toivonen, 2005). One of the most important measures for enabling species' movement was the building of a spatially and temporarily representative network of protected areas (PAs) for species vulnerable to climate change. It was thought to be difficult to maintain temporarily representative occurrences of vulnerable species in PAs, especially in southern Sweden where there are small environmental gradients and where there are only small areas of fragmented key habitats. Many of the FNSACC adaptation options for biodiversity were considered practical and represented win-win or no-regrets solutions, although there are still research gaps in the knowledge of the effectiveness of some measures.

The Dutch have also started implementation in terms of ensuring that their Netherlands Ecological Network (NEN) established to rehabilitate and safeguard biodiversity, as well as to improve or establish connections between units of national and international biodiversity interests, is climate change proof (Piper et al., 2006).

In the German study discussed in Section 2.3, stakeholders from the the federal states of Schleswig-Holstein, Hamburg, Brandenburg, Hesse, Thuringia, and Saxony completed questionnaires

[12] http://ec.europa.eu/environment/climat/adaptation/index_en.htm

[13] http://www.environment.fi/print.asp?contentid=228121&lan=en&clan=en

including rating the degree of effectiveness of adaptation measures to mitigate risks and capitalize on opportunities of climate change in the nature conservation sector (Zebisch *et al*., 2005). Five out of six of the stakeholders questioned said the improvement of migration options for species was a suitable and effective form of adaptation for species movement (Table 4.4, Zebisch *et al*., 2005). This was reported from Brandenburg and Schleswig-Holstein as being "partially implemented". All the adaptation measures for nature conservation were rated as "complicated" or "very complicated", so that their full implementation, which has so far only been achieved for the concepts of water balance management and in few federal states, is difficult. It was also questioned whether the existing and planned measures will suffice to confront the anticipated changes in biodiversity and nature conservation due to climate change; since, according to respondents, climate change was nearly never among the reasons to implement measures. The adaptive capacity of nature conservation in the Alpine region, with its high occurrence of endemic plants and animals, many azonal ecosystems and extraordinary climatic locations, is small. In this region, climate change will cause the disappearance of habitats, without alternatives for the impacted species (Zebisch *et al*., 2005).

Various SEE and EECCA countries concerned about the vulnerability of their nature systems also have various proposed adaptation measures including the establishment of a good monitoring network in Albania and Georgia, inclusion of climate change into nature plans in Belarus, changes in management in the Russian Federation and the establishment of new areas to act as "green corridors" in Kyrgyzstan (EEA, 2007). There are also some examples of multilateral adaptation initiatives, such as the Pan-European Ecological Network PEEN which seeks to establish a stronger (i.e. 'climatically robust') network of ecological areas within Europe.

CONCLUSIONS

There is abundant evidence from observations and monitoring that climate change is already impacting species and habitats, and, for some, this is leading to increased vulnerability. There is little direct information on the attribution of source(s) of this vulnerability, as species are subject to multiple stresses, but the majority of the observed responses are consistent with those expected from climate change. These observations provide important information on the current sensitivity of species and their potential future responses, at least to current rates of climate change. They suggest that globally ecosystems such as coral reefs and mountains are currently most sensitive, along with Arctic regions. Island ecosystems, the Karoo and Cape Floral province in South Africa, wetlands, mangroves and sea grass beds are becoming increasingly vulnerable.

In Europe, the Arctic, mountain regions, various coastal zones including the Baltic and parts of the Mediterranean Basin are consistently projected as being most vulnerable, but for different reasons. In the Arctic, for example, it is a consequence of the highest increases in temperature, with consequential losses/reductions in ice and snow, with many species having limited adaptation potential due to their ecology and limited opportunity for polewards movement. Mountains have many similar issues and in both species could also be affected by competition from species' adaptation through polewards or upwards response to increased temperatures. In the Mediterranean, however, it is the projected increase in drought stress which primarily is the source of vulnerability and for coastal ecosystems it is sea-level rise combined with a lack of adaptation opportunity. Within these regions, species and habitats will vary in their vulnerability as a function of their response to the exposure. This will partly depend on their ecology and species composition respectively. This was illustrated with examples of research from Britain and Ireland and Germany, which showed that in order to assess vulnerability it is necessary to identify not only the magnitude of climate change, but also the sensitivity of the species and habitats to these changes and their ability to adapt. It should be noted that many of the assessments are based on responses to current climate and mean changes in climate parameters, but changes in extreme events are also expected and so there could be some unanticipated surprises.

Given the rarity, endemicity and threatened status of many of the Bern Convention species and habitats, climate change is likely to add to concern about their conservation status. Although comparatively little is known explicitly about their vulnerability to climate change, their characteristics suggest that for many this is likely to increase, especially in those vulnerable regions and ecosystems previously identified. The ability of these species to adapt through evolutionary changes is thought to be low in most cases, but on going research has found a few cases where it might be possible at a local scale. The modelling studies have shown that autonomous adaptation through tracking changing suitable climate space could lead to most species which have space for polewards expansion not being vulnerable, but the fulfillment of this space is thought to be limited due to inadequate species' dispersal capacities, both as a consequence of their inherent dispersal ability and the fragmented and hostile nature of the landscape over which they would have to move.

There are a range of planned adaptation strategies that can help overcome the latter, as seen in Huntley (2007), but given the level of endemicity and rarity of many Bern Convention species building up population numbers may need to be a first step. Mitigation is an additional response to climate change and, while important, it is a longer-term strategy. Also, considerable care needs to be taken with mitigation as not all strategies are beneficial to biodiversity and even adaptation strategies may favour certain species or groups of species over others. In a broader context, mitigation and adaptation activities in other sectors can have either positive or negative effects on biodiversity and thus a more integrated, cross-sectoral approach to responses to climate change is needed.

Most of the very limited evidence for the potential impacts of climate change on Bern Convention species and habitats is inferential and based on monitoring and observations of responses to current climate change, expert knowledge and modelled projections. Nevertheless, using the components of vulnerability: exposure, sensitivity and adaptive capacity it is possible to start to build up a picture of their vulnerability, but this information base needs to be developed, as the nature of the threatened status of many suggests that climate change will only compound the situation.

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