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Review

A Review of Climate-Change Adaptation Strategies for Wildlife Management and Biodiversity Conservation

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Abstract: *The scientific literature contains numerous descriptions of observed and potential effects of global climate change on species and ecosystems. In response to anticipated effects of climate change, conservation organizations and government agencies are developing "adaptation strategies" to facilitate the adjustment of human society and ecological systems to altered climate regimes. We reviewed the literature and climate-change adaptation plans that have been developed in United States, Canada, England, México, and South Africa and found 16 general adaptation strategies that relate directly to the conservation of biological diversity. These strategies can be grouped into four broad categories: land and water protection and management; direct species management; monitoring and planning; and law and policy. Tools for implementing these strategies are similar or identical to those already in use by conservationists worldwide (land and water conservation, ecological restoration, agrienvironment schemes, species translocation, captive propagation, monitoring, natural resource planning, and legislation/regulation). Although our review indicates natural resource managers already have many tools that can be used to address climate-change effects, managers will likely need to apply these tools in novel and innovative ways to meet the unprecedented challenges posed by climate change.*

Keywords: adaptation, biodiversity, climate change, conservation, management, restoration, wildlife

Una Revisión de las Estrategias de Adaptación al Cambio Climático para el Manejo de Vida Silvestre y Conservación de la Biodiversidad

Resumen: *La literatura científica contiene numerosas descripciones de efectos observados y potenciales del cambio climático sobre las especies y ecosistemas. En respuesta a los efectos anticipados del cambio climático, las organizaciones de conservación y agencias de gobierno están desarrollando "estrategias de adaptación" para facilitar el ajuste de la sociedad humana y los sistemas ecológicos a régimenes climáticos alterados. Revisamos la literatura y los planes de adaptación al cambio climático que se han desarrollado en Estados Unidos, Canadá, Inglaterra, México y Sudáfrica y encontramos 16 estrategias generales de adaptación que se relacionan directamente con la conservación de la biodiversidad. Estas estrategias se pueden agrupar en cuatro grandes categorías: protección y manejo de agua y tierras; manejo directo de especies; monitoreo y planificación; legislación y política. Las herramientas para la implementación de estas estrategias son similares o idénticas a las utilizadas actualmente por conservacionistas en todo el mundo (conservación de tierras y agua, restauración ecológica, esquemas agroambientales, translocación de especies, propagación en cautiverio, monitoreo, planificación de recursos naturales y legislación/regulación). Aunque nuestra revisión indica que los manejadores de recursos ya cuentan con muchas herramientas que pueden ser utilizadas para atender los efectos del cambio climático, las tendrán que aplicar de manera novedosa e innovadora para enfrentar los retos sin precedentes que plantea el cambio climático.*

Palabras Clave: adaptación, biodiversidad, cambio climático, conservación, manejo, restauración, vida silvestre

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Introduction

Global climate change is already having significant effects on species and ecosystems (Gitay et al. 2002; Hannah et al. 2002*a*, 2002*b*; Schneider & Root 2002; Stenseth et al. 2002; Walther et al. 2002; Hannah & Lovejoy 2003; Parmesan & Yohe 2003; Root et al. 2003; Inkley et al. 2004; Thomas et al. 2004; Lovejoy & Hannah 2005; Parmesan 2006; Fischlin et al. 2007). Effects described to date include

- shifts in species distributions, often along elevational gradients;
- changes in the timing of life-history events, or phenology, for particular species;
- decoupling of coevolved interactions, such as plant–pollinator relationships;
- effects on demographic rates, such as survival and fecundity;
- reductions in population size (especially for boreal or montane species);
- extinction or extirpation of range-restricted or isolated species and populations;
- direct 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);
- increased populations of species that are direct competitors of focal species for conservation efforts; and
- increased spread of invasive or non-native species, including plants, animals, and pathogens.

Although further attempts to describe, understand, and predict the effects of climate change are important, there is also considerable interest in identifying practical strategies that could help reduce or ameliorate anticipated negative effects of climate change (Hannah et al. 2002*a*; Inkley et al. 2004; Da Fonseca et al. 2005; Fischlin et al. 2007). In the rapidly evolving dialogue on climate-change science and policy, these approaches are commonly termed as "adaptation strategies" (The Heinz Center 2007; Julius & West 2007).

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 the physical environment (Lamarck 1809; Mayr 1982). In the context of climate-change planning, however, the term adaptation generally refers to human activities intended to minimize the adverse effects of climate change on human infrastructure and sensitive aspects of the natural environment (Fischlin et al. 2007; Julius & West 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, whereas others will decline and may even become extinct (Hannah et al. 2005). For species that will be adversely affected by rapid anthropogenic climate change, certain human activities—adaptation measures under the second definition—may ameliorate anticipated adverse effects.

We describe 16 possible adaptation strategies that have been proposed in the scientific literature and in public policy documents. We grouped these strategies into four broad categories: land and water protection and management; direct species management; monitoring and planning; and law and policy. We attempted to be as inclusive as possible in our review, even when a recommended strategy seemed overly general or simplistic. We critiqued each strategy on the basis of information from the conservation literature. Each strategy has distinct strengths and limitations and varies in its appropriateness for particular management contexts.

The strategies we reviewed are broad and general, such as might be adopted by management agencies at a national or subnational level. Much of the actual work of climate adaptation will necessarily occur at a finer scale, on the level of individual nature reserves, parks, and watersheds (Hughes et al. 2003; Singh 2003; Opdam & 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 vegetative communities (Carroll 2005; The Heinz Center 2007).

Although we attempted to be comprehensive in developing this synopsis, additional strategies will inevitably be developed in response to particular challenges. We hope our review will stimulate further thinking on the part of the management and scientific communities on this important topic.

We drew on adaptation strategies that have been described to date in the scientific literature and in policy documents that have been developed by government agencies and nonprofit organizations in Canada, México, South Africa, and United States (Hansen et al. 2003; The Sheltair Group 2003; Mukheibir & Ziervogel 2006; UN Environment Program [UNEP] Convention on Migratory Species 2006; Mitchell et al. 2007; Intersecretarial Commission on Climate Change 2007; Fischlin et al. 2007; Julius & West 2007; The Heinz Center 2007). These documents list a broad spectrum of potential adaptation strategies, ranging from human infrastructure changes to improved natural resource management.

As part of our initial review of these documents, we compiled lists of strategies that appeared to be most relevant to the direct management of species and ecosystems. Comparison of these lists quickly revealed that no one document provided a truly comprehensive set of strategies for the maintenance of biodiversity. To enhance future discussions, we used an integrated framework based, in part, on a taxonomy of natural resource management actions developed by the IUCN (International Union for the Conservation of Nature) and Conservation Measures Partnership (2006b) to compile a reasonably complete set of strategies. Strategies are numbered 1–16 under the four broad categories of conservation activities. This taxonomy does not include categories for monitoring or planning activities, which we nonetheless believe are important for effective climate-change adaptation.

Strategies Related to Land and Water Protection and Management

Land and water protection and management activities, as described by the IUCN and Conservation Measures Partnership (2006b), are often combined within a single management authority (such as a parks department, forestry department, or land trust). Strategies involve protectionist and interventionist approaches to natural resource conservation, and the focus is on the land (or water) resource.

1. Increase Extent of Protected Areas

This strategy would increase the extent of terrestrial and aquatic habitat protected from nonclimate anthropogenic threats (McNeely & Schutyser 2003; Mitchell et al. 2007). The strategy could also be used to protect refugia (areas with minimal climate impacts), movement corridors, or stepping stones for wildlife dispersal (strategy 5).

A suite of legal tools is already available for protecting lands, waterways, and marine areas (including fee title acquisition, easements, proclamation, legislation, and condemnation). The global conservation community has used these tools to protect high-priority conservation areas in ecosystem types and human societies around the world (Bruner et al. 2001).

Given the resource needs of the world's growing human population, it is unlikely that society will be able to directly protect enough land to facilitate the movement of all species and communities. Furthermore, the world's existing protected-area networks have been designed to protect static (rather than dynamic) patterns of biodiversity (Lemieux & Scott 2005; Lovejoy 2005; Scott & Lemieux 2005). The performance of static networks at conserving biodiversity in the face of climate change remains largely untested (Zacharias et al. 2006), but simulation studies suggest that some of these networks will likely fail to achieve their original objectives (Hannah et al. 2005). New approaches to land conservation that acknowledge the dynamic nature of climate-change effects on ecosystems will likely be needed (e.g., strategy 14; Hannah & Hansen 2005).

2. Improve Representation and Replication within Protected-Area Networks

Representation attempts to build a more comprehensive portfolio of protected areas (e.g., protecting examples of all major ecosystem types within a country), whereas replication attempts to conserve multiple examples of each ecosystem type (Julius & West 2007).

As noted, conservation tools are 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 (strategies 5 and 7). Representation has already been used as a strategy for local and regional land-protection efforts (Wisconsin Natural Areas Program 2008), and tools such as land-cover maps and geospatial data on rare species distributions could facilitate the broader application of both strategies.

It is unclear that representation will continue to be a relevant conservation strategy over the long-term because distributions of the individual components of ecosystems may shift in different ways as a result of climate change, potentially resulting in new combinations of species and even new ecosystem types (Carroll 2005; Hannah & Hansen 2005).

3. Improve Management and Restoration of Existing Protected Areas to Facilitate Resilience

It may be possible to offset some of the small-scale effects of climate change in protected areas through direct management activities (Mitchell et al. 2007). A number of commonly used techniques for ecological restoration (SERI 2006) may be relevant here (Julius & West 2007): riparian forest plantings could shade streams and offset localized warming; dikes and levees could protect coastal sites from sea-level rise; and prescribed fire could reduce fuel loads and potential for catastrophic wildfires (The Sheltair Group 2003; Fischlin et al. 2007).

Intensive management is usually more tractable at small, well-defined sites such as parks, nature reserves, and natural areas (Kusler & Kentula 1990; Thayer 1992; National Research Council 1994). Restoration techniques for certain communities, such as tallgrass prairie and longleaf pine, have received considerable attention and testing (SERI 2006; Julius & West 2007). Nevertheless, direct management is expensive and may only be feasible for small sites and limited areas (Fischlin et al. 2007). Also, focusing on protected areas neglects the overall matrix in which these areas are embedded: what happens outside protected areas often influences what happens inside (da Fonseca et al. 2005).

4. Design New Natural Areas and Restoration Sites to Maximize Resilience

It may be possible to design new natural areas and restoration sites to enhance the resilience of natural systems to climate-change effects (Lovejoy 2005). For example, saltmarsh restoration sites adjacent to steep shorelines would likely be inundated and lost under conditions of accelerated sea-level rise. In contrast, restored marsh communities adjacent to gently sloped shorelines may be able to regress naturally landward as sea-level rises (Yamalis & Young 2007). Similarly, the establishment of protected-area networks along elevational gradients may be a viable adaptation strategy for certain taxa; such networks would provide organisms with the spatial flexibility to shift distributions along elevational gradients as climatic conditions change. 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 multiple plant species, some of which may exhibit greater resilience to climate change at particular sites. Species mixes for restoration projects could be adjusted to include species that are thought to be more resilient to anticipated changes in a particular area. Increased vigor and rate of spread of invasive plant species has been identified as a potential problem under certain climate-change scenarios (Truscott et al. 2006; Yamalis & Young 2007), and innovative management strategies will probably be needed to address this problem.

This strategy is likely to serve as an important filter criterion for future protection and restoration efforts. Funders and project managers may question the wisdom of investing scarce conservation dollars in projects that are not sustainable in the face of climate change. Nevertheless, projects that are not sustainable over the long-term may nonetheless have important short-term benefits, for example providing intermediate areas of habitat for climate-sensitive species until longer-term refugia are identified (Hannah & Hansen 2005).

5. Protect Movement Corridors, Stepping Stones, and Refugia

This strategy represents a refinement of strategies 1 and 2 and would direct protection efforts toward areas and regions that have been deemed essential for climate-induced wildlife movements (Allan et al. 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, stopover areas for migratory waterfowl, or refugia where climate-change impacts are predicted to be less severe (Julius & West 2007). In aquatic systems, unblocked streams and rivers serve as important movement corridors for aquatic species (Pringle 2001; Chu et al. 2005).

As described under strategy 1, tools are already available for protecting terrestrial areas and riverine corridors. A pilot project is already underway in the Netherlands to designate and protect movement corridors (Fischlin et al. 2007).

It can be difficult to predict future species movements with confidence. For example, Carroll (2005) used dynamic population-habitat models to study potential movements of lynx (*Lynx canadensis*), marten (*Martes americana*), and wolves (*Canis lupus*) in the northeastern United States and southern Canada. He found significant contrasts in predicted linkage needs for these three species, which suggests it may not be straightforward to identify more general movement corridors for larger suites of terrestrial species. A practical concern is the tremendous cost associated with protection of large-scale movement corridors (Fischlin et al. 2007).

6. Manage and Restore Ecosystem Function Rather than Focusing on Specific Components (Species or Assemblages)

This strategy focuses on the maintenance of aspects of ecosystem function (such as nutrient uptake by riparian forest buffers or wetland filtration of nutrients and sediments) in conservation areas. It de-emphasizes historical condition, historic species composition, and the condition of reference sites as sources of management information. To implement this strategy, managers would first define key variables or indicators of ecosystem function, and then undertake activities designed to keep those variables within acceptable parameters (Harris et al. 2006; Fischlin et al. 2007; Mitchell et al. 2007).

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, those practicing ecological restoration have used historic data or undisturbed reference sites as a baseline for management (SERI 2006). Given the significant shifts that have and will occur in species distributions, it may be easier for managers to focus on sets of variables describing ecosystem function, rather than attempting to maintain a particular species composition or community type at a given site (Harris et al. 2006).

This strategy may be difficult to implement in practice without focusing on individual ecosystem components. Shifting the focus of management from components to functions may mean some components will become extirpated or extinct. Depending on the attributes of ecosystem function selected, it may be possible to maintain these variables within acceptable limits with a greatly reduced complement of species or even with non-native species.

7. Improve the Matrix by Increasing Landscape Permeability to Species Movement

This strategy focuses on increasing broader landscape connectivity and permeability to species movement (da Fonseca et al. 2005), especially outside protected areas and protected-area networks. Rather than focusing on a single species or ecosystem type, this approach would use a variety of existing management techniques to enhance the ability of the broader landscape matrix to support movements by large numbers of animal and plant species in response to climatic changes. This strategy is consistent with a number of existing management approaches, such as agrienvironment schemes in United States and Europe (Donald & Evans 2006; Giliomee 2006) and dam removals, fish ladders, and other techniques to restore connectivity in freshwater aquatic systems (Pringle 2001; Chu et al. 2005; Battin et al. 2007).

A suite of conservation tools is already available for implementing this approach (including agrienvironment schemes and dam removals), and large-scale implementation programs have been successfully demonstrated in the United States and Europe (Donald & Evans 2006). Modeling techniques are available to assess landscape permeability to species movement (Singleton et al. 2002) and to predict likely paths of dispersal across the landscape matrix under particular climate-change scenarios (Carroll 2005). Nevertheless, 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.

Strategies Related to Direct Species Management

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

8. Focus Conservation Resources on Species that Might Become Extinct

This strategy would invest resources in the maintenance and continued survival of those species most likely to become extinct as a result of global climate change. Although this strategy is not explicitly described in the policy documents reviewed for this study, it is implicit in efforts such as the campaign to prevent polar bear extinction. The IUCN (2008) has recently begun incorporating projections of future risk from climate change into its red-list rankings, an activity that is also consistent with this strategy.

This is an intuitive strategy for wildlife managers, following a long tradition of conservation efforts for rare or extinction-prone species. Rare species may be especially susceptible to climate-change effects, and there may be climate thresholds above which extinction probabilities for these species increase dramatically (Hoyle & James 2005; Fischlin et al. 2007). There are numerous published reports 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.

Conventional management of endangered species has relied heavily on in situ conservation approaches. Such approaches will be increasingly difficult to sustain in a world where 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 et al. 2005). Traditional endangered species management can also be extraordinarily expensive (Canadian Wildlife Service & 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.

9. Translocate Species at Risk of Extinction

This approach recommends moving 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. Other names for this strategy include assisted dispersal, assisted migration, and assisted colonization (Julius & West 2007; McLachlan et al. 2007; Mitchell et al. 2007; Hoegh-Guldberg et al. 2008).

Translocation techniques have been developed and demonstrated for many plant and animal species (e.g., Schweitzer 1994; Thomas 1995; Griffith et al. 1989; Thomas 1999; Haight et al. 2000; Bothma 2002; Tenhumberg et al. 2004). Nevertheless, with any translocation attempt, there is a risk of failure and even extinction (Maxfield et al. 2003; Groombridge et al. 2004). For many species, it will 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 and to challenges associated with forecasting optimal future habitats (Suarez-Seone et al. 2004; Tolimieri & Levin 2004; Carroll 2005).

10. Establish Captive Populations of Species that Would Otherwise Go Extinct

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 et al. 2003). Seed, sperm, and egg banking represent extreme forms of this strategy (Guerrant et al. 2004).

Rearing techniques and approaches to captive husbandry and propagation have been described for many animals (Kleiman et al. 1997) and plants (Guerrant et al. 2004), and modern society has an industry (zoos, botanic gardens, and aquaria) dedicated to this approach. Nevertheless, given the resources required for captive maintenance programs (Kleiman 1989), this is unlikely to be a viable long-term strategy for any more than a few species. Under extreme climate-change scenarios, ecosystem conditions may be so altered that the reintroduction of these species will be unfeasible, essentially making these species living fossils.

11. Reduce Pressures on Species from Sources Other than Climate Change

This strategy seeks to reduce or remove other, nonclimate stressors to give wildlife species the maximum flexibility to evolve responses to climate change (Lovejoy 2005; Robinson et al. 2005; Julian & West 2007; Mitchell et al. 2007).

Species clearly experience multiple stressors, and the removal of these other stressors may allow individual species the flexibility needed to adapt 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.

Although numerous other stressors affect species (IUCN and Conservation Measures Partnership 2006a), limited resources are available to address the broad suite of stressors. Given these circumstances, there is potential for a loss of focus and much diffuse action across a broad range of stressors.

Strategies Related to Monitoring and Planning

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

12. Evaluate and Enhance Monitoring Programs for Wildlife and Ecosystems

Monitoring systems provide information that managers can use to adjust or modify their activities (Walters 1986; Margoluis & Salafsky 1998). Such information is particularly relevant in times of rapid global change (Adger et al. 2003; Fischlin et al. 2007). This strategy suggests evaluating the current state of the systems that collect, analyze, and interpret environmental information. Many of the systems for collecting this information are incomplete (Heinz Center 2002, 2006).

Significant gaps exist within and among current environmental monitoring systems (Heinz Center 2002, 2006). Society clearly needs a better system for monitoring and reporting on ecosystem condition.

Costs to adapt existing monitoring systems and develop new monitoring systems are likely to be high, in many cases requiring new legislation and regulations and possibly new tools and approaches to monitoring. Also required is better integration and coordination across the existing monitoring programs (Heinz Center 2006).

13. Incorporate Predicted Climate-Change Impacts into Species and Land-Management Plans, Programs, and Activities

Climate change is not addressed in many existing natural resource plans (Hannah et al. 2002). This strategy recommends incorporating climate-change information into existing and future natural resource planning activities.

Information about actual and potential climate-change impacts can be of considerable benefit to land and natural resource managers in refining decisions (Intersecretarial Commission on Climate Change 2007). 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 into these documents. In addition, the IUCN (2008) is now including projections of future risk to species from climate change into its Red List.

The problems with this approach are mainly practical at present. There is a cost associated with revisiting and revising management plans (as well as institutional inertia and potential unwillingness to do so), and detailed predictions of potential climate-change effects are currently only available for a small subset of species and areas.

14. Develop Dynamic Landscape Conservation Plans

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 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. It also describes any intermediate conditions that may be necessary for a species to transition between current and future conditions. The management guidelines suggest mechanisms and tools for management and provide specific recommendations to the government agencies responsible for implementation.

Unlike many traditional resource management plans, dynamic landscape conservation plans explicitly address the climate adaptation needs of wildlife and biodiversity at a landscape scale (Hannah & Hansen 2005). Such plans are likely to be compatible with other regional planning efforts (e.g., county or watershed management plans). Nevertheless, planning efforts can be resource-intensive, and many natural resource management plans have been developed but not implemented. Dynamic landscape plans may recommend that certain spatial elements (areas of land or water) be converted from human uses to "natural" management to facilitate species movements (Hannah & Hansen 2005). 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.

15. Ensure Wildlife and Biodiversity Needs Are Considered as Part of the Broader Societal Adaptation Process

Many of the adaptation strategies being developed in communities around the globe are focused on human health and infrastructure needs (The Heinz Center 2007). Mitchell et al. (2007) recommend that the needs of wildlife and biodiversity also be considered as part of the overall societal adaptation process.

Given the importance of wildlife for human recreation and enjoyment and the value of ecosystem services, such as pollination and water filtration, wildlife and ecosystems should also be addressed in climate-change adaptation plans (Mitchell et al. 2007).

If global climate change leads to 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 could trump the needs of wildlife and biodiversity.

Strategy Related to Law and Policy

This strategy includes efforts to reform or enhance public policies regarding wildlife management and biodiversity conservation. Tools include legislation, regulations, policies, private-sector standards and codes, and compliance and enforcement actions (IUCN and Conservation Measures Partnership 2006b).

16. Review and Modify Existing Laws, Regulations, and Policies Regarding Wildlife and Natural Resource Management

Laws and policies related to wildlife management, natural resource management, and biodiversity conservation should be reviewed to ensure that their provisions are consistent with the needs of managers dealing with the effects of climate change (Intersecretarial Commission on Climate Change 2007) . Many of these laws and regulations are decades old, and most were developed before climate change became a significant concern. New legislative tools or regulations may be necessary to address specific climate-change impacts.

Existing laws and regulations were designed for the conservation of "static" biodiversity (Lovejoy 2005; Lemieux & Scott 2005; Scott & Lemieux 2005). Many of these regulatory tools and approaches will need to be revisited in the light of the significant changes that are anticipated under even moderate climate-change regimes.

Actually addressing the deficiencies identified through these reviews may be difficult without significant political will. There will likely be significant concern expressed from all sides about sweeping revisions to existing laws and regulations.

Discussion and Conclusions

To those who are already familiar with the practice of wildlife management and biodiversity conservation, many of the strategies reviewed here will undoubtedly look like business as usual. Strategies such as land protection, habitat restoration, species translocation, and captive propagation have long been considered integral components of the manager's toolbox (IUCN and Conservation Measures Partnership 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 approaches, rather than the development of new techniques.

On the one hand, this is reassuring. Our review of the literature showed that society (and the community of wildlife and natural resource managers in particular) already possesses 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. Our old, static views of biodiversity will need to yield to new and dynamic understandings of changing ecosystems and changing climates (Lovejoy 2005). Dynamic landscape conservation plans (Hannah & Hansen 2005) represent just one approach for combining existing management approaches with the most up-to-date projections of 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 the strategies described here will probably prove more useful than others. Targeted land protection and efforts to increase landscape permeability will clearly benefit a broad range of species. Other activities, such as species translocation and captive propagation, will benefit only a handful of species and may ultimately be unsuccessful at preventing the extinction of individual species, 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 considerable opportunity for the development of additional strategies and approaches; we have only begun to think about the management of climate-change effects in a systematic manner.

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