Strategies for Managing the Effects of Climate Change on Wildlife and Ecosystems

The H. John Heinz III Center For
Science, Economics and the Environment

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EXECUTIVE SUMMARY

The scientific literature contains numerous descriptions and predictions of the effects of climate change on wildlife populations and ecosystems. Recently, resource managers and planners have proposed "adaptation strategies" to help wildlife and ecosystems adjust to the effects of a changing climate. In this report, we review the scientific literature on climate change adaptation as it relates to biodiversity conservation and wildlife management. We also review a series of actual climate change adaptation plans that have been developed in the U.S.A., Canada, England, México, and South Africa. From these reviews, we identify eighteen general strategies that could be used to manage the effects of climate change on wildlife and biodiversity.

We recommend that any strategy for managing the effects of climate change on wildlife and ecosystems be deployed within an adaptive management framework, in order to enable managers to learn from previous management activities, and to respond quickly and creatively to the challenges posed by climate change.
For each of the eighteen strategies, we provide a brief summary and discussion of its advantages and disadvantages (including availability of tools or techniques for implementation, as well as relative costs). We present a decision tree to help natural resource managers select the most appropriate set of strategies for use in particular management situations.

Strategies related to land protection and management include: increasing the amount of protected areas; improving representation and redundancy within natural area networks; improving the management of existing natural areas to maximize resilience; designing new natural areas and restoration sites to maximize resilience in the face of climate change; protecting predicted movement corridors, "stepping stones," and refugia; focusing restoration and management efforts on the maintenance of ecosystem function rather than specific assemblages and components; increasing overall landscape permeability to species movements; and reducing non-climate stressors on natural areas and ecosystems.

Strategies related to direct species management include: focusing conservation resources on species most likely to become extinct; translocation of select species; captive breeding of select species; and the reduction of non-climate stressors affecting individual species.

Strategies related to monitoring and planning include: reviewing existing monitoring programs to insure that the information needed for the adaptive management of climate change effects is being collected; incorporating information on potential climate change impacts into species and land management plans; developing dynamic landscape conservation plans; and insuring that wildlife and biodiversity are included in broader adaptation plans developed by local, regional, or national governments.

Strategies in the legislative and regulatory arena include: reviewing existing laws, regulations, and policies regarding wildlife and natural resource management, to insure that these instruments provide managers with the flexibility needed to address effects of climate change; and proposing new legislation and regulations as needed to give managers additional tools and approaches to facilitate responses to climate change.

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CHAPTER 1

Introduction

Global climate change is already having significant effects on wildlife populations around the world (Schneider and Root 2002; Lovejoy and Hannah 2005; United Nations Environment Program / Convention on Migratory Species 2006). There is a substantial body of scientific literature that describes these effects, some of which include:

- Shifts in species distributions, often along altitudinal or elevational gradients;
- Changes in the timing of life history events, or phenology, for particular species;
- Decoupling of coevolved interactions, such as plant-pollinator relationships;
- Reductions in population size (especially for boreal or montane species);
- Extinction or extirpation of range-restricted or isolated species and populations;
- Loss of habitat due to sea level rise, increased fire frequency, bark beetle outbreaks, altered weather patterns, glacial recession, and direct warming of habitats (such as mountain streams);
- Increased spread of wildlife diseases, parasites, and zoonoses (including Lyme borreliosis and plague); and
- Increased spread of invasive or non-native species, including plants, animals, and pathogens

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Reviews of this literature have been provided by Gitay, Suárez and Watson (2002), Hannah et al. (2002a, 2002b), Walther et al. (2002), Stenseth et al. (2002), Parmesan and Yohe (2003), Root et al. (2003), Hannah and Lovejoy (2003), Inkley et al. (2004), Thomas et al. (2004), contributors in Lovejoy and Hannah (2005), Parmesan (2006), and Fischlin et al. (2007).

While further attempts to describe, understand and predict the effects of climate change on particular wildlife species are very important, there is also considerable interest on the part of wildlife managers and conservation practitioners in identifying strategies that could be used to assist wildlife species and natural communities in the process of adapting to the effects of climate change (Hannah et al. 2002a; Inkley et al. 2004; Da Fonseca, Sechrest, and Oglethorpe 2005; Fischlin et al. 2007).

What is "Climate Change Adaptation?"

For biologists, the word "adaptation" has been used for almost 200 years to describe the evolutionary process by which populations of organisms change over time in response to other organisms and their physical environment (Lamarck 1809; Mayr 1982). In the context of climate change planning, however, the term "adaptation" generally refers to human activities that are intended to minimize the adverse effects of climate change on human infrastructure and sensitive aspects of the natural environment (The Heinz Center 2007).

With respect to species and natural communities, the two uses of the word "adaptation" are closely related: past climate variation has clearly been one of the major drivers of the process of adaptation in evolutionary time, and it can be expected that more rapid climate shifts, as predicted under a variety of future climate change scenarios, will likewise drive significant evolutionary changes in plant and animal species (Kilpatrick 2006). As with past climatic shifts, some species will adapt and thrive under altered climate regimes, while other species will decline and may even become extinct (Hannah et al. 2005). Many species will be able to adapt to climate change in the absence of human intervention, either by changing their location in space (shifts in distribution), by changing while remaining in place (shifts in physiology and phenology), or by changing over time (evolutionary changes, especially for species with shorter generation times). For species that are unable to adapt in the evolutionary sense to the effects of climate change, certain human activities—"adaptation" measures under the second definition—may be able to prevent or ameliorate adverse impacts.

Purpose and Scope of this Document

The intent of this document is to provide a "snapshot" of the rapidly-evolving science and policy dialogue on the subject of wildlife management and biodiversity conservation under altered climate regimes. We acknowledge that this field is changing rapidly, and that new approaches will likely be developed in the near future. At the same time, we feel it is important to synthesize the existing literature and compile some basic information on the rather large set of strategies that have already been proposed. We hope that this information will help to provide a foundation for further discussions and also serve as a resource document for climate scientists, wildlife planners and other conservation practitioners who are actively investigating strategies and activities to counteract the effects of climate change.

U. S. Fish and Wildlife Service

This document describes eighteen possible "adaptation strategies" that have been proposed in the existing scientific literature and a variety of public policy documents. These strategies have been identified by a variety of authors as general methods or approaches by which natural resource managers can begin to directly address the ecosystem alterations that are predicted to occur as a result of global climate change.

The scientific literature also provides information that can be used to critique each of these approaches. In the numbered sections that follow, this information is used to review each strategy, identifying situations where each strategy may be most appropriate, as well as identifying practical and theoretical issues that may enhance or confound the adoption of these strategies. Each strategy has distinct strengths and weakenesses, and may be more or less appropriate for particular management contexts.

Although we have attempted to be reasonably comprehensive in developing this synopsis, there will undoubtedly be additional strategies and approaches that wildlife and natural resource managers will use in adapting to specific situations and challenges. This review will hopefully stimulate further thinking on the part of the management and scientific community, to develop additional realistic, workable strategies that will help wildlife species and habitats adapt to the effects of climate change.

The strategies included in this report are broad and general, such as might be adopted by management agencies operating at a national or subnational level. Much of the work that will be done to actually facilitate the adaptation of wildlife populations to climate change effects will necessarily be done at a very fine scale, on the level of individual nature reserves, parks, and small watersheds (Hughes et al. 2003; Singh 2003; Opdam and Wascher 2004). Tools for facilitating this fine-scale work are currently being tested, including statistical downscaling of climate predictions (Easterling 1999), and fine-scale modeling of climate impacts on wildlife distributions and vegetation types (Caroll 2005; The Heinz Center 2007).

The next section of this report briefly reviews a spectrum of climate change adaptation documents, including many that were treated by The Heinz Center (2007) in an earlier report on climate change adaptation planning. In this review, we have abstracted individual recommendations from these documents that are particularly appropriate for the management of wildlife species and habitats.

The third section of this report discusses the importance of adaptive management approaches for managing wildlife and ecosystems under altered climate regimes. We recommend that the various strategies for species or ecosystem management discussed in this report be deployed within an adaptive management context.

The fourth section of this report describes a decision-tree tool for selecting the most appropriate strategies for particular management scenarios.

The fifth through eighth sections of the report categorize these proposed strategies according to the classification of conservation actions developed by the International Union for the Conservation of Nature and the Conservation Measures Partnership (IUCN – CMP 2006b). For each strategy, there is a discussion of benefits and drawbacks, based on information from the scientific literature.

The final section of the report provides a discussion of the strategies, and some overall conclusions.

CHAPTER 2

Published Wildlife and Biodiversity Adaptation Strategies

This review draws on adaptation strategies for wildlife and climate change that have been proposed in the scientific literature and in various policy documents that have been developed by government agencies and non-profit organizations. Several of these policy documents were included in an earlier review by The Heinz Center (2007). Specific policy documents that were examined for this review include:

- Fischlin et al. (2007): *Ecosystems, their properties, goods, and services. Climate Change 2007: Impacts, Adaptation and Vulnerability. Chapter 4 in Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*
- Julius and West (2007): *Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources*
- Inkley et al. (2004): *Global Climate Change and Wildlife in North America*
- Wildlife Management Institute (2008): *Season's End: Global Warming's Threat to Hunting and Fishing*
- The Sheltair Group (2003): *Climate Change Impacts and Adaptation Strategies for Urban Systems in Greater Vancouver* [produced under contract to Natural Resources Canada]
- Intersecretarial Commision on Climate Change (2007): *National Climate Change Strategy: México*
- Mitchell et al. (2007): *England Biodiversity Strategy – Towards adaptation to climate change*
- Mukheibir and Ziervogel (2006): *Framework for Adaptation to Climate Change in the City of Cape Town* [South Africa]
- United Nations Environment Program / Convention on Migratory Species (2006): *Migratory Species and Climate Change: Impacts of a Changing Environment on Wild Animals*
- Hansen, Biringer, and Hoffman (2003): *Buying Time: A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems* [produced by the World Wildlife Fund Climate Change Program]

Each of these documents lists a broad spectrum of potential adaptation activities, many of which involve multiple sectors of society. In the section that follows, we have attempted to abstract those activities from these documents that are most relevant to the direct management of wildlife species and their habitats. In general, these are the types of activities that are most likely to be implemented by wildlife management agencies, rather than by other governmental agencies and decision-making bodies (such as transportation departments, public works departments, and so forth).

1.) Fischlin et al. (2007) touch briefly on the subject of adaptation strategies in Chapter 4, "Ecosystems, their properties, goods and services" of the Intergovernmental Panel on Climate Change (IPCC) document "Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)." A number of specific strategies are mentioned, including:

- Actions to reduce the impacts of other threats, such as habitat fragmentation or destruction, pollution, overexploitation, eutrophication, desertification, acidification, and the introduction of alien species
- Expansion of reserve systems
- Designing reserve systems with some consideration of long-term shifts in plant and animal distributions, natural disturbance regimes, and the overall integrity of protected species and ecosystems
- Increase agricultural productivity to reduce pressures on natural ecosystems
- Focus management on broader landscapes outside protected areas
- Coordinate species migration strategies over larger regions and across national borders
- Controlled burning and other techniques to reduce fuel loads and the potential for catastrophic wildlfires
- Captive breeding for reintroduction and translocation
- Restoration of habitats currently under serious threat, or creation of new habitats in areas where natural colonization is unlikely to occur
- Enhance or replace diminished or lost ecosystem services (for example, manual seed dispersal or reintroducing pollinators)

2.) A document entitled "Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources" has been made available by the U. S. Climate Change Science Program (Julius and West 2007). This document describes seven general adaptation strategies:

- Protect Key Ecosystem Features–key ecosystem features (e.g., structural habitat, keystone species, corridors, processes) upon which biodiversity (and hence resilience) depend are strategically targeted for special protections
- Reduce Anthropogenic Stresses – reduce or eliminate all direct (non-climate) anthropogenic stresses that can be managed locally, in order to preserve or enhance the resilience of ecosystems to regional, uncontrollable climate stresses
- Refugia – use physical environments that are less affected by climate change than other areas (e.g., due to local currents, geographic location) as a "refuge" from climate change for organisms

- Relocation – use human-facilitated transplantation of organisms from one location to another in order to bypass a barrier (e.g., an urban area)
- Replication – protect multiple replicates of a habitat type (e.g., multiple fore reef areas throughout the reef system) as a "bet hedging" strategy against loss of the habitat type due to a localized disaster
- Representation – ensure that both (1) the full breadth of habitat types is protected (e.g., fringing reef, fore reef, back reef, patch reef) and (2) the full breadth of species diversity is included within sites; both concepts relate to maximizing overall biodiversity of the larger system
- Restoration – manipulate the physical and biological environment in order to restore a desired ecological state or set of ecological processes

3.) The Wildlife Society (Inkley et al. 2004) included a list of recommended actions at the end of a review document that summarizes information about potential effects of global climate change on wildlife in North America. These actions include:

- Recognize global climate change as a factor in wildlife conservation
- Manage for diverse conditions
- Do not rely solely on historical weather and species data for future projections without taking into account climate change
- Expect surprises, including extreme events
- Reduce non-climate stressors on ecosystems
- Maintain healthy, connected, genetically diverse populations
- Translocate individuals
- Protect coastal wetlands and accomodate sea level rise
- Reduce the risk of catastrophic fires
- Reduce likelihood of catastrophic events affecting populations
- Prevent and control invasive species
- Adjust yield and harvest models
- Account for known climatic oscillations
- Conduct medium- and long-range planning
- Select and manage conservation areas appropriately
- Ensure ecosystem processes
- Look for new opportunities
- Employ monitoring and adaptive management

4.) The Wildlife Management Institute (2008) released a report entited "Season's End: Global Warming's Effect on Hunting and Fishing." The report describes potential effects of climate change on fish, wildlife, and big game species, and concludes with a list of potential adaptation actions and strategies:

- Protect central habitat areas for cold-water fish
- Reconnect high quality habitat areas for cold-water fish
- Restore entire watersheds, not just individual streams and rivers
- Employ adaptive management techniques for waterfowl
- Restore wetlands as a natural form of flood control
- Reduce stresses on ecosystems

• Protect coastal wetlands and mitigate sea level rise
• Ensure that global climate change is incorporated into land use plans and ensure that planning efforts include steps to minimize the effects of climate change on ecological communities.
• Maintain or enhance early successional vegetation and ensure connectivity between summer and winter ranges for big game species
• Initiate monitoring programs to collect and evaluate data on biotic community responses to global warming
• Protect and restore key winter and/or summer range for mule deer and elk.
• Include wildlife in national responses to climate change.


Photo by Gene Nieminen/USFWS

5.) Natural Resources Canada has released a series of volumes prepared by The Sheltair Group (2003) entitled "Climate Change Impacts and Adaptation Strategies for Urban Systems in Greater Vancouver." Volumes 1 and 2 in this series ("Preliminary Assessment" and "Influence Diagrams of Potential Climate Change Impacts and Illustrative Adaptation Strategies by Urban System") list the following adaptation strategies to deal with specific natural resource management challenges associated with climate change:
• Plant riparian vegetation, fish for a diversity of species, revise fish allocations accordingly, green roofs, vegetation planting, increased use of swales, use of stormwater detention ponds, use of naturalized stream corridors (to help address issues associated with salmon mortality, diversity, and abundance).
• Develop connected greenways strategy to assist in natural adaptation, ecosystem monitoring (to help address issues associated with increased risk of ecosystem breakdown).
• Increase levels of dykes, create artificial wetlands (to address loss of fish habitat)
• Creation of replacement waterfowl habitat (to address loss of waterfowl habitat)

6.) México's National Strategy on Climate Change (Intersecretarial Commission on Climate Change 2007), contains several lists of national adaptation requirements and priorities, which include the following recommendations relevant to wildlife species and habitats:
• Preserve and strengthen natural buffering functions within watersheds.
• Review and strengthen the implementation of natural resource management instruments such as seasonal bans, marine and coastal Protected Areas and pay-

ment for environmental (hydrological) services, so as to adapt them to changing climatic conditions.
- Establish biological corridors between Protected Areas, and evaluate the need to adjust the current boundaries of these and of Priority Regions for Conservation, to improve the adaptive capacities of ecosystems and species.

7.) Mitchell et al. (2007) in the "England Biodiversity Strategy – Towards adaptation to climate change" include the following specific approaches for species and biodiversity adaptation:
- Direct management to reduce impacts of climate change
- Promote dispersal of species
- Increase available habitat
- Promote conditions for ecosystem functioning
- Optimise [other societal] sectoral responses to climate change for biodiversity
- Continue to reduce pressures not linked to climate change

8.) The City of Cape Town, South Africa, has developed a framework for climate change adaptation (Mukheibir and Ziervogel 2006). Biodiversity is identified in this framework as one of the key sectors for adaptation planning. Specific adaptation activities described in this framework include:
- Prioritising alien plant management and associated fire management for the current and future health of indigenous terrestrial ecosystems.
- Monitoring indicator species and populations that will enable improved understanding of how species respond to climate variability and change, and identifying how species are impacted.

Photo by Steve Matsuoka/USFWS

- Assessing current protected areas in terms of their potential expansion where possible, as well as reducing other human-induced stresses on ecosystems.
- Increasing public sector involvement, including supporting commercial land managers in reducing impacts.

9.) The United Nations Environment Program / Convention on Migratory Species has produced a report entitled "Migratory Species and Climate Change: Impacts of a Changing Environment on Wild Animals." In addition to describing effects, this report also includes descriptions of several concrete adaptation strategies for management of migratory species:

- Reduce other pressures on biodiversity, such as habitat conversion, overharvesting, and introduction of invasive alien species;
- Protect, restore, and maintain ecosystem structure and function in order to maximize local species diversity and enhance ecosystem resilience;
- Manage biodiversity not just on reserves but outside reserves as well, to ensure species dispersal across a habitat matrix that may not always be favourable and that may cross political boundaries;
- Provide information to managers in a timely manner about likely trends in climate, and a deeper understanding of species adaptations to the present climate; and
- Develop models of plant and animal migration that take into account current patterns of land cover/land use type, for predicting pathways of climate-induced species dispersal across habitats fragmented and/or degraded by human actions.

10.) Hansen, Biringer, and Hoffman (2003) outline three broad climate change adaptation strategies and discuss their applicability to specific ecosystem types, including grasslands, forests, alpine and montane, arctic, temperate marine, tropical marine, and freshwater ecosystems. These authors' three broad strategies include:

- Protect adequate and appropriate space;
- Limit all non-climate stresses; and
- Use adaptive management and strategy testing.

Moving Towards Consensus

Comparison of these ten lists clearly demonstrates that no one of these sets of strategies is complete by itself. To enhance future discussions on wildlife management and climate adaptation, we have attempted to organize these approaches into an integrated framework. The framework is based, in part, on the taxonomy of natural resource management actions that has recently been developed by the International Union for the Conservation of Nature and the Conservation Measures Partnership (IUCN – CMP 2006b). Unfortunately the IUCN - CMP framework does not include a number of significant activities that are essential for natural resource management (including directed research, monitoring, and planning). We have therefore included an additional section in this review that includes specific monitoring and planning activities that have been proposed as part of wildlife adaptation strategies.

CHAPTER 3

The Importance of Adaptive Management

Adaptive management approaches are specifically mentioned in several of the climate adaptation documents cited above (e.g. Hansen, Biringer, and Hoffman 2003; Inkley et al. 2004; Wildlife Management Institute 2008). Such approaches allow wildlife managers to learn from the results of their current management activities, by using monitoring programs to collect data on project effectiveness that can then be used to refine and adjust future management prescriptions (Walters 1986; Margoluis and Salafsky 1998; Williams, Szaro, and Shapiro 2007). These types of adjustments and refinements will undoubtedly be necessary as managers attempt to respond to the effects of climate change on wildlife and ecosystems.

In addition to providing information on program effectiveness, monitoring programs can also be used to track the effects of climate change on wildlife and ecosystems, allowing managers to target their activities to meet specific management challenges (Inkley et al. 2004). Although modeling studies can offer projections of the potential effects of climate change on wildlife and ecosystems, these projections are often at coarse scales and have high levels of uncertainty associated with them. By comparison, monitoring programs can be designed to track the actual effects of climate change and the effectiveness of specific management responses. Both modeling and monitoring information are potentially important for the management of climate change effects on wildlife and ecosystems, and consequently both types of studies are incorporated in standard adaptive management approaches (e.g. Walters 1986; Williams, Szaro, and Shapiro 2007).

Adaptive management approaches provide managers with a framework for adjusting their activities in response to actual changes in climate and ecosystems. Such approaches appear to be especially well suited for managing the effects of climate change on wildlife and ecosystems. Additional information about specific adaptive management techniques and approaches is available from sources such as

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Walters (1986); Margoluis and Salafsky (1998); Williams, Szaro, and Shapiro (2007). Most of these approaches employ a multi-step process:

1.) Identify actions that could achieve management objectives;

2.) Use a modeling exercise to predict the outcomes of these management actions, based on best available scientific data, and design a monitoring program to determine whether or not the management actions will achieved the desired effect;

3.) Implement the management activities and monitoring program; and

4.) Review the results of the monitoring program and update management activities accordingly.

We recommend that the individual strategies for land, water, and species management described in this document be deployed within an adaptive management framework, to allow managers to modify their management prescriptions in response to environmental changes and in response to information about the effectiveness of management activities.

CHAPTER 4

Selecting the Most Appropriate Strategies for Management

Not all of the strategies described in this document will be appropriate for every management situation. For example, strategy 6 (manage sites for function, not specific components) is not useful to managers who are interested in promoting the survival of a particular imperiled species. And strategy 11 (captive propagation) is probably going to be less useful than some of the other strategies for managers of large natural areas or national parks. To help managers and conservation practitioners make sense of the data presented in this report, we have developed a simple decision tree (Figure 1) that is based on terminology and approaches to management that are widely used by conservation practitioners (Margoluis and Salafsky 1998). This terminology is broadly consistent with the management approaches that are currently used by major conservation organizations and many wildlife management agencies in the U. S.

The Decision Tree

The decision tree first asks managers to identify a conservation target, which can be either a species, group of species, ecosystem, or fixed geographic area (such as a nature preserve or national park). For each target, we suggest that it may be valuable to conduct a modeling exercise, or review existing climate projections from other studies, to determine the types and magnitude of changes that might be expected under various climate change scenarios. Depending on the target that is selected, there may already be published or unpublished modeling studies that are already available that can provide information about likely climate effects on a species or area of interest.

Techniques for modeling the effects of climate on species and ecosystems are numerous, varied, and rapidly evolving (Hannah et al. 2002b). Sulzman et al. (1995) provide an introduction to the types of climate models that are of greatest use to wildlife and natural resource managers. Current modeling approaches generally rely on a source of climate information (either global or regional climate models) as well as a model that explicitly links climate parameters to key ecosystem or species parameters (such as dynamic and equilibrium vegetation models, species bioclimatic envelope models, or site-specific sensitivity analysis; Hannah et al. 2002b). Examples of published modeling exercises include Rutherford et al. (1999), Peterson et al. (2001), Berry et al. (2002), Midgely et al. (2002), Mohseni (2003), Carroll (2005), and Battin et al. (2007). Managers will probably want to engage the services of modeling experts who can determine the most appropriate modeling approach for particular management situations. Modeling experts may also be able to point to existing modeling studies that provide information about the effects of climate change on a particular conservation target.

Continuing with the decision tree, the results of the modeled scenarios for species or fixed areas are combined with other information and feed into additional choice points on the decision tree, which in turn lead to lists of potential strategies. In the case of multiple species and ecosystems, the modeled scenarios are used to inform the construction of dynamic landscape conservation plans (Strategy 15 below), which, in turn, can be used to drive the deployment of land conservation strategies.

Photo by Terry Tollefsbol/USFWS

It should be noted that several of the strategies are broadly applicable across targets and management scenarios, including: 8.) and 12.) reduce non-climate stressors on species and ecosystems; 13.) improving monitoring systems; 14.) and 16.) improve planning processes to better account for climate change and wildlife; and 17.) and 18.) improve regulatory processes to enhance the management of climate effects on wildlife and ecosystems. In addition, several strategies are listed multiple times in the decision tree, indicating their broad applicability to a variety of management situations. These include 7.) increase landscape permeability, 4.) manage natural areas in ways that maximize resilience to climate effects, and 1.) protect lands and waters.

What If Modeling Is Not An Option?

We fully understand and appreciate that detailed climate modeling studies are not currently available for many of the species and ecosystems that are under active or passive management. Wildlife and natural resource management agencies will probably want to commission new studies or review existing studies of possible climate effects on the specific resources under their management. However, given the cost and time required for these studies, it is likely that managers will need to start to implement climate adaptation measures before all possible studies are completed. And given the uncertainties in the existing climate models and the substantial differences that can exist between model scenarios, it is possible that even the best modeling studies may not provide definitive answers to specific management questions.

In the absence of clear results from modeling studies, managing the process of climate adaptation becomes more challenging, but is by no means impossible. In particular, several of the land conservation strategies will undoubtedly still be ben-

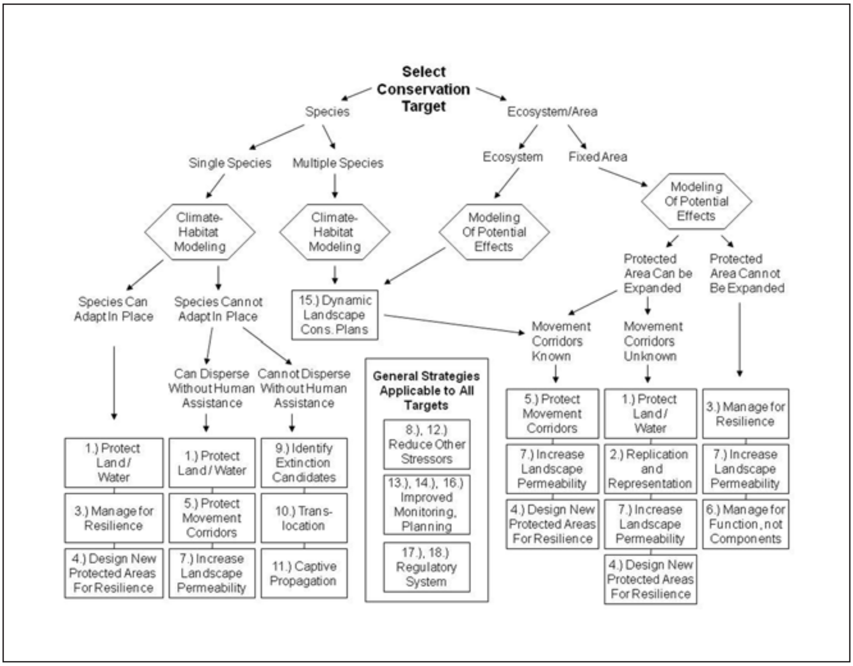

Figure 1: Decision tree for natural resource managers engaged in wildlife and biodiversity conservation. The numbers in the boxes refer to the numbered strategies that follow in this document.

eficial to a wide range of species: 1.) protect lands and waters, 2.) increase replication and representation in natural area networks, 7.) increase landscape permeability, 3.) improve natural areas management, and 4.) design new natural areas and restoration sites to maximize resilience in the face of climate change. In many cases it may also be possible to identify species at risk for extinction (Strategy 9) and reduce other stressors on species of conservation concern (Strategy 12) in the absence of detailed models of climate effects on particular species.

The Importance of Monitoring and Adaptive Management

Improvements in wildlife monitoring systems (Strategy 13) are critically important for the management of climate change, especially in situations when modeling studies are either unavailable or uninformative. Monitoring systems have the potential to provide "early warnings" of possible effects of climate change, which may give managers time to take preventive or corrective action before changes become truly irreversible. Monitoring also plays an important role in adaptive management approaches for wildlife and ecosystems (Walters 1986; Margoluis and Salafsky 1998; Williams, Szaro, and Shapiro 2007). Adaptive management approaches are increasingly important in times of uncertainty, including our current uncertainties about the magnitude and direction of the effects of climate change on individual species and ecosystems.

Many of the existing wildlife monitoring programs were not designed with the effects of climate change in mind, and will likely need to be adapted or modified in order to track these effects. Changes to monitoring programs may include:

- Use of new or improved techniques for analyzing the data being generated by existing monitoring programs.
- Additions or adjustments to existing data collection protocols, to improve the measurement of demographic or ecosystem parameters that are thought to be especially sensitive to climate change.
- Incorporation of additional data sources (which may include physical climate parameters such as rainfall and temperature, or habitat parameters such as stream flow or vegetation condition) into the analysis and interpretation of wildlife monitoring data.

A comprehensive climate change monitoring program will likely combine different types of indicators and metrics, including (but not limited to):

- Leading indicators that provide advance warning of climate change effects. These indicators may track key demographic parameters in individual wildlife species, or measures of habitat quality such as vegetative condition and changes in stream flow / stream temperature, or measures of important physical parameters such as rainfall, temperature, and snowpack.
- Status indicators that measure short-and long-term changes in wildlife populations, which may result from stressors such as climate change.
- Effectiveness measures that report and assess the results of management strategies designed to facilitate the adaptation of wildlife species and ecosystems to altered climate conditions.

CHAPTER 5

Strategies Related to Land/Water Protection and Management

This section includes two of the basic types of activities described by the International Union for the Conservation of Nature - Conservation Measures Partnership taxonomy of conservation actions: Land/water Protection; and Land/water Management (IUCN – CMP 2006b). In practice, these types of actions are often combined within a single management authority (such as a parks department, forestry department, or local land trust). The strategies here involve protectionist and/or interventionist approaches to natural resource conservation, and the focus is on the land (or water) resource.

Some of the conservation goals that could be addressed by these strategies include:

- Facilitate movements of plant and animal species in response to climate change
- Maintain ecosystem integrity and function in the face of climate change
- Maximize opportunities for "natural" (= unassisted by humans) adaptation of species and ecosystems to modified climate regimes.

1.) Increase the amount of protected areas

Description: This strategy would increase the amount of terrestrial and aquatic habitat that is protected from the suite of human activities that threaten species and ecological communities (conversion to agriculture, real estate development, resource extraction, etc.). It is specifically recommended by McNeely and Schutyser (2003) and by Mitchell et al (2007) in the document "England Biodiversity Strategy – Towards adaptation to climate change." The strategy could also be used to protect refugia or key habitats such as coastal wetlands (as per the recommendations of Inkley et al. 2004 or Julius and West 2007) or to protect corridors or "stepping stones" for wildlife dispersal (Strategy # 5 below).

a.) Pros: A suite of legal tools are available for protecting lands, streams, and rivers, and creating marine protected areas (including fee title acquisition, easements, proclamation, legislation, and condemnation). The global conservation community has demonstrated that it is adept at using these tools to protect high-priority conservation areas in a variety of ecosystem types and human societies around the world (Bruner et al. 2001).

b.) Cons: Given other significant resource needs by the world's human population, it is unlikely that society will be able to directly protect enough land to facilitate the movement of species and ecological communities. Furthermore, the world's existing protected area networks have been designed to protect static (rather than dynamic) patterns of biodiversity (Lovejoy 2005; Scott and Lemieux 2005; Lemieux and Scott 2005). The performance of these networks at conserving biodiversity in the face of climate change remains largely untested (Zacharias, Gerber, and Hyrenbach 2006).

2.) Improve representation and replication within protected area networks

Description: The representation strategy would direct protection efforts towards building a more comprehensive portfolio of protected areas (for example, protecting representative examples of all major ecosystem types within a country; Julius and West 2007). The replication strategy would direct protection efforts towards conserving multiple examples of each ecosystem type (Julius and West 2007).

a.) Pros: As described under the first strategy, a robust suite of tools is available for protecting terrestrial and aquatic areas. Both strategies may work well as part of a matrix conservation or "stepping-stone" approach to facilitate dispersal. Representation has already been employed as an explicit strategy in land protection efforts (for example, the Wisconsin Natural Areas Program **http://www.dnr.state.wi.us/ORG/land/er/sna/**) and there are tools available such as land cover maps (**http://landcover.usgs.gov/**) and geospatial data on rare species distributions (available from **http://www.natureserve.org** and affiliates) that could facilitate the broader application of both strategies.

b.) Cons: It is not clear that representation will continue to be a relevant conservation strategy over the long term, since the individual components of ecosystems will likely be shifting significantly as a result of climate change (Hannah and Hansen 2005; Carroll 2005). Both representation and replication may be most helpful if the new protected areas are designed to function as part of a "stepping-stone" or corridor approach.

3.) Manage and restore existing protected areas to maximize resilience

Description: It may be possible to offset small-scale effects of climate change at individual protected areas through direct management activities (as proposed by Mitchell et al. 2007). A number of commonly-used techniques for ecological restoration (SERI 2006) may be relevant here (Julius and West 2007). For example, riparian forest plantings could be used to shade streams and help offset warming of important cold-water fish habitats on a local scale (The Sheltair Group 2003). Dikes and levees could be used to protect individual coastal sites from

Photo by Donna Dewhurst/USFWS

increased sea levels (The Sheltair Group 2003). Setback lines for coastal development could be used to facilitate natural migration of coastal wetlands as sea level rises (Inkley et al. 2004). And prescribed fire could be used to reduce fuel loads and potential for catastrophic wildfires (Inkley et al. 2004; Fischlin et al. 2007).

a.) Pros: This type of intensive management is usually more tractable at small, well-defined sites such as parks, nature reserves, and natural areas (Kusler and Kentula 1990; National Research Council 1994; Thayer 1992). Focusing activities on protected areas also reflects the reality that it may be much more difficult to implement conservation actions at sites that are outside of conservation ownership, where private property rights and conflicting demands on land use may limit the types of activities that can actually be implemented.

: Direct management, like outright ownership, is expensive and thus is only likely to be feasible for small sites and limited areas (Fischlin et al. 2007). Focusing on protected areas neglects the overall matrix in which these areas are embedded: what happens outside protected areas undoubtedly influences what happens inside protected areas (Da Fonseca, Sechrest, and Oglethorpe 2005).

4.) Design new natural areas and restoration sites to maximize resilience

Description: The potential for climate-induced changes should be considered whenever new natural areas are proposed, extensions to existing natural areas are contemplated, or habitat restoration projects are undertaken (Lovejoy 2005). There may be ways to design these projects to favor resiliency in the face of climate change. For example, salt marsh restoration sites adjacent to steep shorelines or “hard” anthropogenic shoreline structures would likely be inundated and lost under conditions of accelerated sea level rise. In contrast, restored marsh communities adjacent to gently sloped and undeveloped shorelines may be able to regress naturally landward as sea level rises (Inkley et al. 2004; Yamalis and Young 2007). Protection of such "future habitat" areas should be a key consideration whenever new natural areas or extensions to existing natural areas are proposed (Fischlin et al. 2007).

Ecological restoration projects often use a variety of plant species, some of which may display more resiliency than others at particular sites in the face of climate change. Species mixes for restoration projects could be adjusted to include species thought to be more resilient to the predicted climate fluctuations in a particular area. Increased vigor and rate of spread of invasive plant species has also been identified as a potential problem under certain climate change scenarios (Truscott et al. 2006; Yamalis and Young 2007). Innovative management strategies will likely be needed in order to arrest the spread of these species (Inkley et al. 2004).

a.) Pros: This strategy is likely to serve as an important "filter" criterion for future protection and restoration efforts. Funders and project managers should question the wisdom of investing scarce conservation dollars in projects that are not sustainable in the face of climate change.

b.) Cons: Projects that are not sustainable over the long term may nonetheless have important short-term benefits, for example providing intermediate areas of habitat for particular species until longer-term refugia can be identified (Hannah and Hansen 2005).

5.) Protect movement corridors and "stepping stones"

Description: This strategy represents a refinement of strategies 1 and 2 and would direct protection efforts towards areas and regions that have been deemed essential for climate-induced wildlife movements (Allan, Palmer, and Poff 2005). Such areas might include movement corridors for terrestrial species (Intersecretarial Commission on Climate Change 2007), habitat islands that could serve as "stepping stones" between larger reserves, or stop-over areas for migratory waterfowl. In aquatic systems, unblocked streams and rivers can serve as movement corridors for aquatic species (Pringle 2001; Chu, Mandrak, and Minns 2005). In coastal systems, setback lines for coastal development could be used to facilitate the natural progression of coastal wetlands and other coastal ecosystems as sea level rises (Inkley et al. 2004).

a.) Pros: As described in Strategies 1 and 2 above, tools are already available for protecting terrestrial areas and riverine corridors (fee title acquisition, easements, wild & scenic river designation, etc.). Small-scale implementation projects are already underway to designate and protect movement corridors for wildlife and plant species (for example, in the Netherlands; Fischlin et al. 2007).

b.) Cons: It is difficult to predict future movements of individual species with confidence. Carroll (2005) used dynamic models linking population and habitat variables for lynx, marten, and wolf in the northeastern U. S. and southern Canada. The results of this study suggest that these three carnivore species will move in independent ways, using different portions of the same landscape as the climate changes. The significant contrasts in predicted linkage needs among these three species suggest that efforts to identify more general movement corridors for broader suites of terrestrial species will not be straightforward. A more practical consideration is that large-scale land protection efforts will undoubtedly be controversial in many parts of the U. S. and other countries with a strong private property tradition. Another significant practical concern is the tremendous cost that would be required to protect outright all possible movement corridors (Fischlin et al. 2007), even if lower-cost tools such as restrictive conservation easements are used rather than fee title acquisition. To provide just one example, protection and managing a comprehensive reserve network in one small country, the Netherlands, will require an estimated annual expenditure of ? 1 billion, of which ? 280 million will be used for new reserve areas and habitat improvements (Fischlin et al. 2007).

6.) Manage and restore ecosystem function, rather than focusing on specific components (species, community assemblages).

Description: This strategy focuses on the maintenance of ecosystem function in conservation areas, rather than maintaining specific ecosystem components such as individual species or assemblages of species (Harris et al. 2006). Instead of trying to manage sites to resemble reference conditions at a particular point in history, this strategy would have managers define key attributes of ecosystem function for particular sites and then manage the sites to maintain these attributes within acceptable parameters (Harris et al. 2006). Promotion of ecosystem function is explicitly recommended by Inkley et al. (2004), Mitchell et al. (2007), and Fischlin et al. (2007).

a.) Pros: This strategy implicitly acknowledges that ecological conditions at individual sites are likely to shift in ways that are difficult to predict and that differ from historic reference conditions (Harris et al. 2006). To date, the practice of ecological restoration has attempted to restore sites based on historic data or comparison with undisturbed reference sites (SERI 2006). Given the significant shifts that have and will occur in species distributions, it may be easier for managers to maintain a set of variables describing ecosystem function within acceptable parameters than to try to maintain a particular species composition or community type at a given site (Harris et al. 2006).

b.) Cons: Shifting the focus of management from components to functions may mean that some components that currently require intensive management will become extinct. Depending on the attributes of ecosystem function that are selected, it may be possible to maintain ecosystem function within acceptable limits with a greatly reduced complement of species, or even with non-native species.

7.) Improve the matrix—increase landscape connectivity and permeability to species movement

Description: This strategy focuses on increasing broader landscape connectivity and "permeability" to species movement (Da Fonseca, Sechrest, and Oglethorpe 2005). Rather than focus on any one species or community type, this approach would use a variety of existing management techniques to enhance the ability of the broader landscape matrix to support movements by a broad suite of animal and plant species in response to climate change. This strategy is consistent with a number of existing management approaches, such as "agri-environment schemes" [= wildlife habitat creation, restoration, or enhancement projects in agricultural settings] in the U. S. and Europe (Donald and Evans 2006; Giliomee 2006) and dam removals, fish ladders, and other techniques to restore connectivity in freshwater aquatic systems (Pringle 2001; Chu, Mandrak, and Minns 2005; Battin et al. 2007).

a.) Pros: A suite of conservation tools are already available for implementing this approach (including agri-environment schemes, dam removals, and riparian plantings). Large-scale implementation programs have been successfully demonstrated in the U. S. and Europe (for example, U. S. Department of Agriculture wildlife habitat conservation and restoration programs such as the Conservation Reserve Program, Conservation Reserve Enhancement Program, and the Wildlife Habitat Incentive Program). Modeling techniques are available to assess landscape permeability to species movement (Singleton, Gaines, and Lehmkul 2002) and predict likely paths of dispersal across the landscape matrix under particular climate change scenarios (Carroll 2005).

b.) Cons: This approach does not focus on rare species or species with narrow habitat requirements, and a pure application of this approach would likely consign some of these species to extinction. However, this is still probably the best general approach for insuring the long-term viability of "matrix" or widespread species (Donald and Evans 2006).

8.) Reduce non-climate stressors on natural areas and ecosystems

Description: This strategy seeks to reduce the effects of other, non-climate stressors on natural areas and ecosystems (Inkley et al. 2004; Lovejoy 2005; Robinson et al. 2005). Reductions in the effects of significant ecosystem stressors such as invasive species, chemical contaminants, or catastrophic wildfires could potentially provide ecosystems with additional flexibility in adapting to altered climate regimes (Lovejoy 2005). Many of these stressors are already the focus of conservation activities by wildlife biologists and other natural resource managers (IUCN-CMP 2006b).

a.) Pros: The strategy recognizes the obvious fact that ecosystems and natural areas experience multiple stressors, and that the removal of these other stressors may give individual species additional flexibility in adapting to climate change. Fischlin et al. (2007) and Robinson et al. (2005) note that this may be the only practical large-scale adaptation policy for marine systems.

b.) Cons: There are a very broad spectrum of other stressors affecting natural areas and ecosystems (IUCN-CMP 2006a) and only limited resources at present to address this broad suite of stressors. Given these circumstances, there is potential for a loss in focus and much diffuse action across a broad range of threats, rather than targeted action to address a few key threats.

CHAPTER 6

Strategies Related to Species Conservation

These strategies include actions intended to manage or restore species, where the focus of management is the individual species (IUCN-CMP 2006b).

Conservation goals that could be addressed by these strategies include:

- Prevent species from becoming extinct as a result of climate change.
- Facilitate the movement of plant and animal species in response to climate change.
- Maximize the flexibility of species to respond to climate change without human assistance.

9.) Focus conservation resources on species that might become extinct.

Description: Invest resources in the maintenance and continued survival of those species that are most likely to become extinct as a result of global climate change. This strategy is not explicitly described in the policy documents reviewed for this study, but it is implicit in efforts such as the international campaign to save polar bears and other Arctic and Antarctic species from extinction.

a.) Pros: This is an intuitive strategy for wildlife managers, following in a long tradition of conservation efforts for rare or extinction-prone species. Hoyle and James (2006) and Fischlin et al. (2007) emphasize that rare species may be especially susceptible to climate change effects, and that there may be climate thresholds above which extinction probabilities for these species increase dramatically. There are numerous reports in the primary literature of species declines and even extinctions correlated with climate change (Parmesan 2006). From a management perspective, climate change may provide opportunities for innovative approaches, such as the scheme described by Kilpatrick (2006) to accelerate the evolution of resistance to avian malaria in native Hawaiian birds.

b.) Cons: Traditional endangered species management has usually relied on in situ conservation approaches. It is hard to see how these approaches will continue to be applicable in a world in which climate change is dynamically altering both ecosystem components and processes (Lovejoy 2005). Despite our best efforts, rare or endemic species will likely become extinct as a result of climate change. Koprowski, Alanen, and Lynch (2005) review the case of the highly endemic Mount Graham red squirrel, a montane species whose habitat has been heavily damaged by increased insect outbreaks. These authors note that climate change will only exacerbate the squirrel's plight and conclude that "conservation options are limited in such situations." Even when feasible, traditional endangered species management can be extraordinarily costly: the total cost for recovery of the whooping crane is projected to be $31,817,000 (US) through 2010 and nearly $125 million (US) through 2035 (Canadian Wildlife Service and U. S. Fish and Wildlife Service 2005). Unless significant new sources of funding are developed, resources will simply not be available for comprehensive conservation actions targeting every species imperiled by climate change.

Photo by Gary M. Stolz/USFWS

10.) Translocation or assisted dispersal of species

Description: Move animals, plants, and other organisms from sites that are becoming unsuitable due to global climate change to other sites where conditions are thought to be more favorable for their continued existence. This strategy is explicitly recommend as part of the U. S. Climate Change Science Program's "Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources" (Julius and West 2007) and the "England Biodiversity Strategy – Towards adaptation to climate change" (Mitchell et al. 2007).

a.) Pros: Translocation techniques are available for many vertebrate species (for examples, see Bright and Morris 1994; Dublin and Niskanen 2003; Bothma 2002; Butler, Malone, and Clemann 2005; Morkel and Kennedy-Benson 2007; Heaton et al. 2008), and some invertebrates (Schweitzer 1994; Tolson et al. 1999).

b.) Cons: With any translocation attempt, there is a risk of failure and even extinction (Maxfield, Wanger, and Simmons 2003; Groombridge et al. 2004). For many species, it will also be difficult to predict optimal locations for assisted dispersal. This is due to significant gaps in our knowledge regarding the biology of many rare species, as well as the challenges associated with forecasting optimal future habitats. Different models may give different results: for example, Carroll (2005) found significant differences in dispersal and habitat suitability predictions made by static versus dynamic habitat models for wolf, lynx, and marten populations in the northeastern United States and southeastern Canada. Similar differences in predicted distributions were found in comparisons of habitat versus climate-habitat models for three agro-steppe bird species in Spain by Suarez-Seone, Osborne, and Rosema (2004). Furthermore, there is even evidence from modeling studies to suggest that different populations within a single species may respond in different ways to climate change (Tolimieri and Levin 2004).

11.) Establish captive populations of species that would otherwise go extinct

Description: This approach would initiate captive maintenance programs for species that would otherwise become extinct due to climate change. Such an approach would necessarily serve as the strategy of last resort for species otherwise facing extinction (Hansen, Biringer, and Hoffman 2003).

a.) Pros: Rearing techniques and approaches to captive husbandry and propagation are have been described for many animals (Kleiman et al. 1997) and plants (Guerrant, Hayvens, and Maunder 2004), and our society has a whole industry (zoos, botanic gardens, and aquaria) that is already devoted to this approach.

b.) Cons: Given the resources required for captive maintenance programs (Kleiman 1989), this is unlikely to be a viable long-term strategy for anything more than a handful of species. Past practices suggest that these will probably be large, charismatic megafauna, such as large mammals and birds. There is also the possibility that ecosystem conditions may be so altered that reintroduction of species back into the wild will be unfeasible, consigning these species to become "living fossils."

12.) Reduce pressures on species from sources other than climate change

Description: This strategy seeks to remove other, non-climate stressors from wildlife species, to give wildlife species the maximum flexibility possible to evolve responses to climate change (Inkley et al. 2004; Lovejoy 2005; Robinson et al. 2005). It is specifically recommended as part of the U. S. Climate Change Science Program's "Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources" and "England Biodiversity Strategy – Towards adaptation to climate change."

a.) Pros: The strategy recognizes the obvious fact that species experience multiple stressors, and that the removal of these other stressors may give individual species additional flexibility in adapting to climate change. Fischlin et al. (2007) and Robinson et al. (2005) note that this may be the only practical large-scale adaptation policy for marine systems.

b.) Cons: There are a very broad spectrum of other stressors affecting species (IUCN-CMP 2006a) and only limited resources at present to address this broad suite of stressors. Given these circumstances, there is potential for a loss in focus and much diffuse action across a broad range of threats, rather than targeted action to address a few key threats.

Strategies Related to Monitoring and Planning

These strategies are related to the monitoring of wildlife populations, and the development of wildlife and natural resource management plans, as well as general societal climate change adaptation plans.

Conservation goals that would be addressed by these strategies include:

- Provide information on wildlife populations and ecosystem processes to relevant managers and governmental bodies, to enable informed decision-making and better adaptive management of natural resources.
- Ensure that climate impacts are considered for species and ecosystems that are already under active management.
- Ensure that the needs of wildlife and ecosystems are considered as part of the general societal response to climate change.

13.) Evaluate existing monitoring programs for wildlife and key ecosystem components and determine a.) how these programs will need to be modified to provide management-relevant information on the effects of climate change and b.) what new monitoring systems will need to be established in order to address gaps in our knowledge of climate effects.

Description: Monitoring systems provide information that managers can use to adjust or modify their activities through the process of adaptive management (Walters 1986; Margoluis and Salafsky 1998; Williams, Szaro, and Shapiro 2007). Such information is particularly relevant in times of rapid global change (Adger et al. 2003; Fischlin et al. 2007). This approach would evaluate the current state of the systems that collect, analyze, and interpret environmental information. Based on analyses conducted by The Heinz Center (2002; 2006), we already know that many of the systems for collecting this information are incomplete. This analysis would focus specifically on those systems that are most important for monitoring possible effects of climate change.

a.) Pros: Significant data gaps exist both within and among the current environmental monitoring systems, including many of the systems that track and monitor wildlife populations (Heinz Center 2002; 2006). Society clearly needs a better system for monitoring and reporting on ecosystem condition, especially in the face of significant climate-induced changes. Such systems are also needed in order to adaptively manage the effects of climate change on species and ecosystems, especially in cases where detailed modeling studies are unavailable, unlikely to be available, or unclear in their projections regarding the magnitude and direction of climate effects.

b.) Cons: The costs to adapt existing monitoring systems and develop new monitoring systems are likely to be high. In many cases this will probably require new legislation and regulations, and possibly new tools and approaches to monitoring. It will also require better integration and coordination across existing monitoring programs (The Heinz Center 2006).

14.) Incorporate predicted climate change impacts into species and land management plans, programs and activities

Photo by Robert Karges II/USFWS

Description: Information about actual and potential climate change impacts can be of considerable benefit to land and natural resource managers in making decisions and taking actions. This strategy, derived from México's National Strategy on Climate Change, suggests that information and predictions regarding climate change impacts should be incorporated into a broad spectrum of natural resource management processes and activities. Many existing natural resource plans already contain provisions for updates and revisions, which could provide a mechanism for incorporating information about climate change effects and adaptation strategies.

a.) Pros: Climate change is not addressed in many existing natural resource plan documents (Hannah, Midgley, and Millar 2002) including many of the endangered species recovery plans and State Wildlife Action Plans in the United States (Mawdsley, unpublished data). This strategy would use existing natural resource planning mechanisms to inform decision-making on a broad spectrum of natural resource management topics.

b.) Cons: The problems with this approach are mainly practical at present: there is a definite cost associated with revisiting and revising management plans; in practice, many resource management plans are updated infrequently (if ever). Also, detailed predictions of potential climate change effects are currently only available for a small subset of species and areas (The Heinz Center 2007).

15.) Develop dynamic landscape conservation plans

Description: As described by Hannah and Hansen (2005), dynamic landscape conservation plans include information on fixed and dynamic spatial elements, along with management guidelines for target species, genetic resources, and ecosystems within the planning areas. Fixed spatial elements include protected areas where the land use is fully natural. Dynamic spatial elements include all other areas within the landscape matrix, where land use may change over time. The plan includes a desired future condition for each element, based on predicted shifts in distribution of species and other ecosystem components, as well as any intermediate steps that may be necessary to transition between current and future condition. The management guidelines suggest mechanisms and tools for management (such as land acquisition, riparian plantings, or other wildlife-friendly farming practices) and specific government agencies responsible for implementation.

a.) Pros: Unlike more traditional resource management plans, dynamic landscape conservation plans directly address a suite of climate change needs on a broader landscape (Hannah and Hansen 2005). That said, the actual planning activities required to develop these plans are likely to be compatible with other local or regional-scale planning projects such as State Wildlife Action Plans or watershed management plans.

b.) Cons: Planning efforts can be resource-intensive and natural resource management plans are often developed but not implemented. According to Hannah and Hansen (2005), dynamic landscape plans may recommend that certain spatial elements (= areas of land or water) will need to be converted from human uses to "natural" management, in order to facilitate species movements. Such recommendations are likely to prove controversial, especially in settings where the condemnation of private property or the translocation of human populations would be required.

16.) Ensure that wildlife and biodiversity needs are considered as part of the broader societal adaptation process.

Description: Planning is currently underway in a number of communities around the globe to address the effects of climate change and develop strategies to help human societies adjust or adapt to these effects. Many of these strategies focus on human health and infrastructure needs (The Heinz Center 2007). Given the enormous stresses that will undoubtedly be placed on the fabric of human society, this focus is understandable. What is less understandable is the lack of attention in many of these strategies to wildlife and natural ecosystems, which are often discussed briefly or not at all (The Heinz Center 2007). Given the importance of wildlife for human recreation and enjoyment, and the value of "ecosystem services” such as pollination and water filtration, it is clear that wildlife and ecosystems should be addressed in climate change adaptation plans. This strategy is explicitly recommended as part of the “England Biodiversity Strategy – Towards adaptation to climate change” (Mitchell et al. 2007).

a.) Pros: Modern wildlife professionals and natural resource managers are acutely aware that their management activities take place within a broader societal context, and that the broader society must be supportive in order for management to succeed. Managers can even take proactive steps to engage local and regional government entities in adaptation planning, thereby ensuring that the needs of wildlife and natural resources are included at the start of these discussions, rather than being added on as an afterthought.

b.) Cons: If global climate change provokes significant crises in human society, there may be a tendency to view the needs of wildlife and the needs of humans as conflicting, rather than complementary. In such “either/or” comparisons, the needs of human society will likely trump the needs of wildlife and biodiversity.

CHAPTER 8

Strategies Related to Law and Policy

These strategies include efforts to reform or enhance public policies regarding wildlife management and biodiversity conservation. Tools may include legislation, regulations, policies, private-sector standards and codes, as well as compliance and enforcement actions (IUCN-CMP 2006b).

Conservation goals that would be addressed by these strategies include:

- Ensure that existing laws, regulations, and policies will provide managers with the flexibility needed to address the effects of climate change on wildlife and ecosystems.

17.) Review existing laws, regulations, and policies regarding wildlife and natural resource management, to insure that these instruments provide managers with maximum flexibility in addressing the effects of climate change.

Description: This strategy would initiate a review of all applicable laws, regulations, and other public policies related to wildlife management, natural resource management, and biodiversity conservation. Many of these laws and regulations are decades old, and most were developed before climate change became a significant concern. This strategy is explicitly recommended as part of México's National Strategy on Climate Change (Intersecretarial Commision on Climate Change 2007), but would certainly be relevant to a broad spectrum of national, subnational, and international laws, regulations, agreements, and policies.

Pros: Existing wildlife and biodiversity laws and regulations were designed for the conservation of "static" biodiversity (Lovejoy 2005; Scott and Lemieux 2005; Lemieux and Scott 2005). Clearly many of these regulatory tools and approaches will need to be revisited in the light of the significant changes that are anticipated.

Cons: Actually addressing the deficiencies that are identified through these reviews may be difficult without significant political will to overcome institutional inertia. There will likely be significant concern expressed from all sides about any sweeping revisions to existing laws and regulations – "better the devil you know than the one you don't."

Photo by Dave Menke/USFWS

18.) Propose new legislation and regulations as needed to provide managers with the flexibility, tools and approaches needed to effectively address climate change impacts.

Description: New legislative tools or regulations may be necessary to address specific climate change impacts. In the absence of the regulatory review recommended in Strategy 16, it is difficult to envision what new legislation or regulation might look like. This strategy is implicit in México's National Strategy on Climate Change ("Review <u>and strengthen</u> the implementation of natural resource management instruments…") and would clearly be relevant for policy-setting at national, subnational, and international levels.

Pros: Given that existing wildlife and biodiversity legislation is often decades old, new legislative or regulatory approaches may very well be needed to address specific effects or challenges associated with climate change.

Cons: Many of the predicted adverse climate impacts could arguably be handled within existing regulatory programs (Lovejoy 2005), provided that the program managers are given the flexibility needed to directly address climate threats.

CHAPTER 9

Discussion and Conclusions

To those who are already familiar with the practice of wildlife management and biodiversity conservation, many of the strategies reviewed in this document will undoubtedly look like "business as usual." Techniques such as land protection, habitat restoration, species translocation, and captive propagation have long been considered key components of the wildlife manager's toolbox (IUCN-CMP 2006b). Even many of the adaptation strategies that are proposing new activities (such as reviewing monitoring programs or laws and regulations) involve the review of existing strategies and approaches, rather than the development of new techniques.

On the one hand, this is reassuring. The literature reviewed here indicates that we as a society (and the community of wildlife and natural resource managers in particular) already possess many of the tools that will be necessary to help wildlife and ecosystems adapt to climate change. "Business as usual" may not be so bad after all!

Yet in a very real sense "business as usual" is no longer an option in a world where climate change has the potential to irrevocably alter biodiversity and ecosystems in both major and minor ways. Managers may still be using many of the same tools, but they will increasingly need to view the ways in which they use these tools through the lens of climate-induced changes to species and ecosystems. Dynamic landscape conservation plans (Hannah and Hansen 2005) represent just one approach for combining existing management approaches with the most up-to-date information regarding climate change effects. Other new and innovative tools such as statistical downscaling (Easterling 1999) and small-scale climate-habitat models (Carroll 2005) will undoubtedly become increasingly important for managers in the future (The Heinz Center 2007)

Some of these strategies will likely prove to be more broadly applicable than others. For example, targeted land protection or efforts to increase landscape permeability will probably be of direct benefit to a broad range of species. Other strategies, such as species translocation and captive propagation, will benefit only a handful of species and may ultimately be unsuccessful at preventing extinction, despite our best efforts. The literature discussing these approaches clearly indicates that no one strategy is optimal; each has particular circumstances in which it may be more or less appropriate.

There is also plenty of room for improvement and the development of additional strategies and approaches for facilitating climate change adaptation by wildlife and ecosystems. The documents reviewed here show how hard it is even for leading scientists to shift their thinking about biodiversity from static to dynamic worldviews (Lovejoy 2005). To give just one example, Julius and West (2007) list the identification and protection of "refugia" (areas where climate change effects are less severe or absent) as one of seven key adaptation strategies for ecosystems. However, such "refugia" will be increasingly difficult to identify in a world that is increasingly altered by climate change. It is potentially risky to assume that we can even count on the continued existence of "refugia" in the decades and centuries to come. The scientific and natural resource management communities have only recently begun to think about the management of climate change effects in a systematic manner. Our hope in preparing this document is that it will help to stimulate further thought and innovation regarding opportunities and approaches for climate change adaptation.

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