Title
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Journal
Frontiers in Ecology and the Environment, 8(1)

ISSN
1540-9295

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Publication Date
2010-02-01

DOI
10.1890/070146

Resource management in a changing and uncertain climate

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Climate change is altering ecological systems throughout the world. Managing these systems in a way that ignores climate change will likely fail to meet management objectives. The uncertainty in projected climate-change impacts is one of the greatest challenges facing managers attempting to address global change. In order to select successful management strategies, managers need to understand the uncertainty inherent in projected climate impacts and how these uncertainties affect the outcomes of management activities. Perhaps the most important tool for managing ecological systems in the face of climate change is active adaptive management, in which systems are closely monitored and management strategies are altered to address expected and ongoing changes. Here, we discuss the uncertainty inherent in different types of data on potential climate impacts and explore climate projections and potential management responses at three sites in North America. The Central Valley of California, the headwaters of the Klamath River in Oregon, and the barrier islands and sounds of North Carolina each face a different set of challenges with respect to climate change. Using these three sites, we provide specific examples of how managers are already beginning to address the threat of climate change in the face of varying levels of uncertainty.

Front Ecol Environ 2010; 8(1): 35–43, doi:10.1890/070146 (published online 10 Oct 2008)

Climate change has already had important effects on ecological systems (Parmesan 2006; Root and Schneider 2006; IPCC 2007a; Rosenzweig *et al.* 2008). Projected changes in climate for the coming century are all greater than the climatic changes the Earth has experienced in the past 100 years (IPCC 2007b). Consequently, future changes in climate are likely to result in even more dramatic ecological responses, including declines in particularly sensitive species (eg corals), continued shifts in species distributions, and substantial changes in ecosystem processes (IPCC 2007a). Changes in hydrologic and fire regimes will fundamentally alter ecological systems. Sea-level rise, in particular, will have dramatic effects on coastal systems (Watson *et al.* 1996). Changes in phenology will affect the delicate relationships between pollinators and plants, parasites and hosts, foragers and forage, and predators and prey (eg Memmott *et al.* 2007). Despite the pervasiveness of climate change, most land, water, and resource managers are still following management plans that were developed before there was a scientific consensus that climate-change impacts were both real and substantial (Pyke *et al.* 2008).

In a nutshell:

- The outcomes of management interventions in the face of climate change differ markedly in their predictability
- While some management strategies will be robust to different future climates, others will not
- Successful management will require strategies in which management actions are coupled with monitoring to provide informative feedback loops
- Despite uncertainties in future projections, managers can begin to actively address climate change now

Climate change poses difficult challenges for many already overstretched natural resource managers, who must deal with day-to-day crises and who have little access to climate experts. Much of the widely available information about climate change focuses on global or regional scales that are often too broad to fully inform the management of specific nature reserves or regional forests. Moreover, much of the information that is available has a high level of uncertainty, and thus can be difficult to interpret. Finally, although climate change is having impacts today, the largest impacts are still decades in the future. Envisioning these impacts and acting well in advance of their realization will require a new level of proactive management.

Several articles have provided general recommendations for managing particular systems in a changing climate (Noss 2001; Hannah *et al.* 2002; West and Salm

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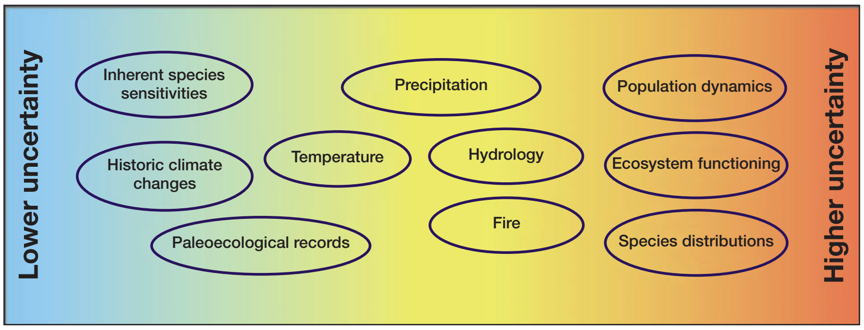


Figure 1. *Information used to develop management strategies for addressing climate change across a range of levels of uncertainty. The level of uncertainty assigned to each of the general types of information is necessarily subjective. Particular datasets in these general categories may be associated with more or less uncertainty than the levels depicted here.*

2003; Lemieux and Scott 2005; Pyke and Fischer 2005; Welch 2005). There have been calls for increasing the resilience of systems, landscape and aquatic connectivity, the spatial and temporal scale of management, and cooperation among agencies and landowners. Here, we explicitly address the question of how to select management strategies in light of the uncertainty imposed by future climate change. We discuss some of the basic uncertainties associated with future climatic and ecological data and projections, and look at how the outcomes of potential management strategies are influenced by those uncertainties. Finally, using three case studies, we provide specific, on-the-ground examples of how these strategies can be applied.

■ Uncertainty in future conditions

Perhaps the greatest challenge for managers is to act in the face of the uncertainty inherent in future climate-change projections. Although there is general consensus on the most basic implications of increased greenhouse-gas concentrations (eg temperature and sea-level rise), we cannot predict the magnitude, or even the nature, of other projected changes (IPCC 2007b). For example, average global temperatures are projected to rise from anywhere between 1.1–6.4°C (IPCC 2007b). Projected changes in precipitation are even more uncertain, with predictions that often include both increases and decreases for a given region (IPCC 2007b). The range of projected changes in specific regions varies and can be larger or smaller than the range of global averages. This variability is the result of uncertainties, both in the general circulation models that are used to simulate the Earth's climate and in the different scenarios for future greenhouse-gas emissions that determine inputs into these models. All of these uncertainties make it difficult to predict future ecological impacts.

Many different types of information can be used to assess the potential ecological impacts of climate change. These range from basic information about the current functioning of a system, or the biology of a species, to modeled changes in species distributions or population dynamics. The level of uncertainty associated with this information spans a relatively large range (Figure 1). At one end of the spectrum is basic information about species biology and ecosystem functioning. For example, as a result of their physiology, specific habitat requirements, or interspecific dependencies, some species will be more sensitive to changes in climate than others. This basic knowledge can be augmented with information from controlled experiments and observational studies designed to determine how species and systems respond to changes in temperature and moisture. For example, knowing how plant communities respond to the combined effects of increased atmospheric CO_2, temperature, precipitation, and nitrogen deposition (Zavaleta *et al.* 2003), or how predators alter the effects of climate change on prey populations (Wilmers and Getz 2005), may allow us to anticipate potential responses to climate change within specific systems so we can start to design management responses.

Paleoecological data, such as those obtained from pollen records, tree rings, charcoal deposits, or animal fossils, provide another source of information to aid in anticipating the effects of climate change (Willis and Birks 2006). Although there is some uncertainty in the spatial and temporal accuracy of the different types of paleoecological data, these uncertainties are likely to be small as compared with those inherent in future climate-change projections (Brubaker 1989; Whitlock *et al.* 2003; Willis and Birks 2006; IPCC 2007b). These past records can provide us with estimates of rates of species movement and the magnitude of changes in species composition in response to climate change (eg Davis and Shaw 2001). Recent records of ecological change are also less uncertain than future projected changes (IPCC 2007a). These more recent records provide additional estimates of rates of species range shifts and changes in phenology (Parmesan and Yohe 2003). However, according to the paleoecological evidence, these shifts, summed over long periods, tend to result in very different (ie no-analog) ecological systems (Brubaker 1989).

Projected changes in climate are inherently more uncertain than historic records or experimental results (IPCC 2007b). There are currently at least 24 different atmosphere–ocean general circulation models (AOGCMs) being used to project climatic changes for more than 10 different greenhouse-gas emissions scenarios (PCMDI 2007). Each AOGCM models the Earth's climate in a slightly different way (eg by making different assumptions or using different parameters), and each emissions scenario produces a different projection of future atmospheric greenhouse-gas concentrations. This variability results in what are often major differences in climatic projections from different models and emissions scenarios (Dettinger 2005). Accounting for the differences will entail focusing on the range of projected changes, as well as on whether there is more or less consensus on a given level of change occurring (eg Hayhoe *et al.* 2004; Dettinger 2005).

Finding consensus among predictions will be easier to do for some climatic factors than for others. For example, projections of global temperature and sea-level rise are relatively consistent across greenhouse-gas emissions scenarios and AOGCMs for the next 30 years (IPCC 2007b). There is much more variability in projected changes in precipitation in the near term and in projections for all aspects of climate change in the more distant future. Nonetheless, even knowing the relative magnitude of projected temperature changes and the likely direction of projected precipitation changes for a region will allow managers to begin to assess the nature of the potential threat of climate change.

Also at the high end of the spectrum of uncertainties lie the ecological models that are used to project the potential impacts of climate change on species or systems. Bioclimatic envelope models used to predict species range shifts (Pearson and Dawson 2003), dynamic global vegetation models used to predict changes in large-scale vegetation patterns (Cramer *et al.* 2001), forest gap models used to predict changes in stand structure (Bonan *et al.* 1990), and population models used to predict changes in abundance or persistence (Carroll 2007) have the potential to provide some of the most useful and specific information about future climate impacts. However, these models are imbued with their own uncertainties, which are, in turn, compounded by the uncertainties in the climate projections that they use as inputs. For example, the differences in projected range shifts obtained from various types of bioclimatic envelope models can be even greater than the differences that result from using an array of climate-change projections as inputs to a single bioclimatic model (Thuiller 2004; Lawler *et al.* 2006). There is a need to reduce this uncertainty through the development of more rigorous models that account for more ecological processes (Hulme 2005). However, despite these uncertainties, ecological models can provide estimates of the range of potential climate impacts, assessments of where these impacts are likely to be greatest (Thuiller *et al.* 2005; Lawler *et al.* 2009), or evaluations of the efficacy of different management strategies (eg Battin *et al.* 2007).

Climate projections, climate-impact assessments, and climate-change information in general are all rapidly becoming more available and can often be found online (Panel 1). However, much of the species-specific information, regional climate-change projections, and information that managers will need is dispersed throughout the scientific literature or scattered across the Internet. To more efficiently address the effects of climate change on ecological systems, scientists will need to compile, synthesize, and make this information readily available. Because interpreting and using climate-change projections will often be difficult, in many instances, it will be necessary for managers to partner with scientists working on climate-impact assessments.

Panel 1. Online climate-change resources

Intergovernmental Panel on Climate Change
www.ipcc.ch/
An excellent source for climate-change reports, graphics, and highly readable summaries.

Pew Center on Global Climate Change
www.pewclimate.org/what_s_being_done/
A good source for background information on climate change and its policy implications.

Real Climate
www.realclimate.org/
In-depth discussions with scientists about many different aspects of climate change. A good source for definitions of scientific terms and for learning the facts behind debated or divisive issues.

US Global Change Research Information Office
www.gcrio.org/
Reports and information about climate change, focusing on the US.

IUCN Climate Change Initiative
www.iucn.org/about/work/initiatives/climate/
Basic information about climate change, as well as some limited system-specific recommendations for management.

The Nature Conservancy's Climate Change Initiative
www.nature.org/initiatives/climatechange/strategies/art19628.html
Highlights several systems in which research is being conducted and management strategies developed to address climate change.

Australian Government Natural Resource Management Ministerial Council
www.environment.gov.au/biodiversity/publications/nbccap/pubs/nbccap.pdf
A national biodiversity and climate-change action plan for Australia.

Climate Impacts Group, University of Washington
www.cses.washington.edu/cig/
One example of some of the regional climate-change research that is available on the web. The site offers climate-change research results and projections for the US Pacific Northwest, as well as some planning tools for managers.

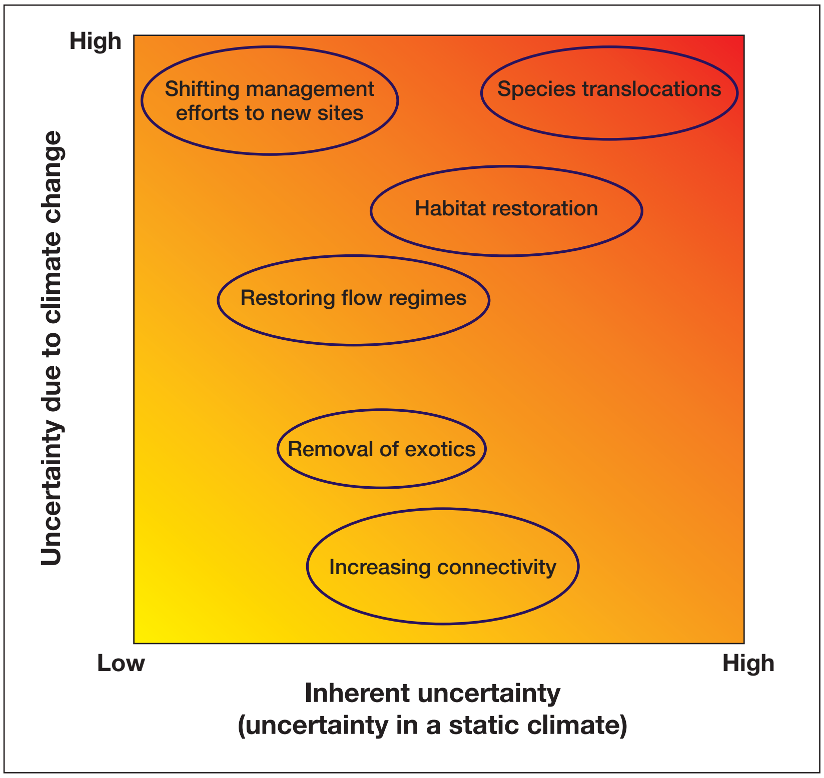


Figure 2. *Management strategies for addressing climate change, plotted with respect to the relative degree of uncertainty associated with their outcomes. Inherent uncertainty (x axis) is the uncertainty associated with a management action, irrespective of climate change. The uncertainty due to climate change (y axis) is a measure of how dependant the outcome of a management strategy is on a particular direction or magnitude of climatic change. Strategies at the bottom and top of the plot are, respectively, more and less robust to uncertainties in climate-change impact projections. The plot is necessarily a generalization – specific management actions of one type or another may be associated with relatively more or less uncertainty than the levels depicted here.*

■ Choosing management strategies in the face of uncertainty

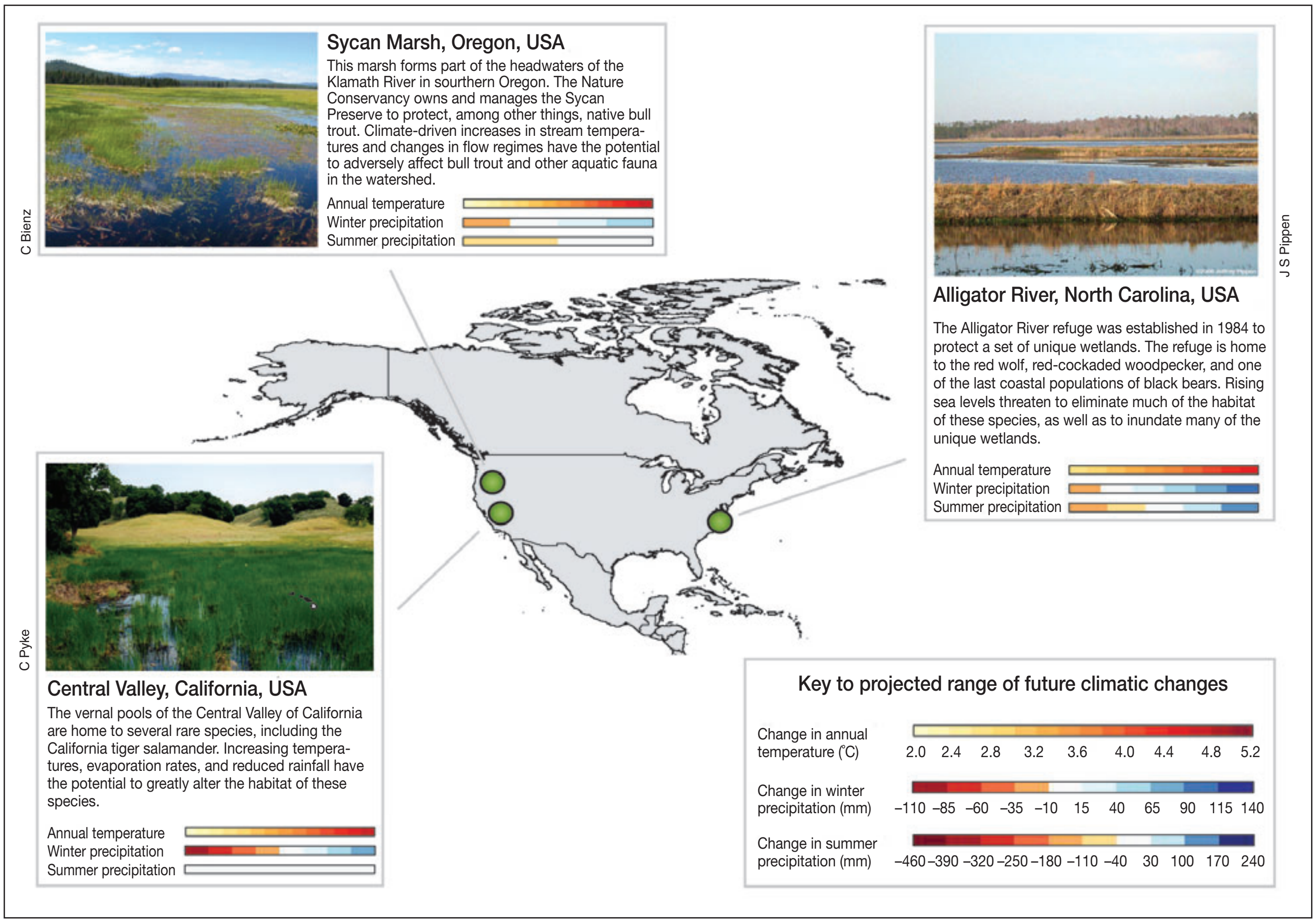
There is always some degree of uncertainty associated with the outcome of any natural resource management action. The results of management strategies designed to address the potential effects of climate change will generally be even less certain, given the uncertainties in future climate impacts. Thus, as with the information on which strategies to address climate change are based, the results of applying some of these strategies will be less certain than the results of applying others (Figure 2). Some of the more general recommended strategies, such as removing other threats, increasing connectivity, and expanding reserve networks (Hannah *et al.* 2002), are all based on a relatively simple understanding of species biology and historic climate-change effects on species distributions. They are not based on less certain projected potential climate impacts, and, thus, these strategies are likely to be useful measures for protecting species, regardless of the exact nature of climate change. Although there is still uncertainty in the outcome of applying these strategies (eg will they adequately address climate-change impacts?), they are unlikely to adversely affect target populations if the magnitude or even the direction of projected climatic changes proves to be incorrect.

In contrast, implementing management strategies that are designed to address a specific climatic change (eg decreased summer stream flow or a shift from an herbaceous wet meadow to a dry shrubland) will often have much more uncertain outcomes because, in part, they will depend on the nature of the future climatic impacts. For example, conducting translocations (McLachlan *et al.* 2007) for a rare or threatened species, or making triage-like decisions to abandon the management of a given population or site, will often be based on more uncertain projected climate-change impacts. Although it may be possible to implement many management strategies for which the outcomes rely less on the exact nature of climate change, it will probably be impossible to avoid some management actions for which the potential results are highly uncertain.

Addressing this uncertainty will require a flexible management approach. Strategies with highly uncertain outcomes that depend on the specific nature of future climatic changes will be most successful if they include regular monitoring and prescriptions for alternative actions. This will allow managers to change course in response to actual climate impacts. This type of adaptive management has long been recommended for dealing with the uncertainties inherent in highly variable or unpredictable systems (Walters and Hilborn 1978). Although the term adaptation has come to be used in reference to responses to climate change, in this paper, we refer to the traditional definition of adaptive management. In this sense, management actions are coupled with monitoring and evaluation to provide feedback loops, such that management can continuously change to address new knowledge about the system (Holling 1978; Walters and Hilborn 1978). The high level of uncertainty regarding future climatic changes and the even greater uncertainty with respect to ecological responses to future climatic changes make adaptive management approaches crucial. Fortunately, adaptive management is being formally embraced by many environmental non-governmental organizations, as part of a shared approach to conservation planning (The Conservation Measures Partnership 2007).

■ Managing for climate change: three case studies

The following case studies provide an overview of the diversity of climate-related threats and their associated uncertainties that managers will have to address. These examples



Sycan Marsh, Oregon, USA

This marsh forms part of the headwaters of the Klamath River in southern Oregon. The Nature Conservancy owns and manages the Sycan Preserve to protect, among other things, native bull trout. Climate-driven increases in stream temperatures and changes in flow regimes have the potential to adversely affect bull trout and other aquatic fauna in the watershed.

Alligator River, North Carolina, USA

The Alligator River refuge was established in 1984 to protect a set of unique wetlands. The refuge is home to the red wolf, red-cockaded woodpecker, and one of the last coastal populations of black bears. Rising sea levels threaten to eliminate much of the habitat of these species, as well as to inundate many of the unique wetlands.

Central Valley, California, USA

The vernal pools of the Central Valley of California are home to several rare species, including the California tiger salamander. Increasing temperatures, evaporation rates, and reduced rainfall have the potential to greatly alter the habitat of these species.

Figure 3. *Three sites with climate-sensitive management goals. The colored bars below each site description represent the range of projected changes in temperature and winter and summer precipitation from ten different climate-change simulations run for a mid-to-high (SRES A2) greenhouse-gas emissions scenario (Lawler* et al. *2009). A key to the ranges reported is found in the lower right corner of the figure. Bars with a solid color or only a few colors (eg summer precipitation in the Central Valley of California or the Sycan Marsh) depict little variability in model projections; conversely, bars with a large number of colors depict a greater range in model projections.*

provide insight into how both general management strategies (that are more robust to climate uncertainties) and more specific adaptive management strategies can be applied to address specific threats. The ecosystems described in each case study offer different types of resources, have different climate sensitivities, and are projected to experience different climatic changes (Figure 3).

Tiger salamanders and fairy shrimp in the Central Valley of California

Vernal pools are found throughout the Mediterranean-like climatic region of California. These ephemeral wetlands provide habitat for a large number of endemic and increasingly rare species, including the California tiger salamander (*Ambystoma californiense*) and several species of branchiopods (Eriksen and Belk 1999; Trenham *et al.* 2000). The aim of state and federal resource agencies is to reduce the risk of extinction of these vernal-pool-dependent species, by maintaining multiple self-sustaining populations across the region.

Climate is one of the most important determinants of the suitability of individual vernal pools for salamanders. Typically, a pool must receive at least 35 cm of precipitation to remain flooded long enough for the salamanders to be able to reproduce (Trenham *et al.* 2000). Most climate-change scenarios indicate that surface air temperatures will increase substantially in the Central Valley of California over the next 100 years. However, there is less certainty regarding the amount of warming that the area is likely to experience and, importantly, there is substantial uncertainty about important aspects of seasonal precipitation patterns (Figure 3). For example, according to one (mid- to high-range) greenhouse-gas emissions scenario, temperature projections for the end of the century for the Central Valley range from increases of 2.1°C to 4.6°C. Changes in winter precipitation range from *decreases* of 66 mm to *increases* of 65 mm. The magnitude of warming, which will affect evaporation rates, and changes in precipitation will affect both regional hydrology and vernal pool persistence. These changes are likely to act in concert with ongoing habitat loss to dramatically change the distribution of hydrologically suitable habitat across the Central Valley. However, given the uncertainties about future climate scenarios and ecological responses, specific predictions are highly uncertain.

Two strategies have been identified for managing the system: (1) strategic protection of additional habitat (Pyke and Fischer 2005), and (2) continued moderate grazing (Pyke and Marty 2005). The first strategy will likely benefit vernal-pool-dependent species, regardless of the exact nature of climate change. Instead of concentrating solely on existing pools, this strategy requires expanding the network of pools to increase the present and future diversity of hydrologic conditions represented in protected areas. This will increase the likelihood of having a network of pools capable of maintaining viable populations of sensitive species during the next hundred years. The success of the second strategy – continued moderate grazing – will be closely tied to the degree of warming and precipitation patterns in the coming years and decades. Moderate grazing extends the duration of pool inundation and allows salamanders and branchiopods time to complete the aquatic stages of their life cycles (Pyke and Marty 2005). Implementing grazing as a strategy will require systematic monitoring and an adaptive management approach. Feedback from monitoring will allow managers to adjust the level of grazing pressure, provide adequate inundation, and avoid the adverse effects of overgrazing.

Sycan Marsh, headwaters of the Klamath River

The Sycan Marsh is a 12 364-ha protected area in the Klamath Mountains of southern Oregon, owned and managed by The Nature Conservancy (TNC). The system of streams and marshes on the preserve provides habitat for a diverse community of aquatic invertebrates, as well as several imperiled fish species, including the Sycan tui chub (*Siphateles bicolor obesus*), the Klamath speckled dace (*Rhinichthys osculus klamathensis*), and the bull trout (*Salvelinus confluentus*). In 1998, the bull trout was listed as threatened in the Klamath and Columbia river basins under the US Endangered Species Act. Improving hydrologic connectivity (Pringle 2003) is a primary management objective of TNC, as it may be the defining element of riverine ecosystems.

Bull trout are cold-water fish that generally inhabit even cooler waters than many other salmonids (Selong *et al.* 2001). Temperature constrains all life history stages in this species. For example, the optimal temperature for growth in juveniles is 12.3˚C (McMahon *et al.* 2007). Spawning adults are generally limited to headwater streams in patchily distributed and fragmented populations spanning discontinuous stream segments and multiple watersheds (Rieman and McIntyre 1995; Dunham *et al.* 2002; Rieman *et al.* 2007). Thus, increases in stream temperatures have the potential to further reduce the amount of habitat available to bull trout and to further isolate fragmented populations.

In Oregon, climate models generally project increases in atmospheric temperature and decreases in snowpack. Slight increases in winter precipitation and small decreases in summer precipitation are predicted, but the direction of these changes varies across models (Figure 3). Average annual temperatures (again, given one mid- to high-range greenhouse-gas emissions scenario) are expected to rise between 2.2˚C and 4.8˚C. Changes in mean annual water temperature of only 1–3˚C may influence dispersal or displacement of bull trout, reducing their range by as much as 40% (Rieman *et al.* 2006). Increased atmospheric temperatures will exacerbate the effects of loss of riparian vegetation and ongoing stream-water withdrawals, resulting in higher stream temperatures and further fragmenting and reducing bull trout habitat (Nelson *et al.* 2002; Rieman *et al.* 2006; Rieman *et al.* 2007). Higher temperatures may also reduce snowpack and will probably alter flow regimes and sediment loads, potentially burying gravel essential for spawning (eg Beechie *et al.* 2006).

Several current restoration activities to improve bull trout habitat and to address some of the effects of climate change on the Sycan Marsh preserve take both a longer-term and larger spatial perspective. For example, preserve managers are increasing connectivity within the stream network by removing barriers to dispersal, thereby allowing fish to move in response to changes in stream temperature. Managers are also restoring the historic hydrologic regime by removing water-control structures. These removals will allow the stream to expand, contract, and move through its floodplain, potentially buffering the impacts of projected changes in future stream flow. Other management activities include increasing riparian vegetation to reduce channel width and improve in-stream habitat conditions, and restoring hardwoods in riparian areas to provide microhabitats that reduce the effects of irradiance. All of these activities should benefit bull trout regardless of the exact nature of climate change, and thus can be undertaken despite the uncertainty in the magnitude of temperature changes and projected changes in precipitation.

However, managers also recognize that, as a result of climate change, water temperatures may rise above the bull trout's viability threshold, no matter how much restoration is accomplished in the watershed. In this case, bull trout protection and restoration efforts will need to shift to higher elevations. Determining when restoration efforts need to shift upstream, or whether fish need to be moved, will require targeted monitoring and active adaptive management. Closely monitoring stream flow, temperatures, habitat quality, and fish condition and movements will provide indications of how fish are responding to both restoration efforts and climatic changes. These responses can then be used to modify management actions and reset management goals.

Alligator River, North Carolina

The Alligator River Climate Change Adaptation Project covers approximately 220 000 ha on the coast of North Carolina. Most of the land covered by the project is in conservation ownership, including such owners as the US Fish and Wildlife Service, the US Air Force, North Carolina Wildlife Resources Commission, North Carolina Division of Coastal Management, Conservation Fund, and TNC. The first and largest conservation holding, the Alligator River National Wildlife Refuge, was established in 1984 to provide protection for pocosins, which are unique, elevated, shrubby wetlands characterized by poorly drained soils that are high in organic content. These pocosins include stands of swamp hardwoods, pond pine, and Atlantic white cedar, and are bounded by freshwater and brackish marshes, all of which provide habitat for a diversity of wetland plants. The refuge provides protection for a reintroduced, endangered red wolf (*Canis rufus*) population, and the whole project includes protection for many other imperiled species, including the red-cockaded woodpecker (*Picoides borealis*) and American alligator (*Alligator mississippiensis*), as well as one of the few remaining coastal populations of black bears (*Ursus americanus*). Management goals for all of the conservation owners include protecting local ecosystems and maintaining habitat to support viable populations of these species.

Protecting the resources of the Alligator River will likely require management strategies with less certain outcomes, based, in part, on climate-impact projections. Because of the low-lying nature of the refuge, all habitats are extremely sensitive to sea-level rise. Global sea level is projected to rise 18–59 cm by the year 2100 (IPCC 2007b). Even more modest increases of 18 cm will cause saltwater intrusion into freshwater marshes and bogs, and convert forested land into marsh. Sea-level rise of 0.6 m will submerge much of the region. These changes have already begun, and will continue over the next 100–200 years. Although some current management activities adopted by some of the conservation managers, such as installing riserboard structures and tide gates in old drainage ditches to prevent saltwater intrusion and enhance wetland functioning, may help to buffer the coastal ecosystems from climate change, a broader temporal and spatial approach to management will also be necessary.

To address rising sea levels, managers have also identified several new management strategies. These include protecting additional land upslope to allow habitats and species to move, planting marsh grasses to prevent mass wasting of the shore as the sea rises, establishing linear oyster reefs and seagrass beds along the coast to abate the higher energies expected in the system from storms and the breaching of North Carolina's Outer Banks, and planting bald cypress on previously converted forest lands upslope from the rising sea to stabilize the soils and aid in the transition to new forest types (Pearsall 2005; Pearsall and Poulter 2005). The degree to which these actions will help to buffer the effects of rising sea levels depends on where and when the actions are implemented, and how quickly sea levels rise. Given the uncertainty in the projected rate of sea-level rise, an adaptive management strategy with targeted monitoring efforts will be needed to ensure that land acquisition and planting efforts are concentrated in the appropriate areas at the optimal times.

■ Conclusions

In order to protect biodiversity and natural resources for future generations, it will be necessary to explicitly address climate change in management plans. This will require making difficult decisions that have substantial risks of failure in the face of uncertainties in climate-change projections. Some management responses are likely to be helpful across a wide range of climate futures, whereas others will make sense for only a subset of climate futures. The outcomes of translocations are especially uncertain. First, translocations are inherently unpredictable. Even when detailed habitat assessments have been conducted, the success of a translocation project tends to be highly uncertain. This is compounded by the uncertainties in projected future climates and the responses of the ecological systems that will affect the suitability of translocation sites. In contrast, strategies that are designed to increase connectivity or remove other stressors, such as the dam removal and restoration of riparian vegetation being carried out at the Sycan Marsh, are likely to be more robust to the uncertainties of climate change. These actions are less dependent on the particular nature of climate change, and thus are likely to be beneficial to bull trout despite the wide range of potential future scenarios.

Each of the three case studies discussed here illustrates a number of management strategies with outcomes that rely on the particular nature of climatic changes. To be successful, these strategies will require targeted monitoring, the re-evaluation of management goals and actions, and that the rate and magnitude of climatic change are manageable. In a rapidly changing climate, active adaptive management is critical for achieving natural resource management goals. Although there is still much uncertainty in climate-impact projections, the case studies presented here show that natural resource managers already have some of the tools they need to begin to address the impending challenges and take action to respond to changing conditions.

■ Acknowledgements

We would like to acknowledge funding from TNC for the National Center for Ecological Analysis and Synthesis (NCEAS) workshop held in October 2005. In addition, JJL was supported in part by a David H Smith conservation fellowship. We thank F Davis, L Joyce, S Julius, E Maurer, P Miller, J Overpeck, T Root, E Saxon, A Shlisky, W Stanley, R Wilkinson, and J Olden for helpful discussions. This is publication number DHS-2008-04 of the David H Smith Conservation Fellowship program.

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Director of the Institute for Environment

Northern Illinois University

College of Liberal Arts & Sciences and College of Engineering & Engineering Technology

The College of Liberal Arts & Sciences and College of Engineering & Engineering Technology at Northern Illinois University anticipate hiring the first director of the university's new Institute for Environment. The Institute is one of NIU's strategic planning initiatives, a new interdisciplinary unit that involves multiple departments and colleges. The goal of the program is to meet pressing social and scientific needs for a workforce with an understanding of environmental and energy-related issues. The program will take a comprehensive approach, educating students to apply foundational and theoretical knowledge from the natural and social sciences, engineering, and the humanities to current environmental issues and policies. Working with faculty associates in Anthropology, Biology, Engineering, Geography, Geology, History, Law, Political Science, Technology, and other fields, the director will provide leadership in the creation of an interdisciplinary and multidisciplinary undergraduate degree program, to be followed by a graduate program in Environmental Studies. The director will also maintain an active research program in a field within one of the participating colleges and will have teaching responsibilities primarily in Environmental or Energy Studies. For more information about this new unit at NIU, contact Carl N. von Ende, cvonende@niu.edu.

Requirements: This position requires a Ph.D. and a research record appropriate for appointment as a full or associate professor with tenure in an existing department at NIU; the field of scholarship is open. Other requisites include evidence of outstanding teaching; research and scholarly publications related to environmental studies; a strong record of extramural funding; experience in working cooperatively with a broad, multi-disciplinary constituency; and demonstrated skills in organization, program development and management, and leadership.

Application Process: Candidates must send a statement of professional interest in the position and current curriculum vitae. Please list, with contact information, three people qualified to independently assess your candidacy.

Applications may be submitted electronically at envsdir@niu.edu, or sent by mail to
Carl N. von Ende, Department of Biological Sciences, Northern Illinois University, DeKalb, IL 60115.
Review of the complete applications will begin on February 1, 2010 and will continue until the position is filled.

NIU values diversity in its faculty, staff, and student body. In keeping with this commitment, we strongly encourage applications from diverse candidates and candidates who support diversity and understand the interrelationship of environmental issues and such factors as race, class, and gender. NIU is an AA/EEO institution.

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