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PROTECTED AREAS AND CLIMATE CHANGE IN EUROPE

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EXECUTIVE SUMMARY

1. Climate change impacts on the European continent are amongst the best studied in the world. Impacts of ongoing climate changes on the phenology and distributions of species have been thoroughly documented, and forecasts of 21st century climate changes are available for a large number of organisms.

2. Terrestrial European protected areas are likely to act as buffers against climate change better than expected by chance, but the Natura 2000 network is more vulnerable and no more effective in retaining climate conditions for Habitats Directive species than the surrounding landscape matrix. This is partly due to the existence of extensive areas of farmland among Natura 2000 sites, which have a greater area located in flatlands than protected areas – exposure to climate change is greater in flatlands than in areas with rugged terrain.

3. Up to 52%±12.1 of European vertebrates and plants are forecasted to lose suitable climate within existing terrestrial protected areas by 2080. This figure is higher for Habitats Directive species occurring in Natura 2000 sites, where up to 58%±16.0 of all species are expected to lose suitable climate. Most European protected areas are projected to lose suitable conditions for species rather than gain, but high latitude and altitude countries have a tendency for having a greater proportion of species winning climate suitability than the remaining European countries where more species are expected to lose climate suitability. However, high latitude and altitude countries may gain species at the expense of the loss of cold-adapted species, some of which are narrow endemics.

4. Addressing climate change impacts on terrestrial protected areas requires a paradigm shift in protected areas planning and management. Effective biodiversity conservation requires the identification and management of stationary refugia, or range retention areas (where species are most likely to survive despite climate changes), displaced refugia (where species are able to find suitable conditions after being displaced by climate change), and areas of high connectivity (allowing species to track climate changes through dispersal).

5. An integrated policy for mitigation of climate change impacts on biodiversity requires that current priorities for the management of protected areas are revised; that more flexible mechanisms for the management of protected-area networks are implemented; and that proactive strategies for off-protected-areas management are established. A number of real-world examples of policies for mitigation of climate change impacts on biodiversity from different parts of the world are reviewed.

6. Under climate change scenarios, proactive conservation management of the land is required, without which important losses of biodiversity are to be expected. European policies for biodiversity adaptation under climate change are reviewed and a discussion of future pathways is proposed. It was found that in most cases, policies for adaptation of biodiversity have not been detailed and specified in clear action plans. Thus, greater focus on biodiversity within inter-sectoral plans for adaptation under climate change is required.

I. INTRODUCTION

A recent report by Brian Huntley to the ‘Group of Experts on Biodiversity and Climate Change’ of the Bern Convention provided background to the past, current, and future projected impacts of climate change on biodiversity in Europe (T-PVS/Inf 2007-3). More detailed reports for plant and invertebrate species were drafted by Vermon Heywood (T-PVS/Inf-2009-9) and by Robert J. Wilson (T-PVS/Inf-2009-8) respectively. These reports provide a number of recommendations towards the development of adaptation strategies for biodiversity. Several countries and European bodies are starting to develop strategies for adaptation to climate change (Table 1). Such strategies tend to focus on technological, structural, and socio-economic developments, and linkages between biodiversity and adaptation are often overlooked (Campbell et al. 2008). Nevertheless, biodiversity is linked to climate change adaptation in three main ways: biodiversity can play a role in societal adaptation; biodiversity can be impacted by societal adaptation strategies, and biodiversity conservation is a sector that requires adaptation on its own right (Campbell et al. 2008).

The present draft paper deals with biodiversity adaptation on its own sake. In particular it examines how climate change might affect terrestrial protected areas in Europe, and what specific measures might be needed to mitigate such effects. The paper was prepared for discussion in the July and November 2009 meetings of the ‘Group of Experts on Biodiversity and Climate Change’ of the Bern Convention. The author was asked to ‘*provide a report on protected areas and climate change in Europe, including consideration of protected area networks and systems inside and outside the European Union; and recommendations to Bern Convention’s Parties as to how best to manage vulnerability and impacts of climate change on the designation and management of protected areas. This work will inform the development of guidance for the Contracting Parties of the Bern Convention so that they can integrate climate change concerns in their implementation of the Convention*’.

The current paper is structured into three main chapters. In chapter II, a brief review of the potential effects of climate change on European protected areas is provided. Unpublished results by the author of this report and colleagues, regarding the effects of climate change on protected areas and the Natura 2000 network are provided. In chapter III, general approaches for mitigation of climate change impacts on biodiversity are reviewed and discussed. As the peer-reviewed scientific literature in this area is scarce, grey literature across the world was also used. The approaches reviewed include strategies for management of protected-area networks, management of individual protected areas, and off-protected areas management. Finally, chapter IV reviews European initiatives that are already in place for mitigating climate change impacts on biodiversity and provides a prospective discussion of required actions for the future.

Table 1 – Strategies for climate change adaptation (Bern Convention’s contracting parties)

Country	**Status**	**Year**
	Member States of the Council of Europe	
Austria	*In preparation*	*Expected for 2010*
Belgium	*In preparation*	*Expected for 2012*
Czech Republic	*Climate Change Protection Policy in preparation*	*Expected for 2009*
Denmark	Danish Strategy for Adaptation to a Changing Climate	2008
Estonia	*In preparation*	*Expected for 2009*
Finland	Finland’s National Strategy for Adaptation to Climate Change	2005
France	National Climate Change Adaptation Strategy	2007
Germany	Combating Climate Change: The German Adaptation Strategy	2009
Hungary	National Climate Change Strategy 2008-2025	2008
Italy	*In preparation*	*n.a.*
Latvia	*In preparation*	*Expected for 2009/10*
Malta	*In preparation*	*n.a.*

Country	Status	Year
Netherlands	National Programme for Spatial Adaptation to Climate Change “Make Space for Climate!”	2007
Norway	*In preparation*	*n.a.*
Portugal	Climate Change Adaptation National Strategy: *public consultation closed*	*Expected for 2009*
Spain	National Climate Change Adaptation Plan	2006
Sweden	*In preparation*	*Expected for 2009*
Turkey	*In preparation*	*Expected for 2010*
United Kingdom	Adapting to Climate Change in England: A Framework for Action	2008
	England Biodiversity Strategy Climate Change Adaptation Principles	2008
Non-Member States of the Council of Europe		
Burkina Faso	National Action Programme for Climate Change Adaptation	2007
Senegal	National Action Plan for Climate Change Adaptation	2006
International Organisations		
EU	Recommendation No.135 (November 2008) of the Standing Committee of the Bern Convention “Addressing the impacts of climate change on biodiversity”	2008
	EU White Paper COM (2009) 147 “Adapting to climate change”	2009

Source: Web-based search of information from national environmental institutes, the European Environment Agency, and Swart et al. (2009). Given the rapid pace of development in this area, the information on the table will soon be outdated.

II. EUROPEAN PROTECTED AREAS AND CLIMATE CHANGE

World protected areas cover more than 12% of the land surface (Chape et al. 2003), with new areas still being proposed (Rodrigues et al. 2004). In the European Union (EU), the Natura 2000 network was established with the aim of complementing nationally-designated protected areas and ensuring the long-term survival of some of Europe’s most valuable and threatened species and habitats. The Emerald Network is an extension of the Natura 2000 network that allows implementation of its principles beyond the EU. The Natura 2000 and the Emerald networks are the two major instruments of the Pan-European Ecological Network (PEEN), promoted under the Pan-European Biological and Landscape Diversity Strategy (PEBLDS). Several Natura 2000 sites coincide with existing protected areas, but others cover areas that were previously unprotected. Overall, and according to the European Environmental Agency, protected areas cover 16% of the European territory and figures provided by the European Commission indicate that the Natura 2000 network covers 17% of Europe.

Protected areas, the Natura 2000 and the Emerald networks are established with the goal of isolating the species and habitats of interest from the regional and local processes threatening them. The degree to which European conservation areas represent valued biodiversity features and isolate them from threatening processes is a matter of enquiry (e.g. Dimitrakopoulos et al. 2004, Gaston et al. 2006, Araújo et al. 2007, Maiorano et al. 2007, Jackson et al. 2009), but another question is whether these areas are suitable or sufficient to counteract the impacts of climate change. Studies have highlighted that climate change could have significant impacts on the conservation of species in protected areas. For example, using optimally selected conservation areas in Europe, Araújo *et al*., (2004) showed that 6-11% of a sample of 1200 plant species could be lost from selected areas in the first half of the 21st century. Hannah et al. (2007) provided a coarse examination of potential impacts of climate change on existing protected areas in Europe, Mexico and the Cape Floristic Region and concluded that impacts would be extremely high unless proactive conservation strategies were implemented. Other studies have investigated the potential effects of climate change on protected biodiversity elsewhere in the world (e.g. Scott et al. 2002, Burns et al. 2003, Tellez-Valdes and DiVila-Aranda 2003, Hannah et al. 2005, Lemieux and Scott 2005, Hole et al. 2009), and the conclusion is, invariably, that climate change compounds contemporary threats to biodiversity.

Europe is the region where climate change impacts on biodiversity have been most extensively studied. Ongoing changes in species phenology and range shifts have been reported by several authors (e.g. Parmesan et al. 1999, Thomas and Lennon 1999, Walther et al. 2002, Thomas et al. 2004, Hickling et al. 2005, Walther et al. 2005, Wilson et al. 2005, Hickling et al. 2006), and 21st Century forecasts of species range shifts have been provided for plants (Huntley et al. 1995, Sykes et al. 1996, Thuiller et al. 2005, Bakkenes et al. 2006), birds (Huntley et al. 2008), mammals (Levinsky et al. 2007), amphibians and reptiles (Araújo et al. 2006), and combinations of taxa including plants, vertebrates and invertebrate groups (Berry et al. 2002, Harrison et al. 2006). The importance of the combined effects of climate and land use change (e.g. Berry et al. 2006, Araújo et al. 2008), and the impacts of such changes on ecosystems goods and services have also been explored (e.g. Schroter et al. 2005).

A recent study also provided a detailed examination of the potential impacts of 21st century climate changes on European protected areas (Araújo et al. In preparation). The study investigated climate change impacts on a large number of terrestrial vertebrate and plant species in European protected areas and Natura 2000 sites. The study found that existing protected areas generally conserve species under climate change scenarios better than expected by chance (Figure 1). In other words, protected areas are likely to act as buffers against climate change more effectively than most areas in the surrounding matrix. Notwithstanding, the improved ability of protected areas to retain suitable climate for species under climate change scenarios was not recorded for Natura 2000 sites, which have a greater tendency to be located in flatlands than protected areas – exposure to climate change is greater in flatlands than in areas with rugged terrain, because species are able to track climate changes by short-distance dispersal in the latter areas (e.g., Peterson 2003, Randin et al. 2009). Natura 2000 areas are expected to lose suitable climate conditions for species at least as much as the surrounding matrix and in the particular case of plants, retention of suitable climate was found to be worse in Natura 2000 sites than that expected by chance (Figure 1).

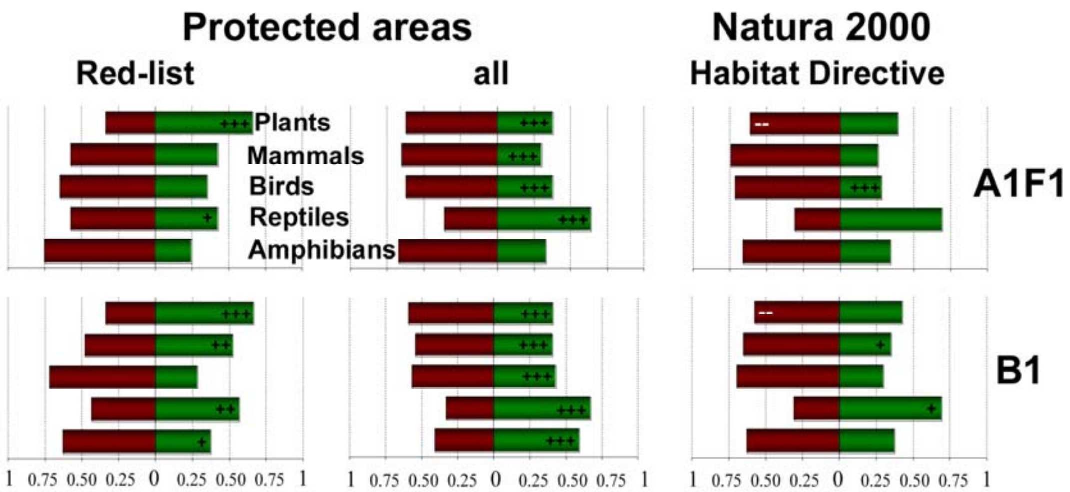

Figure 1 - Proportion of species projected to gain (winners) or loose (losers) climatic suitability within conservation areas in Europe by 2080. Projections are provided for all available species within protected areas; available IUCN Red-listed species within protected areas; and available EU Habitats Directive species within Natura 2000 sites. Conservation areas retaining more climate suitability for species than expected by chance are marked with +++ (*P*<0.001), ++ (P<0.01), + (P<0.05), whereas conservation areas retaining less climate suitability for species than expected by chance are marked with -- (P<0.01) and - (0.05). Redrawn from Araújo et al. in preparation.

The forecast of high retention of suitable climate conditions for target species within protected areas as compared with the surrounding matrix is good news, but it does not logically lead to the conclusion that climate change impacts are low. Indeed, available forecasts suggest that up to 52%±12.1 of European vertebrates and plants might lose suitable climate within existing protected areas by 2080. This figure is slightly higher for Habitats Directive species occurring within Natura 2000 sites (note that Natura 2000 sites include many areas classified as Protected Areas), where up to 58%±16.0 of all species considered are expected to lose suitable climate. A country by country analysis also reveals that Finland would be the only European country expected to display a positive net balance between winner and loser species (Figure 2); all remaining European countries are projected to have a greater number of Habitat Directive species losing suitable climate within Natura 2000 sites than gaining. For protected areas, the analyses reveal a greater degree of variation in the ratio between species winning and losing climate suitability, but the overwhelming majority of European countries are projected to lose more suitable conditions for species within protected areas than gain (Figure 2); nevertheless, protected areas in high latitude and altitude countries display a tendency for having a greater proportion of winner species whereas the remaining countries would have more losers than winners. Note that this analysis concerns total numbers of species and does not investigate the fate of particular species. It is more than likely that high latitude and altitude countries might receive many species from warm-adapted climates at the expense of the contraction of cold-adapted species ranges, which in the mountains include many narrow endemics.

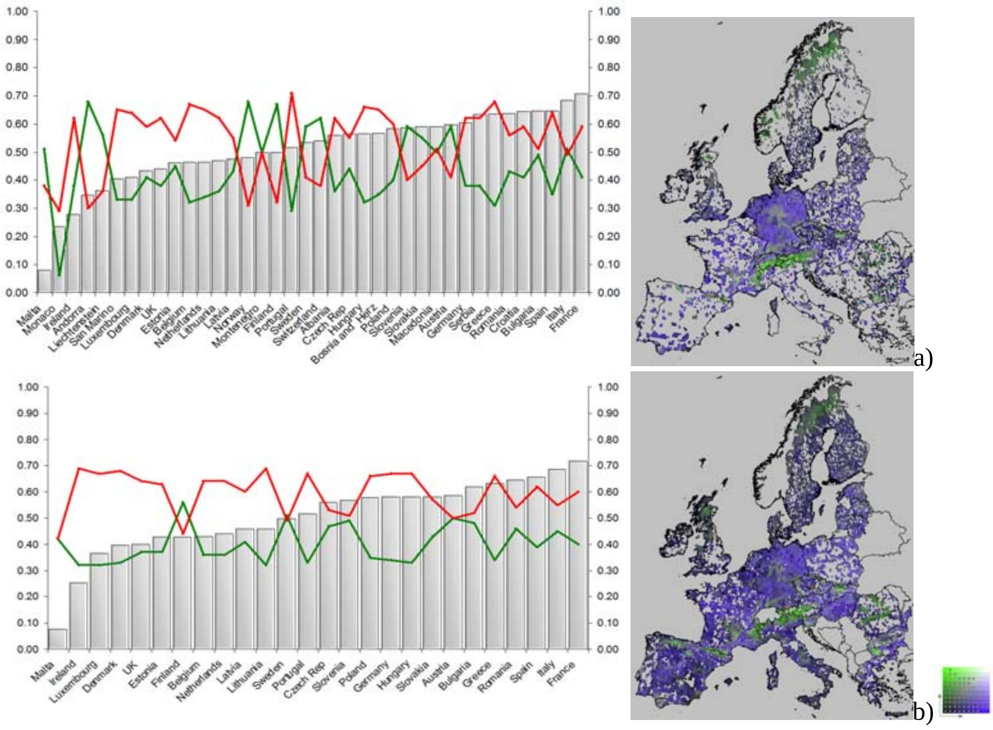

Figure 2 – Left diagram: The proportion of European species that occur within each individual country (bars, right axis) against the proportion of projected loser (red lines, left axis) and winner species (green lines, left axis) in protected areas (a) and Natura 2000 sites (b) as projected for 2080 with the A1FI scenario: (a) vertebrate species occurring in protected areas (*n*=591); (b) Habitats Directive vertebrate and plant species occurring in Natura 2000 sites (*n*=317). Map on the right - Overlay between richness of species losing and gaining suitable climate within protected areas (a) or Natura 2000 sites (b). Scores are divided into 10 equal-interval colour classes, where increasing intensities of blue represent increasing numbers of species losing suitable climate and increasing intensities of green represent increasing numbers of species winning suitable climate; shades of grey represent linearly covarying scores between winners and losers. Redrawn from Araújo et al. in preparation.

III. REDUCING CLIMATE CHANGE IMPACTS ON PROTECTED AREAS BIODIVERSITY

Addressing climate change impacts on protected areas requires a paradigm shift in protected areas planning and management. A common assumption is that successful conservation is achieved by isolating protected areas from the processes that threaten their existence (Margules and Pressey 2000). Yet, it is increasingly evident that conservation strategies, in order to be effective, need to mitigate impacts of climate change in addition to providing sustainable management of habitats and ecosystems (e.g. Hannah et al. 2002, Araújo et al. 2004, Lovejoy 2006, Hannah et al. 2007, Araújo 2009). But how can planning and management of protected areas mitigate climate change impacts on species and habitats?

Climate change presents an important challenge to conventional protected areas planning, because species and their habitats are likely to shift away from their present locations. Conventional rules for protected areas design were proposed by Diamond (1975) and Wilson and Willis (1975). These rules were based on simple principles from equilibrium theories of island biogeography (i.e. the greater the area and the better connected the areas the greater the probability of persistence). More specifically, it was assumed that: a) a large reserve is better than several small ones because of reduced extinction rates; b) reserves should not be fragmented, or be as close as possible to increase the likelihood of dispersal between reserves; and finally, c) reserves should be as nearly circular as possible to minimize dispersal distances within a reserve (but also to minimise edge effects, see Woodroffe and Ginsberg 2000). Rules for reserve clustering are pertinent in situations of quasi-equilibrium between colonisations and extinctions in metapopulations. However, if extinctions are generated by shifting habitat suitabilities and species distributions are able to track these shifts, then there is no logical reason to expect metapopulations to exist in any kind of equilibrium (Araújo 2009). In some cases, a reversal of the conventional design principles, based on equilibrium biogeography and metapopulation theories, can occur (Araújo 2009). When this happens, conservation areas with geometric features that are traditionally viewed as sub-optimal can, effectively, maximise the conserved area that remains suitable in the future (Pearson and Dawson 2005, Araújo 2009). In other words, smaller conservation areas tracking pertinent climatic gradients might be, in some circumstances, preferable to large conservation areas occupying uniform climatic gradients.

To start addressing the requirements for effective protected areas conservation under climate change it is important to acknowledge that species respond to climate changes by adapting, moving or perishing. Given the speed of contemporary climate changes, adaptation by mutation and natural selection is unlikely to play a major role in the short term, but changes in species phenotypes may enable them to tolerate environmental changes without the need for changes in the genotype (Bradshaw and Holzapfel 2006). The capacity to colonize new areas is likely to be critical, but the relevance of dispersal will vary across taxa and regions. Species with low vagility, low abundances, low reproductive rates, specialised for given habitats, or types of food, are more likely to find it difficult to track climate changes by moving across the landscape. This challenge will only be exacerbated in highly fragmented or degraded landscapes.

In order to promote adaptation of species under climate change, at least three types of areas need to be targeted for conservation (Araújo 2009). The first are stationary refugia, or range retention areas. These are regions where species are most likely to survive despite climate changes. Stationary refugia escape the more dramatic climate changes, maintaining climate variation within the range of tolerance of most species, and/or allowing species to persist through short-distance dispersal. Some patches of lowland tropical forest, large temperate forests in eastern Asia, steppe-tundra in the eastern parts of the Beringian region, and sub-tropical laurel forests in oceanic islands remained relatively stable climatically in the Quaternary and include some of the most well-known stationary refugia (Newton 2003, Araújo 2009). South-facing slopes in southern European mountains and deep valleys also provided opportunities for adaptation of species via short-distance dispersal. In the current warming period, cooler and wetter locations, such as north-facing slopes in southern Europe and river valleys, are also likely to play important roles as stationary refugia. Old growth forests may also be important refugia as they have been shown to have greater inertia to climate change than newly-established forests (Noss 2001, Hansen et al. 2003). Floating bogs (Galatowitsch et al. 2009), and ‘cold spots’ of upwelling, shade or freshwater input in marine environments (Hansen et al. 2003) might play analogous roles as refugia in aquatic environments.

The second are displaced refugia, where species are able to find suitable habitats after they have been displaced by climate change from their original location. Typically, displaced refugia are areas at the leading edge of species ranges and their distribution can be easily inferred with bioclimate envelope models (e.g., Huntley et al. 1995, Sykes et al. 1996, Berry et al. 2002, Thuiller et al. 2005, Araújo et al. 2006, Bakkenes et al. 2006, Harrison et al. 2006, Levinsky et al. 2007, Huntley et al. 2008). Like stationary refugia, they can also be found, but not exclusively, in some mountain ranges, deep valleys, and other areas with steep climate gradients that are able to maintain certain types of climate that become regionally restricted with climate change (e.g. Ohlemuller et al. 2008).

The third types of key areas for biodiversity conservation under climate change are regions of high connectivity that allow species to track climate changes through dispersal. An extensive literature is available on this topic, and researchers have began to develop quantitative approaches for the identification of dispersal routes between protected areas under climate change (e.g. Williams et al. 2005, Phillips et al. 2008, Vos et al. 2008). Any policy to mitigating climate change impacts on biodiversity needs to identify and manage these three types of areas.

The conservation of stationary and displaced refugia is likely to be best done in protected areas, or any other type of formally designated conservation areas, because they typically require specific conservation measures to be implemented over long periods of time. In contrast, areas of connectivity may or may not be established in protected areas. In some cases opportunities exist to ensure conservation of such areas in the wider countryside. Below, a description of three alternative strategies for implementation of biodiversity conservation under climate change is provided. They include strategies for the management of networks of protected areas, management of individual protected areas, and off-protected areas management.

III.1 Management of protected-area networks

Conservation-area networks have been and are likely to remain the cornerstone of biodiversity conservation in a changing environment. Some of these areas are likely to act as conservation hubs under climate change; this is expected when conservation areas act as stationary refugia, displaced refugia, or cross-roads for connectivity (see definitions above). Identifying such areas and managing them as part of a broader network is critical to ensure overall management of biodiversity in the regions of interest. In theory, there is a possibility that some protected areas might become dispensable if their valued biodiversity features become locally extinct and/or if their role in conserving existing biodiversity under climate changes becomes negligible. But whilst some areas may lose value, others may become critical for conserving biodiversity. To allow the possibility of adjustments in the networks, there is a need for monitoring changes in the value of protected areas and for establishing flexible mechanisms for the management of existing ones. The principle is that rational management of limited resources available for conservation requires a regular appraisal of the conservation targets and achievements so as to ensure that overarching societal goals for conservation are being fulfilled within the limits imposed by budgets and other socio-economic constraints (e.g. Pressey et al. 1993, Margules and Pressey 2000).

III.1.1 Increasing available habitat

A common strategy for reducing climate change impacts on protected biodiversity will certainly include the classification of new protected areas to increase the available habitat for species and ensure the existence of suitable pathways for species dispersal. New classifications, or adjustments, can be informed by forecasts of species range shifts under climate change (Araújo et al. 2004, Williams et al. 2005, Phillips et al. 2008, Vos et al. 2008), although uncertainties from the models need to be explicitly accounted for, ideally, within an ensemble forecasting framework (Araújo and New 2007). In some cases, there might be advantages in proactively securing the conservation of areas that might become suitable in the future rather than waiting for the impacts to occur and only then take action (Hannah et al. 2007). For example, efforts to counter the effects of sea level rise have already led to anticipatory habitat creation and coastal realignment in some areas of the UK. On the southern shores of the Ribble Estuary in Lancashire, the Royal Society for the Protection of Birds (RSPB) has acquired land that has since the 1980s been reclaimed farmland to create a new wetland reserve next to the Hesketh Out Marsh. By breaching the existing sea walls, the newly flooded area will be able to regenerate as a salt marsh, saline lagoons and muddy creeks, which are important habitats for breeding waders, while potentially making also a useful contribution to flood protection[1].

Likewise, in North Carolina, US, the Albemarle Peninsula's productive natural forest, dunes, wetlands, and rivers is also at risk from sea level rise. A coalition involving the Nature Conservancy, the US Fish and Wildlife Service, and other partners are testing adaptive management actions to allow the adaptation of local ecosystems to environmental changes (Pearsall 2005). Actions include acquisition of new areas for conservation, inland and upland, and the restriction of road fragmentation and drainage ditches to facilitate species dispersal away from rising seas. Acquisition of easements is also planned to prevent shore armouring, and thereby allowing the transition of living shorelines as the sea level rises. By conserving and re-establishing inundation-tolerant bald cypress and other species, and establishing native oyster reefs along the shorelines, it is hoped that these re-engineered areas can facilitate the transition.

Measures are also being proposed to allow adaptation of Florida's coastal biodiversity to sea level rise (Figure 3). Even the most conservative climate models forecast the loss of 13% of rare species and habitats. To mitigate such impacts, a plan has been proposed (Noss 2008, Robbins 2009) to move human development activities inland and preserving coastal areas as habitat for species. Rolling easements are suggested to prevent new armouring of the coast and secure a band of coastal habitats between developed areas and the sea. The safeguarding of new conservation lands alongshore as well as corridors to upland habitats is also planned in the short-term, while the conservation of upland refugia and corridors between upland habitats and running northward would allow the establishment of migrating species in the long-term. Assisted migration of species is also considered.

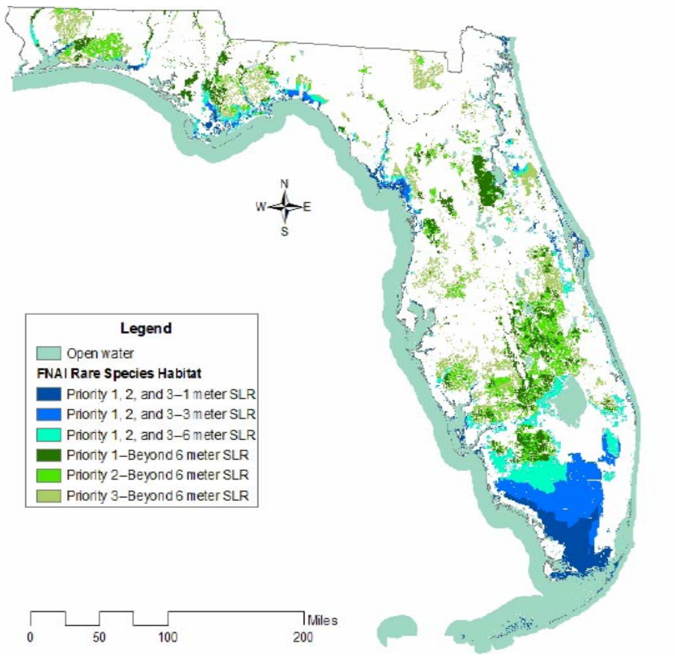

Figure 3 – High priority habitat for species in Florida under different sea level rise scenarios (1m to 6m). From Noss (2008).

[1] Based on information from http://www.rspb.org.uk/climate/help/reserves/index.asp.

Sea level rise is an easy threat to adapt to in the sense that the direction of the changes (rather than its magnitude) is easy to forecast. Preparing for in-land shifts in the distributions of species is slightly more challenging because there are uncertainties even in the direction of the changes, i.e., the direction of the drivers of change and the direction of the responses. Nevertheless, some European countries are taking a lead on adaptation strategies in-land despite uncertainties. One example is the Dutch National Ecological Network (‘Ecologische Hoofdstructuur’, EHS). The EHS encompasses protected areas of national or international importance, privately owned areas managed for nature conservation purposes (often agricultural land), and nature development areas (Bennett and Mulongoy 2006). Originally designed to restore natural ecosystems affected by human activities, the network is being adjusted to become more climate-proof (Nillesen and van Ierland 2006). Adaptation options that are under study include the construction of robust ecological links, the expansion of reserves, and the enhancement of internal heterogeneity of reserves[2]. Creating a corridor of wetland nature reserves is one of the options to increase connectivity within the EHS and with neighbouring countries (Figure 4). Based on population dynamic models, an expansion of wetland reserves has been proposed that increases the area of wetland habitats such as marshland and provides stronger connection between wetland areas (Netherlands Environmental Assessment Agency 2008).

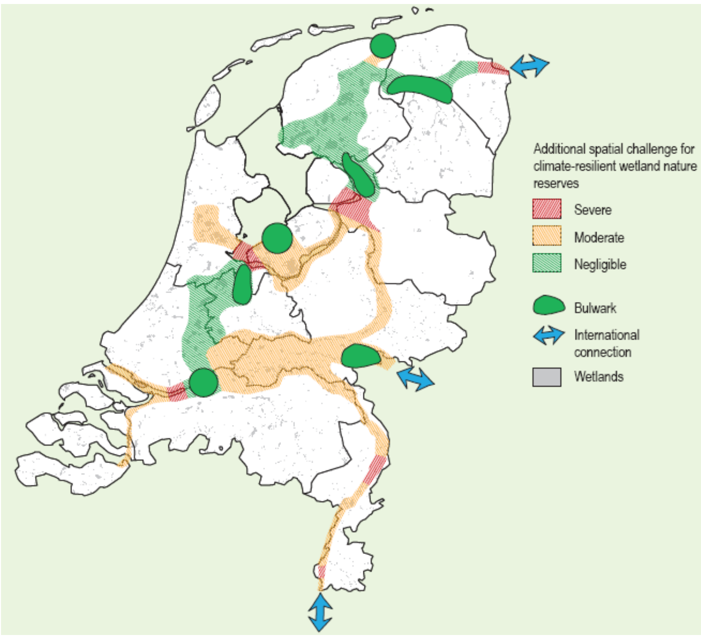

Figure 4 - Suggested climate corridors linking wetland nature reserves in the Netherlands (Netherlands Environmental Assessment Agency 2008).

The need for transboundary pathways for dispersal between areas of conservation importance has been taken even further in the Alpine Convention[3], signed by eight Alpine states in 1991. The convention serves as the transboundary framework for sustainable development of the region. It is anchored on a number of protocols, among which the protocol on the conservation of nature and the countryside aims to preserve functional ecosystems, habitats and species in protected areas as well as in the wider landscape. Cooperation is encouraged in mapping and managing protected areas, defining landscape models and establishing a network of biotopes, and researching and monitoring habitats and species. The use of landowner agreements and financial incentives to preserve and manage near-natural biotopes on farmland and forests is also encouraged. In most cases, political boundaries are not ecologically meaningful and if

[2] Based on information from http://www.klimaatvoorruimte.nl/pro3/general/start.asp.
[3] Based on information from http://www.alparc.org

adaptation policies are to have a real impact on species persistence they need to be planned at the appropriate ecological scale.

The Alpine initiative to improve ecological connectivity in the region is rooted in the recognition that climate change, habitat loss and fragmentation are among the most important drivers of biodiversity loss in the Alps. Work conducted by several partners in the region (Scheurer et al. 2008) has identified priority areas for the establishment of ecological networks, including riverine systems, buffers around existing protected areas, and areas linked to large-scale European networks (Figure 5). At the pan-alpine level, the conservation of areas along ecological gradients is considered to be critical to ensure permeability of the landscape to species dispersal. Multiple economic use areas of connectivity are being considered in pilot areas, where agriculture, tourism and other soft uses are allowed to coexist with nature conservation management.

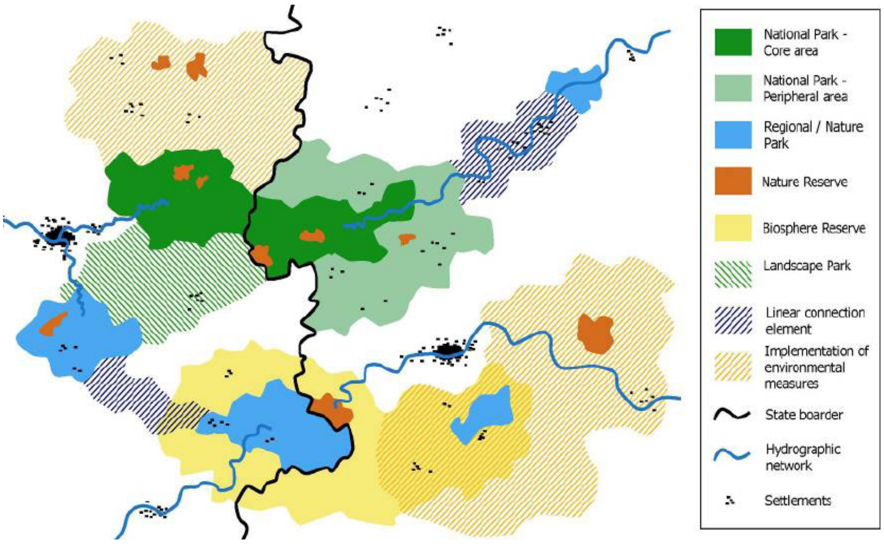

Figure 5 – Model of the ecological network of protected areas in the Alpine region (source: Alpine Network of Protected Areas)

Elsewhere, the need for transfrontier mechanisms for adaptation of biodiversity to climate change is being recognised. For example, Spain and Portugal are working together in a transboundary initiative[4] to provide specific adaptation measures for the Iberian biodiversity. Due to the small size of most European countries such initiatives are critical for effective biodiversity adaptation under climate change. Transboundary conservation is almost as old as the concept of protected areas itself. For example, Canada's Waterton National Park was proposed in 1895, with US Glacier National Park being formed in 1910. In 1932 the two parks were combined to form the Waterton-Glacier International Peace Park (Busch 2008). Conservation International (CI) reported 188 international protected-area complexes in 112 countries, comprised of 818 individual protected areas. These areas span 3.2 million km2, an area roughly the size of India, or 17% of the global extent of protected areas (Mittermeier et al. 2005). There are several initiatives to extend protected areas across political boundaries. For example, the IUCN (World Conservation Union) has a Global TBPA (Transboundary Protected Areas) Network and a TBPA Task Force, whereas CI has a Southern Africa Transfrontier Conservation Unit. Two additional non-governmental organizations (NGOs), the Peace Parks Foundation in Africa and ProNatura in South America, have the explicit goal of establishing more TBPAs (for review see Busch 2008). Explicit consideration of climate change in such initiatives would provide valuable opportunities for adaptation.

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[4] IBERIA CHANGE initiative: http://www.biochange-lab.eu/iberiachange/

III.1.2 Enhancing diversity and resilience of the protected-area network

Efforts to anticipate climate change effects on protected biodiversity have typically been undertaken within individual protected areas, or regional networks of protected areas, with the goal of ensuring the long-term persistence of well-known populations of species. These are bottom-up procedures and they are useful, particularly when the population and community ecology of the species of interest is well-known. However, in less-well studied areas there are advantages in defining general rules to help mitigating the negative impacts of climate change on the protected areas. For example, a general principle with wide application is that species in protected-areas networks that encompass a range of different habitat types and physical characteristics are more likely to be resilient to climate changes (e.g., Noss 2001, Hopkins et al. 2007, Huntley 2007, Millar et al. 2007, Dunlop and Brown 2008, Araújo 2009). The definition of such widely applicable rules-of-thumb for the conservation of biodiversity under climate change can be termed top-down, because it starts from an analysis of biophysical features of the landscape expected to have a positive impact on species persistence in contrast with bottom-up approaches that start with an analysis of the requirements of species to then propose policies that are generalized at the landscape level.

Such top-down approaches to conservation of protected areas or Natura 2000 networks are currently not part of the European mainstream policy but they are being laid out by the South Africa National Protected Area Expansion Strategy (Jackelman et al. 2007), still under discussion. The South African strategy includes the incorporation of rules into coarse- and fine-scale planning enabling the maintenance of processes that increase resilience of ecosystems to climate change. The rules are general and are based on inferences from the best ecological knowledge available. For example, areas of high endemism and species diversity are expected to represent regions with high potential for speciation. Land cover is used to measure habitat fragmentation, thus providing a measure of landscape permeability. Topographic gradients are also mapped as a first step for the identification of potential climate refugia. Following these and other rules laid out in the South Africa National Protected Area Strategy, expansion of the Addo National Park has resulted in the protection of six of the seven terrestrial biomes occurring in the country in what has become the most diverse South African protected area (Bomhard and Midgley 2005). Such diversity of biomes is thought to facilitate species responses to climate change (Kerley and Boshov 1997), and for some species it might enable the overlap between current and future bioclimatic ranges (Rutherford et al. 1999).

Similar approaches are being explored by Australia’s Department of Environment and Climate Change in New South Wales. Here, the National Parks Establishment Plan (Department of Environment and Climate Change 2008) identifies new priorities for building the State’s conservation system. The plan recognises a horizon of 50 years and encompasses conservation activities across the whole landscape. Conservation action for the next decade is guided by a number of priorities, many of which are crucial to address climate change impacts: ensure representation of unrepresented ecosystems and habitats, including those severely threaten by climate change; conserve wetlands, floodplains, lakes and rivers, and other critical landscape corridors to facilitate movements of plants and animals in response to climate change and other human induced challenges; ensure reservation of lands within important water catchments; and fine-tune reserve boundaries by adding relatively small areas to existing reserves, such as areas that can buffer reserves from surrounding land uses and climate change.

III.2 Management of individual protected areas

Ensuring persistence of species and habitats under climate change requires adjustments in the level of prioritization that is given to species and habitats. Adjustments are also necessary regarding the extent and location of protected areas as well as the management practices within them. Traditional management of protected areas focuses on strategies for isolating them from the potentially negative effects of human activities in the surrounding matrix, and managing populations of target native species and habitats occurring within the protected areas. Such focus for building management plans is rooted around concepts of dynamic equilibrium and stationarity, where past conditions provide the context and guidance for contemporary management. Approaches for management of protected areas that assume dynamic equilibrium and stationarity are appropriate when uncertainty is low and managed systems are relatively well understood and predictable (Baron et al. 2009). But under climate change, where expectations of equilibrium are no longer met, managers of protected areas need to take a long view, and actions to promote adaptation of species to climate changes should typically be conceived for periods up to 20 to 50 years, depending on the speed with which ecosystem changes are expected. Further, they need to deal with forecasts that are highly uncertain and with systems with low predictability and for which baselines and previous experience may be missing. Additionally, threats to persistence of biodiversity are likely to arise both from local – the usual focus of conservation management within protected areas – and global forcing as well as interactions between the two. To address such complexity, adaptive management strategies are recommended (Tompkins and Adger 2004, Baron et al. 2009, Lawler et al. 2009). Adaptive management is a structured, iterative process of optimal decision making in the face of uncertainty, with the aim of reducing uncertainty over time via regular monitoring of the system of interest. With adaptive management, decisions may maximise simultaneously one or more conservation targets while providing information needed to improve the future management of the area and its biodiversity features. Adaptive management has been widely used in Australia and North America, but there is little reason why it should not become mainstream practice in protected areas management in Europe.

One example of adaptive management under climate change comes from the Klamath Mountains of southern Oregon, USA. The Sycan Marsh protected area provides habitat for the bull trout (*Salvelinus confluentus*), a species that has been listed as threatened in the region (Lawler et al. 2009). This cold-water species is highly constrained by temperature in all life cycle stages, and the climatic warming predicted for Oregon may affect the availability, distribution, and size of thermally suitable habitats for the already fragmented populations of bull trout (Rieman et al. 2007, Lawler et al. 2009). These concerns have led protected area managers to adopt adaptive management measures to protect bull trout habitat. Activities include an improvement of habitat conditions and connectivity within the stream network, such as removing barriers to dispersal and restoring riparian areas. Such measures are bound to have a positive effect on bull trout populations irrespective of climate change and as such are particularly useful in the face of high uncertainty (Baron et al. 2009). Yet, once the bull trout's threshold for water temperature is crossed, such measures will be insufficient and managers will need to focus restoration action further upstream (Lawler et al. 2009). Monitoring of stream and fish conditions will create a better understanding of the effects of climatic changes on the trout populations thus allowing learning to be integrated with management actions (Baron et al. 2009) and managers to decide when and how to intervene (Lawler et al. 2009).

Another example comes from the Central Valley of California, where ephemeral vernal pools provide habitat for a diversity of endemic plant species and threatened animal species including the California tiger salamander (*Ambystoma californiense*) (Pyke and Marty 2005, Lawler et al. 2009). The endangered tiger salamander is sensitive to changes in vernal pool hydrology, controlled by the relationship between inputs of precipitation and water losses (Pyke and Marty 2005). Both grazing, which occurs in most of the vernal pools, and climate change can affect the water balance and play a key role in maintaining hydrologically suitable habitat for tiger salamander populations (Pyke and Marty 2005). Two main strategies have been designed to handle temperature and precipitation changes projected for the region (Lawler et al. 2009). The first, expanding the network of pools to increase the present and future diversity of hydrological conditions represented in protected areas, is likely to benefit vernal pool biodiversity regardless of climate change. In contrast, the second strategy is a close response to projected temperature and precipitation changes, which are of course highly uncertain. Based on continued monitoring, managers will be able to adjust the level of grazing pressure to secure the required levels of pool inundation for salamanders to complete the aquatic stages of their life cycles.

III.3 Off-protected-areas management

Whereas targeted management of individual protected areas and protected-areas networks is central for mitigating climate change impacts on native species diversity, there are portions of unprotected land that might play a transient role for species dispersal, or that enable species adaptation without a need for intensive conservation management. The identification of such areas is important, but not less important (and challenging) is the implementation of management practices that enable effective conservation in such private land outside formally designated conservation areas. The overarching goal of off-protected-areas management is to make the unprotected matrix more attractive to native species and thus more permeable for dispersal (e.g., Campbell et al. 2008, Heller and Zavaleta 2009). Several authors have recommended softening land use practices within targeted areas of the matrix (for a review see Heller and Zavaleta 2009), and some guidance has been provided regarding the practices that should be encouraged (e.g., Donald and Evans 2006, Berry et al. 2008, Campbell et al. 2008). Here, rather than discussing management options for the matrix, which are likely to be contingent on their role in facilitating adaptation of specific species, a discussion of alternative policy mechanisms for implementing off-protected areas management is provided. The policy framework is based on that proposed by Doremus (2003) and on examples drawn from a variety of real-world applications of off-protected-areas management.

III.3.1 Regulatory prohibitions and requirements

The ability of state agencies to impose constraints on the economic activities of landowners and other local agents varies from country to country, even within Europe. When the state is able to impose constraints on land uses through regulation, opportunities exist to provide coarse-filter rules for the sustainable management of the matrix. It is important to recognize that such rules limit what landowners can do in the landscape, but they can hardly lead to active and voluntary management of the land for conservation. Therefore, trade-offs exist between imposition and persuasion and only a case-by-case analysis can enlighten as to what is the best course of action.

Examples of regulatory approaches leading to constraints on the management of the matrix abound. For example, in Portugal a spatial planning instrument is in place since 1983 to ensure that ‘natural resources, particularly water and soil, are safeguarded together with other natural processes indispensable for good management of the land, including the conservation of nature’ (Decree 321/83). Such areas of high natural value are part of what has been termed the National Ecological Reserve (“Reserva Ecológica Nacional”, REN), which, in spite of its designation, is not a protected area. The REN targets critical areas for coastal protection, functioning of the hydrological cycle, and prevention of erosion, flooding and other natural hazards (for an example see Figure 6). The mapping of the REN follows a set of rules easily implemented in a GIS (geographical information system), and includes areas with slopes steeper than 30%, buffers around rivers, areas of the coastline including beaches, salt marshes, estuaries and small islands. Once defined at the municipal level and approved by the government, REN areas are subjected to specified land-use restrictions to ensure their protection (an analogous scheme exists to protect areas of high agricultural value, RAN).

The REN was not created for climate change impact mitigation, yet it enforces rules to conserve areas that promote connectivity and increase resilience of ecosystems to climate change. For example, the establishment of buffers around rivers can provide corridors for species dispersal and shelter for wildlife in periods of extended drought and fire. The protection of erosion-prone areas, which are often coincident with areas of steep slopes that may occasionally act as climate refugia, also promotes ecosystem resilience by preventing aridity accrued from reductions in soil depth and increased runoff. Protection of the coastline, dunes and other sand formations, and the buffering of flood-prone areas, may also help preserve coastal dynamics and other ecosystem processes. Given its prohibitionist nature, the REN framework has been subject to criticism and its on-the-ground implementation has been far from uncontroversial. Nevertheless, the concept underpinning the REN has been supported by several governments and rather than being scrapped from the Portuguese regulatory system, the REN has gone through several amendments leading to an improved Decree (166/08) that eventually resulted in its integration in the country’s recent nature conservation network (Decree 142/08). Together with areas for the protection of agricultural land (RAN) and areas classified under public hydrological domain, the REN is now part of what is loosely termed “areas of continuity”, aimed at ensuring connectivity between core conservation areas —i.e., nationally designated protected areas, the Natura 2000 network, and areas protected under international conventions.

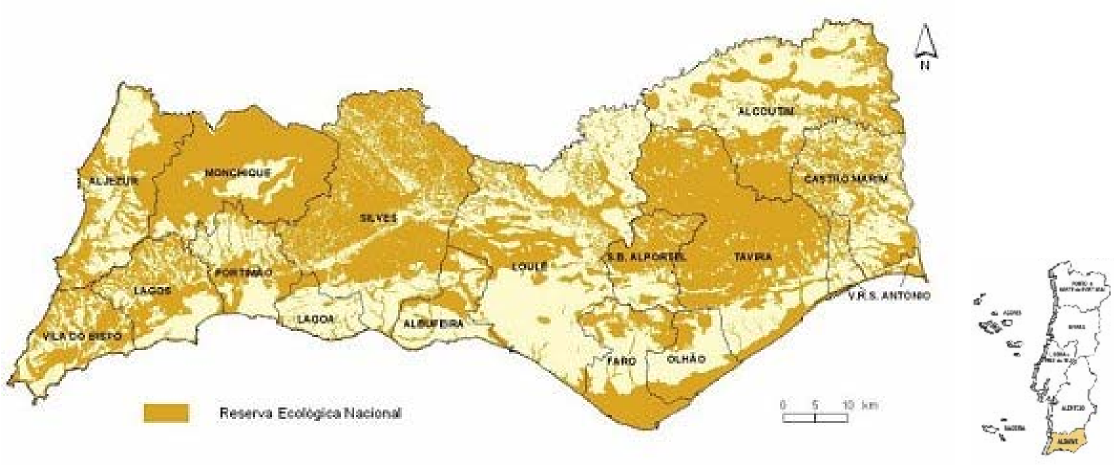

Figure 6 - REN areas in Algarve, the southern-most region of Portugal (source: Algarve Regional Co-ordination and Development Commission http://www.ccdr-alg.pt/ccdr)

A softer top-down regulatory approach for conservation includes the 'South East Plan: Regional Spatial Strategy for the South East of England' (Government Office for the South East 2009). The plan sets rules for land use, within a 20-year horizon, to frame local and regional plans and programmes in the South East and guide local authorities. Recognising climate change as one of the key drivers of change in the region, the Plan offers guidance for regional policies, such as tourism, housing, transport, waste, natural resources, countryside, and landscape management. With regards to biodiversity, the vision is to ensure that the southeast of England is prepared for climate change. To achieve this goal, the plan defines objectives for sustainable flood management, migration of habitats and species, and an increase in the region's landscape diversity. Local and regional planners are encouraged to pursue restoration, enhancement and creation of natural habitats in the areas identified as having strategic value for biodiversity. Rather than simply setting rules to constrain local economic activities, the South East Plan seeks to promote active management of the countryside by promoting the engagement of landowners. The use of agri-environmental schemes, forestry and other land management practices, including developer contributions, are proposed to increase the natural value of the land and facilitate climate change adaptation. Networks of multi-functional green space, such as river and canal banks, green corridors and a variety of urban elements are encouraged to support biodiversity and wider quality of life, particularly in areas undergoing large changes. Guidance for coastal planning is also given to ensure that development does not hinder options for managed realignment, encouraging options for natural coastal defences and time-limited permission for development.

Compensatory measures or offsets are regulatory requirements of a different nature that may also be used for effective conservation action in the landscape (Figure 7). When new developments are proposed and all measures to avoid, reduce or restore potential impacts have been considered, biodiversity offsets can be used to compensate for the remaining 'residual impacts' by securing alternative priority habitat for conservation. Provisions for offsets exist under Environmental and Strategic Impact Assessment (EIA and SEA) policies and the Habitats Directive. The latter requires that "Appropriate Assessments" be conducted of plans or projects that may affect the integrity of sites of international nature conservation importance and considers compensatory measures for residual impacts. To guide the implementation of existing offset regulations, a number of general principles have emerged that are relevant for biodiversity conservation under climate change. For example, when selecting biodiversity offsets it is important to consider the ecological value of the offset site in the landscape context (Vos et al. 2001, van Teeffelen et al. 2006). Favouring offset sites that promote landscape connectivity, buffer conservation sites, or support key ecological processes (Business and Biodiversity Offsets Programme 2009) can contribute to landscapes that are more resilient to climatic changes.

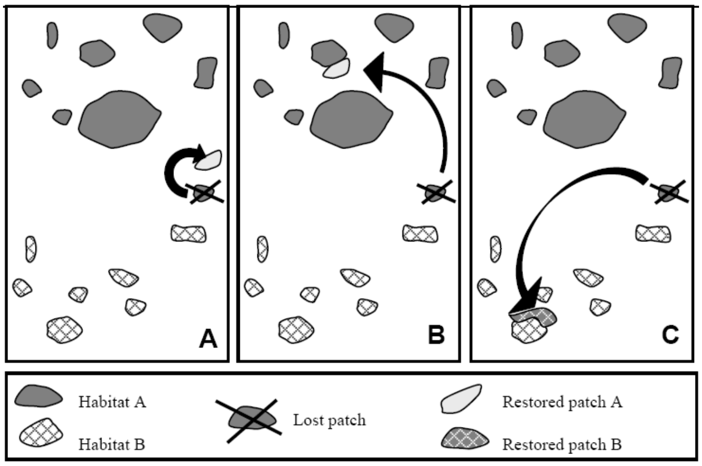

Figure 7 - Selection of offsets when sites with conservation value are impacted by human development activities: Examples of A) offset near impacted location and targeting the same habitat type; B) offset located in preferred location, distant from impacted site, but targeting the same habitat type; C) offset located at preferred location, distant from impacted site, and targeting different habitat type. From Van Teeffelen *et al*., 2008.

To guide biodiversity offsets under South African EIA regulations, the Western Cape Province (Department of Environmental Affairs & Development Planning 2007) uses a range of criteria to locate the offsets. Firstly, sites with the highest priority for biodiversity conservation for the affected ecosystem, as identified in existing plans, are considered. Preference is then given to sites that are important for connectivity, ecosystem functioning and irreplaceability in the landscape. Sites are favoured that provide spatial links and contiguity with protected areas or ensure consolidation of fragments of priority habitat. Areas identified in existing plans as representing core areas and ecological corridors or as contributing to important ecological processes also receive priority. Finally, sites that possess irreplaceable biodiversity value for realising conservation targets for an ecosystem, species or important ecological process are also favoured. While not mentioning climate change explicitly, offsets located under this scheme will likely contribute to generate more permeable landscapes.

III.3.2 Direct incentives for conservation on private land

An alternative approach to induce conservation-friendly management of the matrix is to engage landowners in conservation action. Economists have long suggested that an important factor in the decline of biodiversity is that, because landowners typically bear all the costs but do not capture the benefits of conservation, it is rational for them not to conserve (Doremus 2003). Incentives can correct this imbalance, harmonizing the interests of the landowners with those of society. Incentives may be positive (payments for positive conservation actions, e.g., the agri-environmental measures) or negative (taxes or other fees imposed on actions that negatively affect biodiversity, e.g., fees paid for killing or destroying species or habitats of European concern). Positive incentives can provide full compensation for conservation actions, or they can provide partial compensation, leveraging the willingness of landowners to engage in conservation for other reasons (Doremus 2003).

Examples of partial positive compensation for conservation management in private land are provided by the Cape Nature's Stewardship Programme in the South African Province of the Western Cape[5], and by

[5] Based on information from http://www.capenature.org.za/projects.htm?sm[p1][category]=444 and

the Conservation Partners Programme in the Australian State of New South Wales[6]. Both programmes are voluntary and offer three different levels of engagement each of which with different levels of benefits for landowners. Landowners benefit from technical assistance at all levels of commitment, but at higher-level landowners have more land-use restrictions while receiving greater benefits (Figure 8).

Conservation Partners Programme (Australia)		
Property registration: Non-legally binding property registration, providing landowners with information and support to help them manage habitats.	**Wildlife refuge:** legal declaration on the land title, for purposes of study or species recovery/ habitat restoration. Allows other land uses and provides landowners with property management planning advice and biodiversity assessment assistance.	**Conservation agreement:** permanent legal protection on the title, of areas containing critical habitats or threatened species, scenery or natural phenomena worthy of preservation, or of special scientific interest. Landowners benefit from assistance with detailed management strategies and rate exemption.

Increasing priority/vulnerability sites
Increasing protection for the land
Increasing benefits to landowners

Conservation areas: Suitable to any natural land, with very few land use limitations, and provision of technical advice to landowners.	**Co-operation agreements:** Management of conservation-worthy land in a way that supports natural processes. Landowners benefit from assistance with fire, alien, plant and animal management, and advanced extension services.	**Contract nature reserves:** Registration on the title, for protection of priority areas adjacent to statutory reserves or critically important sites. No development or land use rights allowed (except access and residence). Landowner benefits from substantial assistance with habitat management and potential rates rebates.
Conservation Stewardship Programme (South Africa)		

Figure 8 – The three levels of engagement of landowners in the Conservation Partners Programme in Australia, and the Conservation Stewardship Programme in South Africa. The greater the engagement of landowners in conservation programmes, the greater the benefits given by the state.

In Europe, agri-environmental schemes are a well-known mechanism for rewarding farmers for farming in an environmentally sensitive way. While not created specifically for climate change adaptation, they contribute to softening intensive production landscapes and thus can play a significant role in reducing biodiversity impacts from climate change (Donald and Evans 2006, Nillesen and van Ierland 2006). Such schemes have been implemented across Europe, but examples in the UK and Switzerland have been designed to take landscape connectivity and resilience into account. For example, UK's Environmental Stewardship is an agri-environmental scheme that provides funding to farmers, land managers and tenants according to three levels of engagement in conservation. At the top end of the engagement level, higher level stewardship agreements target areas of high priority for biodiversity and propose sets of appropriate management options for each one of them. Outside these priority areas, agreements are also offered that deliver management options supporting selected themes. Theme 1 is dedicated to 'improving the resilience of nationally important habitats to climate change', giving priority to agreements outside target areas that promote the restoration, maintenance and buffering of diverse UK Biodiversity Action Plan habitats[7].

The Swiss agri-environmental scheme provides incentives for the protection of ecological compensation areas (ECAs) in the form of semi-natural habitats on farmlands, such as hedgerows and extensively farmed meadows and pastures. To be eligible for direct payments, farmers need to establish

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http://www.capebiosphere.co.za/images/nature/English.pdf.
[6]Based on information from http://www.environment.nsw.gov.au/cpp/ConservationPartners.htm.
[7] Based on information from http://www.naturalengland.org.uk/ourwork/farming/funding/es/default.aspx.

ECAs on at least 7% of their agricultural production land (Birrer et al. 2007). The frequent scattered distribution of agri-environmental schemes may compromise the scheme's effectiveness in enhancing biodiversity (Whittingham 2007), but a scheme in place in Aargau has started to take spatial targeting of ECAs in consideration. Here, ECAs are selected based upon their quantity and distribution within the farm as well as their ecological quality, favouring locations that supplement and link existing ECAs or nature reserves in the area (Roth et al. 2008). The scheme in Aargau was found to enhance species richness of the less mobile species studied (vascular plants and snails), suggesting a positive effect of connected ECAs (Roth et al. 2008). Coordination can also exist between Swiss farmers in a watershed, to reach "grouped plans" establishing a set of wider, connected landscape structures to facilitate species movements (Piper and Wilson 2008).

The potential of these schemes to address climate change has not been generally considered in the design of these agri-environmental schemes (Donald and Evans 2006). Their effectiveness to facilitating species dispersal can nonetheless be further improved by integrating predicted species range shifts or the existing spatial arrangement of non-farmed habitats, and tailoring them to the needs of target species, and to specific landscapes and agricultural types (e.g., Donald and Evans 2006, Kleijn et al. 2006, Finche-Savage et al. 2007).

III.3.3 Market creation and improvement

A fundamentally different strategy for off-protected-areas management is to rely on the creation or improvement of markets for biodiversity conservation. Markets for biodiversity are difficult to establish for at least two reasons. The first is that biodiversity has the characteristics of a public good (Stone 1995). Public goods are non-exclusive, which means that they cannot be supplied to some people while being denied to others. They are also non-rival, meaning that their enjoyment by one person does not reduce their availability to others (Ostrom et al. 1994). These characteristics prevent those who supply biodiversity from capturing all its benefits, and thus biodiversity is likely to be neglected by the market in the absence of government intervention (Doremus 2003).

The use of market-based approaches for biodiversity conservation is still in its infancy but there are some examples. Established to address biodiversity loss in New South Wales, Australia, the Biodiversity Banking and Offsets Scheme[8] enables landowners to generate biodiversity credits by committing to a set of management actions at biobank sites. A market is created where credits generated by landowners become available to developers who need to offset impacts and to organisations that wish to secure conservation goals. Actions on biobank sites can include the management of grazing, fire, weeds and human disturbance, on a selected area of the land, and are set out in a banking agreement which is placed on the land title. The funds from the sale of credits can be used to manage the site.

The BioBanking scheme's methodology (Department of Environment and Climate Change NSW 2008b) determines ecosystem and species credits by measuring the loss of biodiversity value on development sites and the gain in biodiversity values on biobank sites. This methodology assesses all biodiversity values as defined by the Threatened Species Conservation Act, including the composition, structure and function of ecosystems. The site value is measured by the condition of native vegetation, while the landscape value considers the size of adjacent remnant areas. Changes resulting from impacts on development sites or from management actions on biobank sites are also captured in the landscape value, by measuring the change in native vegetation and connectivity. The value of biodiversity credits thus takes into account the characteristics of the biobank site generating the credits, favouring larger, healthy sites that are connected to other areas already managed for conservation. By doing this, the NSW scheme allows for more strategic location of offsets rather than a common piecemeal approach to negotiating offsets individually. When used for conservation purposes, purchasers can select credits from the public register that support desired conservation outcomes and then retire the credits, which can no longer be sold to a third party, to ensure protection and management of the site. Credits could be selected, for example,

[8] Based on information from http://www.environment.nsw.gov.au/biobanking/.

that contribute to the establishment of a corridor in a particular area, thereby enhancing connectivity in the landscape.

In Finland, a voluntary land lease mechanism launched in 2003, in the framework of the Forest Biodiversity Programme for Southern Finland, uses a different approach to establishing markets for biodiversity. Under the Trading in Natural Values scheme (Juutinen et al. 2008), the government temporarily leases forest land for biodiversity conservation from landowners who place their land on the market. A forest landowner who proposes land to the programme will have the land assessed for its conservation value. This conservation value includes prices for ecological features as well as compensation for lost harvesting income, and is used as a guideline in the negotiations. Landowners enter into a fixed-term agreement to maintain or improve natural values on the land and, in turn, receive from the state or a forest conservation foundation a compensation payment, which is negotiated in a competitive bid between several landowners. The criteria used to calculate compensation payments for biodiversity protection include ecological criteria such as the presence of threatened species, presence of trees, the distance to existing reserves, and landscape values (Juutinen et al. 2008). Although not designed in the light of climate change, such criteria may contribute to protecting climate change-sensitive species and facilitating dispersal to and from reserves. While the Finnish scheme was found to yield similar costs to land purchasing, the flexibility afforded by land leasing may be important as the biodiversity value and contribution to current conservation priorities of a given target can be revaluated at the end of the contract period (Juutinen et al. 2008).

III.3.4 Information and education instruments

Off-protected-areas conservation is dependent on the landowners or tenants' motivations to implement and maintain conservation actions. In general, policies that encourage learning and participation are more likely to be implemented (Ramakrishnan 1998), placing a premium on educational instruments targeted to guide conservation action on private land (Doremus 2003). For example, in New South Wales, Australia, 'climate change profiles' have been prepared for land users in each catchment area, providing an easy-to-read overview of predicted climate changes for each catchment, impacts on biotic resources and farms, and suggested strategies for adaptation (New South Wales Government 2007). A toolkit is also available for biodiversity planning workshops targeted at landowners, to assist them in assessing the biodiversity on their properties and including biodiversity protection in their management[9].

IV. POLICIES FOR ADAPTATION OF BIODIVERSITY IN PROTECTED AREAS

Several countries in Europe and elsewhere have started embedding adaptation concerns into policy. The EU White Paper on climate change adaptation (EC Communication 2009/147) provides guidance to help prepare for the impacts of climate change and efforts at the national level have, in many cases, resulted in the publication of adaptation plans, strategies, or action plans (Table 1). Are these policies sufficient to promote adaptation of protected areas biodiversity to climate change?

A review of climate change adaptation plans in the developed world (Gagnon-Lebrun and Agrawala 2006) found that only five countries were already moving towards actual implementation of anticipatory measures that take into account future climate changes. These were the Netherlands, the United States, New Zealand, Australia, and the United Kingdom. Like the European White Paper, national strategies typically call for integration of policies for climate change adaptation across economic sectors and political borders. A review of climate policy integration in Denmark, Finland, Germany, the Netherlands, Spain and the United Kingdom (Mickwitz et al. 2009) concluded that most countries have focused on sectors affected by extreme weather events. In the Netherlands, for example, spatial planning policies are shifting from a traditional approach of land reclamation to make room for people to one of making room for rivers (M.V.W. 2000). The Dutch Space for Rivers policy was found to generate additional positive impacts on natural dynamics and ecosystems (Kolhoff and Slootweg 2005), but isolated strategies

[9] Based on information from http://www.environment.nsw.gov.au/cpp/PlanningBiodiversityManagement.htm.

focusing on visible impacts risk neglecting others, less visible, adaptation issues (Mickwitz et al. 2009). It is the case, in particular, of more subtle impacts that may affect biodiversity.

General guidelines for adaptation of European biodiversity are provided by European Commission (EC Communication 2006/216), and more specific guidance exists to address the vulnerability of species and habitats listed by the Bern Convention to climate change (Recommendation 135 of 2008). In national biodiversity strategies, climate change has also increasingly been recognised as an important driver of biodiversity loss, and adaptation principles to increase resilience of habitats and accommodate impacts have been incorporated (Table 2).

While the impacts of climate change on biodiversity are widely acknowledged in documents and plans at different European scales, effective changes in protected-areas network planning are still rare. Most European and national policies for adaptation provide general principles rather than specific, actionable, strategies. In most cases proposed initiatives remain at the level of "soft" policy options and provide general guidance, support governance, and raise awareness or research and development instruments to inform future approaches (Figure 9). While general guidance for adaptation is important, biodiversity strategies need also to be accompanied by detailed action plans, and extend more fully to the use of specific policy instruments, either by creating new mechanisms or reshaping existing instruments (Mickwitz et al. 2009).

Table 2 – Range of biodiversity adaptation measures found in published national and European adaptation documents

European policy initiatives	
EU White Paper COM (2009) 147	▪ **Increasing resilience of biodiversity, ecosystems and water:** incorporating climate change into management of Natura 2000 sites, River Basin Management Plans (RBMP), and implementation of the Floods Directive. ▪ **Increasing resilience of coastal and marine areas:** integrating climate change into coastal and marine areas adaptation guidelines and marine and fisheries policies implementation and reform.
Biodiversity Communication COM (2006) 216	▪ **Supporting adaptation to climate change:** securing coherence of the Natura 2000 network; preventing potential damages to biodiversity arising from adaptation and mitigation measures; and assessing habitats and species in the EU most at risk.
Bern Convention Recommendation No.135 (2008)	▪ **Reducing vulnerability** focusing action on Bern Convention species and habitats potentially more vulnerable to climate change. Action is proposed for protection and monitoring of migratory birds, amphibians and reptiles. ▪ **Enhancing resilience:** maintaining and restoring ecosystem function and variability, relocating and creating new areas, establishing buffer zones, and preventing the spread of invasive species. ▪ **Accommodating impacts:** establishing networks of interconnected protected areas and intervening habitat mosaics, planning future protected areas that allow protection of vulnerable species and habitats, avoiding development along coasts and rivers, and considering species translocation and ex-situ conservation. ▪ **Conserving at the landscape scale:** considering the location and extent of protected areas in the context of the wider landscape, and enhancing permeability by retaining fragments of semi-natural habitat or creating stepping stones.
National policy initiatives	
National Biodiversity Policy Programmes	▪ **Enhancing connectivity:** establishing or strengthening functional ecological networks to allow natural adaptation of species, establishing international agreements where needed, and reducing fragmentation of the landscape. ▪ **Adapting protected area management:** ensuring flexible management, a long-term, ecosystem based approach, improvement of the quality and condition of sites, and buffering from other pressures in the surrounding areas. ▪ **Re-orienting protected area priorities:** identifying priority ecosystems, basing the design of networks on new climate change research data.

	▪ **Reviewing priorities and actions targeted on species:** reviewing targets, translating priorities into action programmes, and preparing for ex-situ conservation of the species most severely threatened. ▪ **Monitoring and adaptive management:** intensifying monitoring systems, defining suitable indicators and gathering data that can support adaptive management and inform policy-making and international co-operation.
National Adaptation Strategies	▪ **Adapting current reserve networks to the impacts of climate change:** preserving or restoring resilience through ecological corridors, changing the management and use of protected areas, long-term monitoring, establishing new reserves where needed, and favouring representative and diverse networks. ▪ **Adapting regional planning structures to take account of climate change:** cooperating across administration levels and stakeholders, providing guidance and information, developing flexible options in landscape planning to permit realignment if needed, and reducing fragmentation.

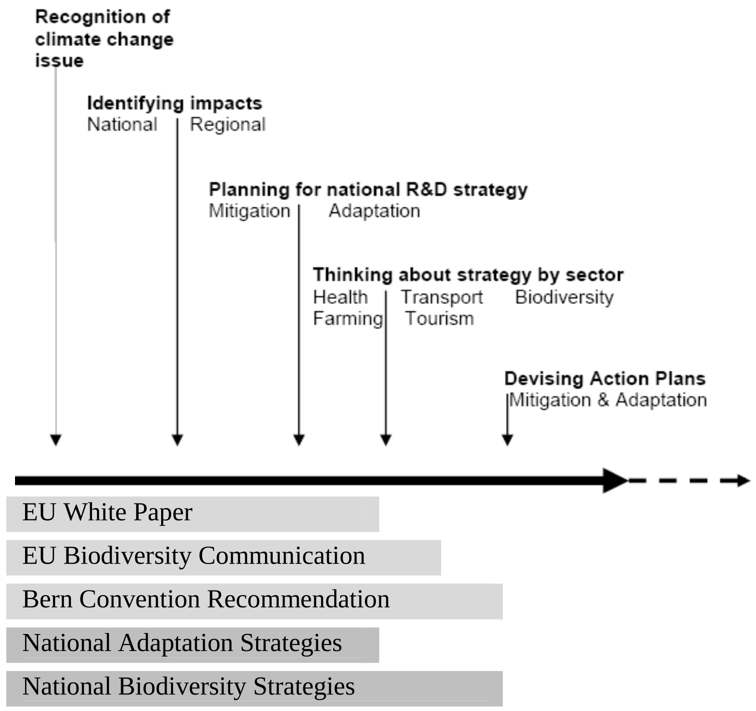

Figure 9 - Stages in climate change response (Piper and Wilson 2008a) of some of the EU and national adaptation policy initiatives that consider the biodiversity sector

Some examples of practical adaptation measures to biodiversity have involved expansion of protected areas via land acquisition by NGOs (III.1.1). There are isolated examples of protected areas management plans being revised to ensure more resilience to future changes and of national and trans-national efforts to establish and climate-proof conservation networks (III.1.1.). Yet, no examples of operational strategies with prescriptive methodologies and objective rules for protected-areas network planning under climate change were found at the national, regional, or European scale (III.1.2).

The increased challenges faced by native biodiversity may, however, require that new top-down strategies for biodiversity conservation, supported by new legislation, are put in place. These may include buffering of existing protected areas, classification of new protected areas, and the creation of mechanisms for off-protected-areas conservation. The latter might in some occasions be implemented with top-down regulatory approaches (III.3.1.) but, whenever possible, there should be mechanisms to promote stakeholders' involvement via direct incentives (III.3.2), or via market-based (III.3.3) and educational approaches (III.3.4).

It is clear, though, that actions for adaptation of biodiversity to climate change will require a variety of different, often creative, solutions. These are likely to vary among countries and regions (Ehrlich and Pringle 2008). The selection of the most appropriate adaptation strategies will necessarily be constrained, in addition to the types of threats faced by biodiversity, by existing conservation policies and planning frameworks (Scott et al. 2002), regulatory structures, property rights and social norms associated with the rules in use (Adger et al. 2005). The appropriate mix of protected areas and off-protected-area conservation action will, hence, differ from place to place.

In general, a portfolio of approaches will be required that includes short-term to long-term strategies. While options to increase resilience of ecosystems to the effects of climate change might be feasible in the short-term and for cases of moderate climate change, with time it will be necessary to switch to strategies encouraging gradual adaptation and transition to inevitable changes (Millar et al. 2007, Galatowitsch et al. 2009). Modelling exercises can inform the selection of adaptation strategies, but where this is not feasible or uncertainties are too great, 'business-as-usual' strategies that promote healthy habitats with high diversity and permeability will remain beneficial. With the uncertain and gradual nature of climate change-induced biotic responses, maximising biodiversity protection in the matrix appears as a no-regrets strategy (Hannah et al. 2002). Such strategies are dependent on broadened spatial and temporal scales of conservation management and increased cooperation among conservation and other agencies and landowners (Lawler et al. 2009).

V. MAIN CONCLUSIONS AND RECOMMENDATIONS

European protected areas and European–wide networks of conservation areas, such as the Natura 2000, are severely threatened by climate change. Up to 52%±12.1 of European vertebrates and plants are forecasted to lose suitable climate within existing protected areas by 2080. This figure is higher for Habitats Directive species occurring in Natura 2000 sites, where up to 58%±16.0 of all species are expected to lose suitable climate. Conventional views on protected-areas planning often assume that successful conservation is achieved by isolating protected areas from the processes that threaten their existence. However, conservation strategies, in order to be effective, need to mitigate impacts of climate change in addition to providing sustainable management of habitats and ecosystems.

Classification of protected areas, but also of the Natura 2000 and Emerald networks, is typically based on the presence of species and habitats of conservation concern. With climate change, species are forecasted to move away from these areas but more fundamentally, changes in species priorities are expected. Species classified as being of no concern under a particular scheme (e.g. IUCN Red List, Bern Convention, or Habitats Directive) might become of high priority if climate change impacts their populations. Changes in the identities of the species that should be listed as being of conservation concern, call for updates in conventions and legislation so to allow adjustments of the priorities for biodiversity conservation under climate change.

More generally, reducing impacts of climate change on European biodiversity requires a paradigm shift in conservation planning. Recommendations involve:

1. Protected-areas management plans need to take a long view and include actions for adaptation of biodiversity to climate change. Such actions should typically be conceived for periods up to 20 to 50 years, depending on the speed with which ecosystem changes are expected. Because forecasts of climate change and biodiversity change are fraught with inevitable uncertainties, adaptive management strategies are recommended.

2. Mechanisms for reclassification of existing protected areas and classification of new ones need to be revisited so to take into account changes in species distributions and consequential changes in community composition. A revision of such mechanisms is important because it may be necessary to allow changes in the position, size, or shape of some conservation areas so to match the needs of biodiversity.

3. Species dispersal is likely to be the most important mechanism of species adaptation to climate change, but habitat fragmentation and modification can hinder this process. Integrated management of the wider countryside is necessary to alleviate the overall pressure on biodiversity and facilitate movement of species between conservation areas. Possible mechanisms for implementation of off-protected-areas management include top-down regulatory prohibitions and requirements, direct incentives for conservation on private land, market creation and improvement, and information and education instruments. While the merits of each one of these strategies are a matter of debate, it is unlikely that all policy options could be applied in a standardized fashion across Europe. Nevertheless, the existence of a minimum-set of common standards, transboundary conservation policies, and shared climate-proofing policies for the wider-countryside would be advisable.

4. The European Union and several European countries have now proposed inter-sectoral adaptation plans for climate change, but in most cases policies for adaptation of biodiversity have not been detailed and specified in clear action plans. A greater focus on biodiversity in inter-sectoral plans for adaptation under climate change is necessary and, whenever possible, win-win-win strategies should be achieved, where the goals of mitigation of climate change, adaptation of society, and biodiversity are simultaneously met. The experience of a small number of European countries where specific adaptation measures for biodiversity are being taken, particularly by NGOs, together with adaptation policies elsewhere in the world, namely Australia, South Africa and the US, should be followed closely.

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