Climate-Smart Conservation

Putting Adaptation Principles into Practice

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Cover: Beaver pond in Grand Teton National Park, Wyoming. Maintaining or reestablishing healthy beaver populations can serve as an adaptation strategy for sustaining aquatic and streamside habitats in a changing climate. Photo © Carr Clifton/Minden Pictures.

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Climate-Smart Conservation

Putting Adaptation Principles into Practice

Edited by Bruce A. Stein, Patty Glick, Naomi Edelson, and Amanda Staudt

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NPS

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Contents

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Executive Summary

Climate change already is having significant impacts on the nation's species and ecosystems, and these effects are projected to increase considerably over time. As a result, climate change is now a primary lens through which conservation and natural resource management must be viewed. How should we prepare for and respond to the impacts of climate change on wildlife and their habitats? What should we be doing differently in light of these climatic shifts, and what actions continue to make sense? *Climate-Smart Conservation: Putting Adaptation Principles into Practice* offers guidance for designing and carrying out conservation in the face of a rapidly changing climate.

Addressing the growing threats brought about or accentuated by rapid climate change requires a fundamental shift in the practice of natural resource management and conservation. Traditionally, conservationists have focused their efforts on protecting and managing systems to maintain their current state, or to restore degraded systems back to a historical state regarded as more desirable. Conservation planners and practitioners will need to adopt forward-looking goals and implement strategies specifically designed to prepare for and adjust to current and future climatic changes, and the associated impacts on natural systems and human communities—an emerging discipline known as *climate change adaptation.*

The field of climate change adaptation is still in its infancy. Although there is increasing attention focused on the subject, much of the guidance developed to date has been general in nature, concentrating on high-level principles rather than specific actions. It is against this backdrop that this guide was prepared as a means for helping put adaptation principles into practice, and for moving adaptation from planning to action.

Making Conservation Climate Smart

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The fate of our wildlife and wild places depends on steps we take now to prepare for and cope with the growing impacts of a changing climate. While managers traditionally have looked to the past for inspiration, increasingly we will be faced with future conditions that may have no historical analogs. Making a transition to forward-looking and climate-smart conservation will require that we pay particular attention to the following overarching themes:

Act with intentionality. We must explicitly consider and address climate impacts—both direct and indirect—in our conservation actions, and be able to "show our work." Most adaptation actions will draw from existing conservation techniques, but may differ in when, where, and why they are applied. Being deliberate and transparent, however, applies regardless of whether adaptation planning indicates a needed change of course with novel strategies, or continues to validate current efforts and traditional strategies. Indeed, acting with intentionality—through linking climate impacts to conservation actions—is at the very heart of climate-smart conservation.

What should we be doing differently in light of climate change, and what actions continue to make sense?

Steve Hillebrand/USFWS

Manage for change, not just persistence. In the face of current rapid climatic shifts, change is likely to be the only constant. Accordingly, conservationists will need to learn how to respond to and manage inevitable changes, rather than assume they can forever be resisted. Increasingly, we will be faced with managing system transformations, and may need to focus on sustaining ecological functions, rather than historical assemblages of plants and animals. In practice, managers may often be faced with simultaneously carrying out persistence and change-oriented strategies, and even cycling between the two based on changing conditions.

Reconsider goals, not just strategies. As conditions change, many of our current conservation goals and management objectives may no longer be feasible. Successful climate adaptation will depend not only on adjusting management strategies, but also in reevaluating—and revising as appropriate—our underlying conservation goals and objectives. In this sense, conservation goals can be regarded as the "ends" and strategies the "means." A climate-informed reconsideration may not require a wholesale revision but reveal the need to modify different components of conservation goals, such as *what* (the conservation targets), *why* (the intended outcomes), *where* (the relevant geography), or *when* (the relevant time frame).

Integrate adaptation into existing work. One of the best ways to facilitate successful implementation of adaptation strategies is through integrating, or "mainstreaming," adaptation into existing processes. Not only is it important to incorporate adaptation into existing natural resource decision processes, but opportunities are available to integrate the services from natural systems into adaptation focused on human communities and the built environment.

What is Climate-Smart Conservation?

An important goal of this guidance is to help practitioners and policy-makers understand what constitutes "good" climate adaptation, how to recognize those characteristics in existing work, as well as how to design new interventions when necessary. Part I of this guide focuses on exploring climate-smart conservation, and offers a structured process for putting it into practice. To this end, we define "climate-smart conservation" as:

The intentional and deliberate consideration of climate change in natural resource management, realized through adopting forward-looking goals and explicitly linking strategies to key climate impacts and vulnerabilities.

Determining what represents appropriate and relevant adaptation is highly context specific, but there are a number of attributes that can help distinguish when and whether climate considerations are suitably being incorporated into conservation work. To assist practitioners in making that distinction, we have identified the following set of key characteristics that collectively define a climate-informed approach to conservation.

Successful climate adaptation will depend not only on adjusting management strategies, but also on reevaluating underlying conservation goals.

Link actions to climate impacts. Conservation strategies and actions are designed specifically to address the impact of climate change, in concert with existing threats; actions are supported by an explicit scientific rationale.

Embrace forward-looking goals. Conservation goals focus on future, rather than past, climatic and ecological conditions; strategies take a long view (decades to centuries) but account for near-term conservation challenges and needed transition strategies.

Consider broader landscape context. On-the-ground actions are designed in the context of broader geographic scales to account for likely shifts in species distributions, to sustain ecological processes, and to promote collaboration.

Adopt strategies robust to uncertainty. Strategies and actions ideally provide benefit across a range of possible future conditions to account for uncertainties in future climatic conditions, and in ecological and human responses to climate shifts.

Employ agile and informed management. Conservation planning and resource management is capable of continuous learning and dynamic adjustment to accommodate uncertainty, take advantage of new knowledge, and cope with rapid shifts in climatic, ecological, and socioeconomic conditions.

Minimize carbon footprint. Strategies and projects minimize energy use and greenhouse gas emissions, and sustain the natural ability of ecosystems to cycle, sequester, and store carbon.

Account for climate influence on project success. Considers how foreseeable climate impacts may compromise project success; generally avoids investing in efforts likely to be undermined by climate-related changes unless part of an intentional strategy.

Safeguard people and nature. Strategies and actions enhance the capacity of ecosystems to protect human communities from climate change impacts in ways that also sustain and benefit fish, wildlife, and plants.

Avoid maladaptation. Actions taken to address climate change impacts on human communities or natural systems do not exacerbate other climate-related vulnerabilities or undermine conservation goals and broader ecosystem sustainability.

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The Climate-Smart Cycle

Carrying out effective climate adaptation involves an array of activities that can at first seem bewildering in their complexity and use of specialized terminology. The intent of this guide is to help natural resource practitioners understand the fundamentals of climate-smart conservation by demystifying this process and by demonstrating how the various parts of this process fit together. To that end, we offer a generalized framework for climate-smart conservation that breaks this process down into discrete steps. Each of the steps in this cycle, of course, has its own set of associated processes, and there may be multiple ways of carrying out each of these steps. Part II of this guide delves into the details of each step, together with case studies that exemplify the application of these approaches. Our primary interest is in helping practitioners understand how the pieces of the adaptation process fit together, and how to recognize when various methods and approaches may be appropriate for carrying out the different steps.

Although the climate-smart cycle mirrors many existing conservation planning and adaptive management approaches, it is designed specifically with climate change in mind. Particularly climate-focused elements include step 2—assessing climate-related vulnerabilities, and step 3—reconsidering conservation goals in light of those vulnerabilities. And while the steps are presented in a linear and stepwise fashion, depending on the specific requirements of a planning effort, one may enter the process at various stages or emphasize different components.

Step 1. Define planning purpose and scope. This includes: articulating the planning purpose; clarifying existing conservation goals; identifying conservation targets; specifying geographic scope and time frame; engaging key participants and partners; and determining resource needs and availability.

Step 2. Assess climate impacts and vulnerabilities. Understanding climate vulnerabilities is crucial for designing effective adaptation strategies, and the specific components of vulnerability—exposure, sensitivity, and adaptive capacity—can provide a useful framework for linking actions to impacts. Identification of “key vulnerabilities” provides a means for targeting the development of strategies and actions in subsequent steps of the cycle.

Step 3. Review/revise conservation goals and objectives. Because goals serve as the basis for subsequent strategies and actions, they should be climate-informed and forward looking. Reevaluation of goals and objectives may either validate their continued relevance, or indicate a need for refinement or modification.

Step 4. Identify possible adaptation options. What are possible approaches for reducing key climate-related vulnerabilities or taking advantage of newly emerging opportunities? At this stage, a broad array of alternative strategies and actions should be identified, with particular attention to creative thinking in crafting possible management actions.

Step 5. Evaluate and select adaptation actions. The array of possible adaptation options can now be evaluated to determine which are likely to be most effective from an ecological perspective, and most feasible from social, technical, and financial viewpoints.

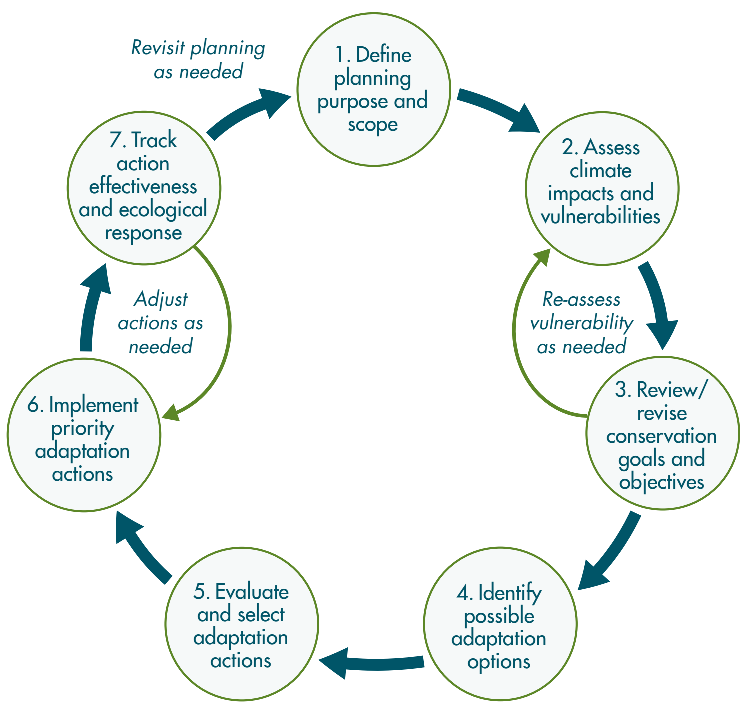
Step 6. Implement priority adaptation actions. Successfully implementing adaptation requires individual leadership as well as institutional commitment and resources, and often depends on engaging diverse partners early on, and emphasizing benefits to multiple sectors of society.

Step 7. Track action effectiveness and ecological responses. Monitoring helps provide context for understanding climate-related impacts and vulnerabilities and for informing agile and adaptive management. Monitoring approaches should be carefully designed to ensure they are capable of guiding needed adjustments in strategies and actions.

Making Adaptation Count

Several cross-cutting topics underlie the various steps in the climate-smart cycle, and Part III offers an in-depth look at a few that are critical for achieving effective adaptation outcomes. These topics include techniques to deal with uncertainty, find and use best available scientific information, understand and employ supportive policies, and improve how we communicate about climate change and adaptation.

Uncertainty figures prominently in how many practitioners think about climate change, sometimes creating a sense of confusion and paralysis. Uncertainty is nothing new, however, and there are a number of useful approaches for addressing uncertainty in conservation planning



Climate-Smart Conservation Cycle
A General Framework for Adaptation Planning and Implementation

and decision-making. We explore several such approaches, including scenario-based planning, structured decision-making, adaptive management, and robust decision-making, with the intent of helping practitioners overcome their fear of uncertainty and instead learn to embrace it.

Climate-smart conservation necessarily relies on information from a wide array of disciplines in the biological, physical, chemical, and social sciences. The ability to accurately assess impacts and vulnerabilities, and to develop suitable adaptation strategies is highly dependent on accessing relevant data sets, and making use of appropriate analytical tools. Yet the wide range of resources available can be bewildering, and finding and understanding the right information and tools can be daunting. New information and tools are emerging constantly, and we provide entry points to some of the most important sources for scientific information and tools relevant to climate adaptation.

The sooner we begin taking meaningful adaptation action, the more successful these efforts will be.

Although this guide largely focuses on how conservation practitioners and natural resource managers can better incorporate climate considerations into on-the-ground conservation efforts, such efforts are strongly influenced by the policy environment in which they are carried out. Laws, regulations, and policies can either help enable climate-smart conservation, or hinder efforts to carry out climate adaptation. Accordingly, we also look at some of the ways that existing legal and policy frameworks can be used by practitioners to advance adaptation objectives, as well as highlight needed changes in the policy environment.

Climate change is still poorly understood by many people, and is the subject of a highly polarized social discourse. Because successfully designing and carrying out adaptation efforts will be highly dependent on how one communicates about the work to various stakeholders and audiences, we offer advice for communicating about climate change generally, and climate adaptation in particular.

We Can Make a Difference

Each conservation challenge is unique and there are no one-size-fits-all solutions to climate adaptation. Instead, we need thoughtfully crafted adaptation strategies that take into account not only likely climatic shifts and impacts, but the specifics of the ecological resources, existing stresses and threats, and opportunities for meaningful action. *Climate-Smart Conservation: Putting Adaptation Principles into Practice* is intended to help practitioners craft such intentional and deliberate approaches to climate adaptation.

Although climate adaptation will have costs, the cost of inaction—through continuing with business as usual—is likely to be far higher. Furthermore, the *sooner* we begin the task of planning for a climate-altered future and taking meaningful adaptation action, the more successful these efforts ultimately will be. It is imperative that natural resource managers begin to act now to prepare for and manage these changes, in order to provide the best chance for cherished conservation values to endure. Putting climate-smart conservation into practice can make a difference for sustaining our nation's diverse species and ecosystems well into the future. Indeed, protecting our rich conservation legacy depends on our rising to this challenge.

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Part 1 | Getting Started

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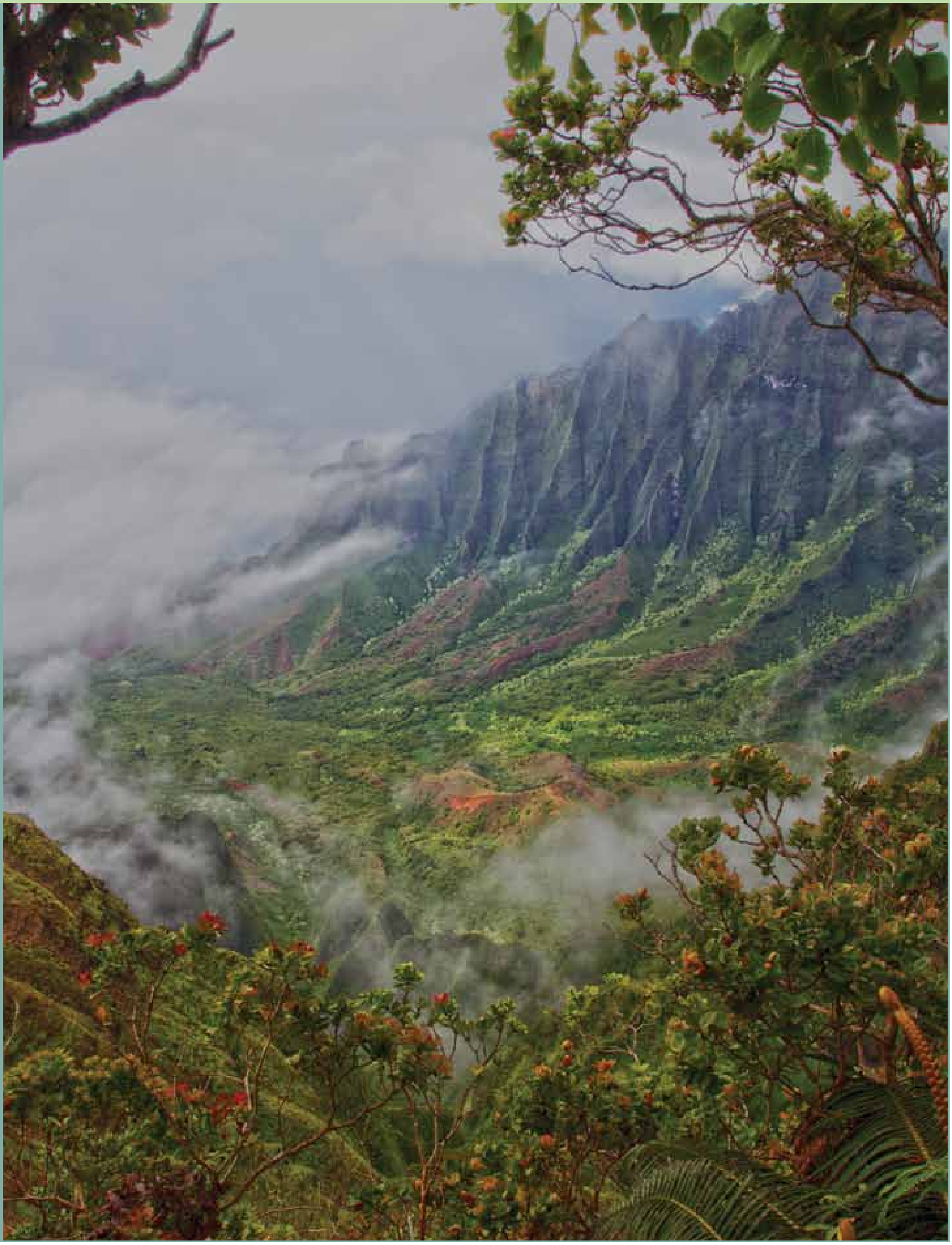

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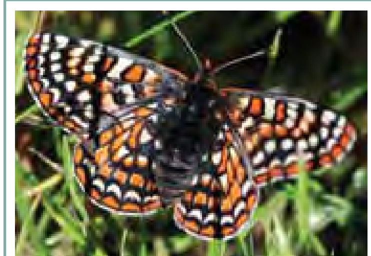
Chapter 1. Introduction[1]

Climate change is emerging as the defining issue for conservation in the 21st century. With each passing year, evidence of changes in the earth's climate system and their impacts on natural systems becomes more profound. Plants and animals are responding to higher temperatures and altered precipitation patterns through changes in the timing of life-cycle events and shifts in their geographical ranges. Grassland and forest systems are facing more frequent and severe disturbances such as drought, wildfires, and insect outbreaks, pushing some past their ability to regenerate. Coastal wetlands and beaches are succumbing to erosion and inundation as sea levels rise and tropical storms become more intense. These and other changes represent just the proverbial tip of the iceberg, as more and larger shifts are expected even under the best-case scenarios for reductions in greenhouse gas emissions. Scientific evidence suggests that we are already pushing or exceeding ecological thresholds that could significantly alter many of the landscapes that we cherish.

Addressing the growing threats brought about or accentuated by rapid climate change requires a fundamental shift in the practice of natural resource management and conservation. Traditionally, conservationists have focused their efforts on protecting and managing systems to maintain their current state, or to restore degraded systems back to a historical state regarded as more desirable. And while over the course of geologic time climate has varied considerably, most conservation and resource management has assumed a relatively stable climatic backdrop, a concept known as "stationarity" (Milly et al. 2008). As the pace of climate change has increased, relying on historical conditions for factors such as average temperature and precipitation, timing of snowmelt, and species assemblages will no longer be sufficient as a benchmark for management actions. Indeed, in the words of Milly et al. (2008) "stationarity is dead." The directional and rapid changes in climate we are now experiencing will increasingly challenge us to rethink long-held conservation assumptions and strategies so that we may better cope with these new climate conditions. Conservation planners and practitioners will need to adopt forward-looking goals and implement strategies specifically designed to prepare for and adjust to current and future climatic changes, and the associated impacts on natural systems and human communities—an emerging field known as *climate change adaptation.* For conservation practitioners and natural resource managers an overriding goal of climate change adaptation is to reduce the risks from these changes to the species, ecosystems, and resources that we value.



John Hull/USFWS

Over the past decade, interest in and acceptance of the need for climate change adaptation has increased sharply, both within the conservation community and beyond. We are now at a point where many agencies and organizations realize that climate change presents a clear and present threat to their interests and assets. Key questions remain though. Specifically, many planners, policy-makers, and managers want to know what they could be doing differently to prepare for and respond to existing and projected climate impacts, and which of the things they already are doing continue to make sense in light of climate change. And while uncertainty figures prominently in current conservation and resource management—as it does in virtually every aspect of everyday life—the

[1] **Lead authors: Bruce A. Stein, Patty Glick, and Amanda Staudt.**

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added layer of uncertainty presented by a changing climate seems to confound, and at times paralyze, many practitioners.

In practice, the field of climate change adaptation is still in its infancy. Although there is now considerable attention focused on adaptation by government agencies, nonprofit organizations, and businesses, much of the guidance to date has been general in nature, focusing for instance on high-level principles rather than specific actions, and emphasizing planning rather than implementation (Bierbaum et al. 2013). Many of these general adaptation principles draw from the rich experience and literature of conservation biology, wildlife management, and restoration ecology. In the context of rapid climate change, though, doing more of the same, only better, will not be adequate. Simply put, in an era of climate change just doing "good conservation" is not good enough. Instead, there is a need to specifically ask how climatic changes—in concert with the array of existing stresses and threats—are likely to affect the resources people care about, and which conservation approaches will be most appropriate in a climate-altered future. In other words, we must strive to make our conservation choices and actions more "climate smart." In this context, we define *climate-smart conservation* as a purposeful or intentional process for incorporating climate considerations into the ongoing work of nature conservation and natural resource management. Indeed, as elaborated in Chapter 2, acting with intentionality is at the very heart of climate-smart conservation.

1.1 Climate Change Impacts: The Imperative for Adaptation

Throughout the United States, we now face a plethora of impacts associated with climate change, including higher average, minimum, and maximum air and water temperatures; shifts in the amount of snowpack and when it melts; reduced ice cover extent and a longer frost-free season; and an accelerating rate of sea-level rise and acidification of ocean waters (Burkett and Davidson 2013, Griffis and Howard 2013, Kunkel et al. 2013). Extreme meteorological events, including heat waves, droughts, and heavy rainfall, are becoming more frequent and severe, as are associated wildfires and floods (IPCC 2012). These trends show a clear directionality consistent with the expected implications of increasing greenhouse gases and have been documented in the atmosphere, oceans, soils, and ice-covered areas spanning the planet (NRC 2011). While the climate has always exhibited variability and major climatic shifts have occurred throughout geological history, warming this century is likely to occur 10 times faster than during any climatic shift in the past 65 million years (Diffenbaugh and Field 2013).

These and other physical changes are affecting species and ecosystems in a wide variety of ways, many of which have been summarized in recent reports and assessments such as the National Fish, Wildlife and Plants Climate Adaptation Strategy (NFWPCAP 2012) and the U.S. National Climate Assessment (Grimm et al. 2013, NCA 2013). Unfortunately, species and ecosystems already are contending with multiple other environmental stresses, such as habitat loss, pollution, invasive species, and overharvest (Staudt et al. 2013). This historical backdrop of environmental degradation means that many species and ecosystems will have less capacity to cope with the new climate-related stresses. The cumulative effect of these multiple stressors, in concert with a rapidly changing climate, is expected to disrupt ecosystem processes (e.g., primary production and nutrient cycling) and services (e.g., provision of pollination services, clean water, etc.); increase the risk of species extinctions; and contribute to biome changes (Williams and Jackson 2007, Kissling et al. 2010, Maclean and Wilson 2011).

Plant and animal ranges are shifting or expanding, often poleward and to higher elevations (Kelly and Goulden 2008). In fact, species throughout North America have moved to higher elevations at a median rate of 0.011 kilometers per decade, and to higher latitudes at a median rate of 16.9 kilometers per decade, two to three times faster than previously reported in the literature (Chen et al. 2011). Current rates of climate change will likely exceed the ability of many species to adjust to new conditions, leading to higher extinction rates (Loarie et al. 2009). Shifts in entire biomes also already are becoming apparent in some areas. For example, in rapidly warming areas of Alaska, evergreen forests are expanding northward into current tundra areas, and grasslands and temperate forests are becoming established to the south (Beck et al. 2011).

Hundreds of studies confirm an earlier timing of life-history events among plants and animals (i.e., phenological changes), consistent with a trend of increasing mean spring air temperatures. Many plants are leafing out and blooming earlier, and birds, butterflies, amphibians, and other wildlife are breeding or migrating earlier than they did during the mid-20th century (Parmesan and Yohe 2003, Schwartz et al. 2006, Cleland et al. 2007, Rosenzweig et al. 2007, Bertin 2008, Miller-Rushing et al. 2008, U.S. EPA 2010, Ault et al. 2011). In other cases, changing hydrological conditions are affecting life-cycle events, such as shifts in the onset of summer "monsoon" rains delaying blooming in arid regions of the Southwest (Crimmins et al. 2011) and earlier peak streamflow in snowmelt-driven rivers disrupting behavior and timing of fish migration (Mantua et al. 2010).

Ryan Hagerty/USFWS

Current rates of climate change will likely exceed the ability of many species to adjust to new conditions, leading to higher extinction rates.

Of particular significance for ecological systems is the fact that species respond to climate change in different ways and at different rates (Walther 2010, Blois et al. 2013). This diversity in responses increases the likelihood that important spatial and temporal connections that have evolved over millennia—such as between pollinators and the flowers they fertilize, or breeding birds and the insects on which they feed—will be disrupted and fail. Considerable differences are likely in the responses of short-lived species with high dispersal abilities (such as birds) and long-lived species with limited dispersal abilities (such as many trees) (Montoya and Raffaelli 2010, Urban et al. 2011). As these changes occur, species that are better adapted to new conditions or have broader ranges of tolerance for relevant variables such as temperatures or climate-related disturbances are likely to gain a competitive advantage over those with narrower tolerances, and may expand in distribution or abundance (Traill et al. 2010).

Furthermore, as climate conditions exceed the historical range of variability under which our current ecosystems function, it is likely that key ecological thresholds or tipping points will be surpassed (Jentsch and Beierkuhnlein 2008). Such concerns exist for forest systems across much of western North America, where the combined effects of higher temperatures, drought conditions, severe bark beetle outbreaks, forest diseases, and wildfires in recent years suggest that some areas are increasingly vulnerable to transformative ecological change (Kurz et al. 2008, McKenzie et al. 2009, Westerling et al. 2011). Threshold responses are also evident in coral reef ecosystems, where the combination of climate change (including rising temperatures and ocean acidification) and other anthropogenic stressors (e.g., pollution and overfishing) has contributed to widespread coral bleaching, diseases, and associated mortality in numerous regions, including the Florida Keys and Caribbean (Doney et al. 2012).

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Increases in species declines and extinctions are predicted across the globe (Good et al. 2010, Maclean and Wilson 2011, Bellard et al. 2012). Particularly vulnerable are those species and populations that cannot easily shift their geographical distributions, or that have narrow environmental tolerances (Staudinger et al. 2013). For example, a study by Sekercioglu et al. (2008) found that the unique climatic, ecological, and physiological factors associated with elevation are important determinants of extinction risk among numerous species of land birds. While the responses of plants and animals to recent climate change indicate some degree of natural capacity for species to adapt (i.e., intrinsic "adaptive capacity," as discussed in Chapter 6), in many cases that capacity may be insufficient given the relatively high rate of climate change and the confounding effects from numerous other human-induced stressors that may hinder or prevent innate adaptive responses (Thomas et al. 2004, Stork 2010, Traill et al. 2010, Hof et al. 2011).

The observed changes to date are important bellwethers for even greater impacts projected in the decades to come, even if carbon dioxide (CO^2) and other greenhouse gas emissions are significantly reduced. Hence, the context for conservation will increasingly be one of novel climates and communities, along with ecological

Kelly Fike/USFWS

surprises (Williams and Jackson 2007). While continuing improvements in ecological modeling may provide us with the capacity to anticipate some of these changes, the results of such efforts likely understate the full extent of the conservation challenges we face given their complexity and unpredictability (Urban et al. 2011). Thus, while historical conditions, including ecological responses to past climatic shifts, will provide important context for future conservation, managers can no longer rely only on past conditions and experience.

1.2. What Is Climate Change Adaptation?

Given the rate and magnitude of climate impacts on natural and human systems, there is an urgent need to prepare for and respond to these impacts. *Climate change adaptation* is the discipline that focuses on addressing these impacts. In contrast, *climate change mitigation* addresses the underlying causes of climate change, through a focus on reductions in greenhouse gas concentrations in the atmosphere. Confronting the climate crisis requires that we both address the underlying causes of climate change and simultaneously prepare for and adapt to current and future impacts. Accordingly, adaptation and mitigation must be viewed as essential complements, rather than as alternative approaches. Because greenhouse gas emissions and concentrations will dictate the type and magnitude of impacts to which we will need to adapt, the ability to successfully accomplish adaptation over the long term will be linked to the success of climate mitigation efforts (Warren et al. 2013). Unfortunately, the current trajectory for global emissions is well on the way to exceeding even the highest-end projections analyzed by the Intergovernmental Panel on Climate Change (IPCC) in 2007 (IPCC 2007a, Anderson and Bows 2008). Even as we strive to prevent what could be considered the worst-case climate change scenario, we must also prepare for impacts that already are evident, and will continue for decades to come.

Formal definitions of climate adaptation have continued to evolve. Among the most commonly used definitions are those put forward by the IPCC, which variously define adaptation as: “initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects” (IPCC 2007a), and “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities” (IPCC 2007b). In common terms, climate adaptation may be thought of as preparing for, coping with, or adjusting to climatic changes and their associated impacts (Stein et al. 2013).

Climate adaptation may be thought of as preparing for, coping with, or adjusting to climatic changes and associated impacts.

Climate adaptation can also be viewed as a form of risk management. Risk management approaches are used extensively in the public and private sectors where decision-makers are faced with incomplete information or unpredictable outcomes that may have negative impacts. In its most general form, risk management is a process for identifying and assessing risk, allocating finite resources, and taking actions under uncertain conditions (U.S. GAO 2013). Traditionally, risk has been characterized as the product of the consequence of a negative outcome and the likelihood of occurrence for that event. More recently, however, the International Organization for Standardization has broadened the definition of risk to refer to the effect of uncertainty on one’s objectives, whether in a negative or positive direction (Leitch 2010). Regardless of the specific definition, understanding adaptation as a means of reducing vulnerability—of both natural and human systems—fits within the well-established framework of risk management.

1.2.1. Anticipatory and Reactive Adaptation

Adaptation actions may be *anticipatory* (i.e., actions that prepare for known or potential future impacts) or reactive (i.e., actions that respond to impacts already realized). Either or both approaches may be appropriate, depending on the circumstances (Palmer et al. 2009). For instance, a decision to relocate a damaged community out of a floodplain following a major flooding event constitutes a reactive adaptation action, while an anticipatory action for the same region might be to preserve currently undeveloped floodplains as a community buffer. Similarly, reactive actions may involve efforts to control an invasive species after it has expanded into new areas as a result of changes in climatic variables. Anticipatory actions might focus instead on identifying invasive species likely to expand their ranges in response to climate change, and establishing early-detection and rapid response protocols designed to keep them from invading sensitive areas.

Choosing between anticipatory and reactive adaptation options is highly dependent on the level of confidence in the likelihood and severity of possible impacts, and requires consideration of both the economic and opportunity costs (and benefits) involved in such actions. While anticipatory adaptation actions will entail some up-front costs, managers must consider the potential benefits (in terms of impacts or damages avoided), compared to what it could cost to ameliorate those impacts after they have occurred (Johnson et al. 2012). It also will be important to identify opportunity costs for deferring possible adaptation actions. For instance, acquisition of currently undeveloped parcels landward of salt marshes vulnerable to sea-level rise can provide a pathway for marsh migration. If such action is deferred until after damage to the marsh is evident, the parcel may already have been developed and no longer be suitable or available for habitat migration.

1.2.2. Varying Usages of the Term "Adaptation"

The term adaptation has long-standing meaning in evolutionary biology, referring to modifications of a trait, organism, or species to become better fitted for its environment. Since the 1980s (e.g., Kates et al. 1985) the term adaptation has also been used to refer to efforts to prepare for and respond to the impacts of climate change. Usage of the term adaptation in a climate change context has, however, created confusion and at times a lack of clarity, especially in reference to climate adaptation for biological organisms and natural systems.

"Adaptation" in the traditional evolutionary sense focuses on genetic changes in organisms over time in response to selective pressures. Evolutionary adaptation typically takes place over long periods of time, but can be rapid and in certain cases might help species counter stressful conditions or take advantage of ecological opportunities related to climate change (Hoffmann and Sgrò 2011). Complicating matters, shifts in traits can occur either through genetic changes (evolutionary adaptation in the narrow sense) or due to phenotypic plasticity, and teasing apart of the relative contributions of genotypic and phenotypic shifts can be difficult. Evolutionary adaptation has a role in climate adaptation, and as discussed later, maintaining the evolutionary potential of organisms represents an important class of climate adaptation strategies. Nonetheless, as used in this document, the term adaptation refers to climate adaptation unless otherwise specified.

1.3. Navigating This Guidance

Conservation needs and challenges vary widely across the landscape, depending on the nature and magnitude of existing and future threats, the condition of the ecological resources, and the level of engagement of management agencies

Brad Waggoner/NWF

and concerned citizens. Consequently, there is no one-size-fits-all approach to climate adaptation. With this in mind, the intent of this guide is to help natural resource practitioners understand the fundamentals of climate-smart conservation, how the various parts of the adaptation process fit together, and to assist them in crafting adaptation strategies and actions that best address the situation at hand.

Much of this guidance document is structured around a generalized framework for adaptation planning and implementation, referred to as the "climate-smart conservation cycle" (Figure 1.1, p. 18), and discussed in detail in Chapter 4. By design,

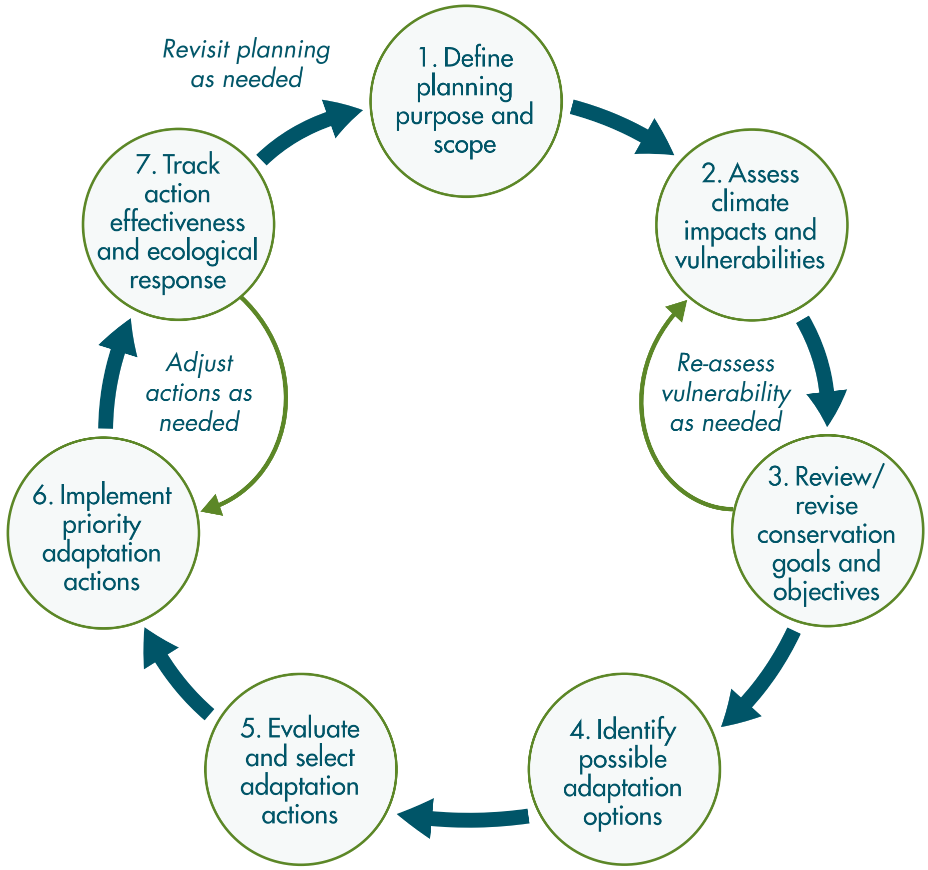

Figure 1.1. Climate-smart conservation cycle. This generalized framework for adaptation planning and implementation mirrors many existing conservation planning and adaptive management approaches and can be used either as a stand-alone planning process, or to inform the incorporation of climate considerations into existing planning and decision-making processes.

this cycle mirrors many existing conservation planning and adaptive management approaches but includes such climate-focused elements as assessing climate-related vulnerabilities (step 2) and reconsidering conservation goals in light of these vulnerabilities (step 3). It is intended for use either as a stand-alone process, or to inform the incorporation of climate considerations into other existing planning and decision-making processes. Although presented in a stepwise fashion, depending on specific needs, one may enter the process at various stages, or emphasize different components. For each stage in this cycle there are various tools, methods, and approaches that may be appropriate. This guide is not so much about prescribing specific tools, analytical processes, or particular adaptation actions. Rather, it is intended to help practitioners make informed choices in designing and carrying out approaches that meet their unique needs and can effectively fit into existing work processes and activities. Indeed, as elaborated on in the next chapter, another overarching principle of this guide is to *integrate adaptation into existing work.*

1.3.1. Moving Past Adaptation Strategies du Jour

The underlying philosophy of this guide is, in some ways, comparable to the difference between offering a book of recipes as distinct from a book on "the way to cook."[2] Following a recipe can be a great way to produce a meal, but does so in a way that replicates a specific culinary vision and requires a particular set of ingredients. In contrast, becoming proficient in different culinary techniques and understanding how various ingredients interact enables one to create meals to match certain interests and make use of seasonally available ingredients. Just as contestants on popular television shows like "Iron Chef" and "Chopped" receive a set of unusual and unexpected ingredients and are challenged to whip them into something tasty and attractive, conservation practitioners routinely face a diverse set of ingredients—various anthropogenic threats, distinctive species assemblages, limited scientific knowledge, budgetary constraints, and social/political/legal challenges—that they need to weave together into coherent conservation strategies and plans. While there may be similarities in certain classes of ingredients (e.g., invasive species, altered ecological processes, fragmentation of habitat, shifts in precipitation patterns), their specific expression combines in unique ways. Accordingly, to craft an effective climate adaptation plan there is a need not only to understand how the system functions and how future changes (climate-related and others) may affect it, but also how it may respond to various types of interventions or conservation techniques. This guide emphasizes the need to be intentional in crafting context-specific adaptation approaches, based on a deliberative process, rather than selecting from someone else's menu, or what might be thought of as the strategies du jour.

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[2] See, for example, *The Way to Cook,* by Julia Child (1989), which uses master recipes to illustrate fundamentals of cooking technique, or *On Food and Cooking: The Science and Lore of the Kitchen,* by Harold McGhee (2004), which explores the science of cooking and the chemical and physical basis for culinary techniques.

1.3.2. Organization of This Guide

This guidance is organized into three main sections. **Part I: Getting Started** introduces climate adaptation and the practice of climate-smart conservation. Chapter 1 introduces the need for climate adaptation and lays out the framework for the guide. Chapter 2 explores the basic concepts of climate-smart conservation, introducing four overarching themes, including the concept of intentionality, while Chapter 3 describes a set of key characteristics for climate-smart conservation, such as linking actions to impacts. In turn, Chapter 4 offers a quick spin around the climate-smart conservation cycle, providing an orientation to how the various steps in the adaptation process fit together and support the design and execution of effective strategies and actions.

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Part II: Putting Principles into Practice delves into further detail of the seven elements of the climate-smart cycle. This includes offering specific guidance on setting the stage, including clarifying the purpose and scope of your planning process (Chapter 5), assessing climate impacts and vulnerabilities (Chapter 6), and ensuring that conservation goals and management objectives are climate informed (Chapter 7). The next two chapters provide guidance for moving from the "assessment" stage of climate change adaptation to the "action" or implementation stage. In addition to identifying a suite of possible management/adaptation options for climate-smart conservation (Chapter 8), we offer input on how to evaluate, compare, and choose among adaptation options to meet your needs (Chapter 9). The final two chapters in Part II address implementation (Chapter 10), especially from the perspective of overcoming common hurdles to putting adaptation into practice, and monitoring (Chapter 11) as a way to track adaptation project effectiveness and ecological responses.

Part III: Making Adaptation Count highlights key tools and information sources to help fill in the blanks and offers suggestions on how to effectively communicate your work to build support among key stakeholders, including policy-makers and the general public. Chapters in this section offer guidance on topics such as dealing with uncertainty (Chapter 12), finding and using best available science (Chapter 13), applying existing policies and authorities to promote climate-smart conservation (Chapter 14), and communicating about climate change and adaptation (Chapter 15).

1.3.3. Building on Best Practices

Adaptation will be relevant to and take place at multiple geographic scales, from sites to broader regions, and from states to entire nations. Although the adaptation principles offered here are applicable across geographic scales, this guide focuses particularly on application of these principles at site to regional scales, largely in response to the need of public and private resource managers to translate these principles into on-the-ground actions. Similarly, the emphasis of this guide is on incorporating climate considerations into project or place-based conservation efforts, rather than at the programmatic level (e.g., agency-wide policies, programs, and regulations). Such policies

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and programs are, of course, major drivers of how specific places and resources are managed and can serve either to promote, or discourage, substantive progress on climate adaptation. Adoption or reform of specific policies can emerge as important actions in place-based adaptation planning efforts.

We also recognize that carrying out climate-smart conservation builds on best practices for conservation and resource management more generally, and it is not our intent to provide guidance for well-understood and broadly applied conservation approaches. Rather, our focus is on how climate considerations can and should inform and be incorporated those practices. Because climate adaptation builds on, and should integrate into, existing practices it is inevitable that there is some overlap in this discussion of climate-smart conservation and the practice of conservation more generally. We have, however, endeavored to focus on and emphasize those aspects of the process that are particularly climate-centric, or where taking climate change into consideration may influence what, where, why, or how managers should carry out their conservation and resource management responsibilities. We also recognize that the approach to climate-smart conservation presented here is but one of several frameworks emerging for improving the practice of climate change adaptation. A number of adaptation planning approaches and tools are emerging, and this guidance on climate-smart conservation draws from and has benefited from many of these other efforts (see Table 5.1 in Chapter 5 for a list of some of these).

As ongoing climate impacts continue to affect habitats and communities across the country, the time to mobilize action on climate adaptation is here. It is our hope that this guidance, together with the associated training course,[3] will promote widespread adoption of the principles and practice of climate-smart conservation as a way to help safeguard our natural resources and precious wildlife heritage. Fortunately, the choice is ours to make. The challenges are great, but there are many actions that we can take today to ensure a better tomorrow. Although we may not have a crystal ball, we have nature as our sentinel, science as our guide, and the foresight of dedicated conservation practitioners ready to develop innovative approaches to ensure that our conservation investments will endure for generations to come.

[3] **Information about the climate-smart conservation training course based on this publication and offered through the U.S. Fish and Wildlife Service's National Conservation Training Center can be found at: http://nctc.fws.gov/.**


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Chapter 2. Exploring Climate-Smart Conservation[4]

Over the past century there have been many important conservation victories and successes, ranging from the establishment of systems of protected lands and waters to the formalized protection of migratory species and endangered plants and animals. Unfortunately, rapid climate change puts much of this conservation legacy at risk, requiring that we consciously prepare for and adapt to a climate-altered future. To do so, we will need to ensure that our conservation policies and practices are designed specifically with climate change in mind—in other words are climate smart. But what is climate-smart conservation, and how does it differ from traditional conservation practice?

Climate-smart conservation can be defined as:

The intentional and deliberate consideration of climate change in natural resource management, realized through adopting forward-looking goals and explicitly linking strategies to key climate impacts and vulnerabilities.

Chapter 1 looked at some of the ways that climate change is affecting species and ecosystems and introduced some of the basic concepts related to the emerging field of climate change adaptation. This chapter elaborates on the brief definition offered above for "climate-smart conservation" by exploring four overarching themes that help define this approach.

Climate-smart conservation should also be seen in the context of a long and continuous progression in the premise and practice of nature conservation. This evolution in conservation practice, and in the environmental movement more broadly, often have been in response to the emergence of new threats to our natural world (or at least new understanding of those threats), such as crashes in waterfowl populations during the dust bowl of the 1930s or Rachel Carson's clarion call about the dangers of unfettered pesticide use in the 1960s. The threats rapid climate change poses to our species and ecosystems similarly is forcing a reassessment of what will be needed to conserve and manage natural resources in the 21st century and beyond. Fortunately, our response to this threat can build on and take advantage of the strong foundations that exist in such fields as conservation biology, restoration ecology, wildlife management, forestry, rangeland management, natural resource economics, and many other disciplines. In this light, climate-smart conservation can be viewed not as an entirely new way of doing conservation, requiring an abandonment of that which came before, but rather as an evolution in the planning and practice of conservation to ensure these efforts can address the pervasive effects of climate change on species and ecosystems in a strategic and rational manner.

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The following four overarching themes help frame our definition of climate-smart conservation and highlight some of its most important attributes.

These are:

- Act with intentionality
- Manage for change, not just persistence
- Reconsider goals, not just strategies
- Integrate adaptation into existing work

[4] Lead authors: Bruce A. Stein and Patty Glick.

2.1. Act with Intentionality

Intentionality[5] is the essence of being climate smart. By this we mean that for climate adaptation to be effective, it must be carried out in a purposeful and deliberate manner that explicitly considers the effects (or potential effects) of climate change on the resources of interest, and that conservation actions should be clearly linked to these impacts. Additionally, there is a need to document that linkage by *showing your work.* Indeed, being deliberate and transparent by showing your work applies regardless of whether adaptation planning indicates a needed change of course with novel strategies, or continues to validate current efforts and traditional strategies.

An emphasis on intentionality is particularly important as climate adaptation becomes more broadly taken up across the conservation community, and cited as justification for an increasingly broad and sometimes indiscriminate set of activities. Hunter et al. (2012), for instance, argue that the "clearest message that emerges from the literature on biological diversity and climate change is that traditional conservation strategies will remain effective," a strategy they refer to as "staying the course." Similarly, many lists of adaptation strategies include some version of "address existing stressors" or "enhance resilience," general approaches that if applied without explicit consideration of climate impacts or vulnerabilities can be used to portray virtually any conservation activity as an adaptation effort.

Existing conservation work and approaches will clearly have an important role in climate adaptation, and in some ways adaptation planning can be thought of as distinguishing when existing strategies and actions continue to make sense, and when new or modified approaches will be necessary. In the face of rapid climate change, however, simply assuming that we should do more of the same, only better, will not be enough. Although most adaptation actions will draw from the existing quiver of conservation tools and techniques, making them climate smart may require a change in when, where, how, and why they are deployed. The "key characteristics of climate-smart conservation," described in Chapter 3, were developed specifically for use as a touchstone in making such determinations. The overall goal of this guide, in fact, is to help improve the incorporation of climate considerations into conservation planning and practice, and ensure that the concept of climate adaptation is not invoked inappropriately and indiscriminately.

Climate-smart conservation emphasizes the need to articulate how proposed actions are expected to link to key impacts and vulnerabilities, and help meet conservation goals. Developing specific conceptual or logic models is a useful way to "show your work" by helping to clarify underlying assumptions and articulate the rationale for how strategies and actions contribute to achieving desired outcomes (Salafsky et al. 2002). Such an explicit articulation of assumptions, causal links, and rationales not only improves the likely effectiveness of the conservation efforts, but provides a basis for ongoing tracking and evaluation of whether those strategies and actions are having their intended results.

Being intentional and deliberate is not unique to climate adaptation, and in this sense tracks broader trends in conservation, exemplified by the emergence of the discipline of systematic conservation planning (e.g., Pressey et al. 2007), and the adoption of more strategic approaches to conservation by a number of organizations and agencies (e.g., Groves et al. 2002, U.S. FWS 2006). Nonetheless, given a general lack of clarity about what qualifies as appropriate climate adaptation, we find that the core attributes of intentionality identified here—linking actions to climate impacts

[5] Our use of the term "intentionality" should not be confused with its use as a philosophical concept (e.g., Le Morvan 2005).

George Gentry/USFWS

and showing your work—can provide a useful antidote to the indiscriminant application of the term adaptation.

The bottom line is that with limited resources and a massive challenge ahead as climate change accelerates, we cannot afford to engage in accidental adaptation, or assume that what worked in the past will continue to be appropriate. Instead, preparing for a climate-altered future will put a premium on acting with intentionality in carrying out adaptation.

2.2. Manage for Change, Not Just Persistence

In the face of current rapid climatic shifts, change is likely to be the only constant. Accordingly, conservationists will need to learn how to respond to and manage inevitable changes, rather than assume they can forever be resisted. From a conservation perspective, a continuum can be thought of as ranging from maintaining status quo conditions through moderate changes to a system, to complete system transformations or ecological regime shifts. Given current trends, conservation will need to shift from emphasizing the preservation and historical restoration paradigm described in Chapter 1, to one that is more open to anticipating and actively facilitating these ecological transitions (Millar et al. 2007, West et al. 2009, Link et al. 2010). In other words, we will need to manage for change, not just persistence.

Approaches to change management can range from resisting changes—in order to protect high-value and climate-sensitive assets—to actively or passively facilitating changes, so that inevitable system transitions might retain desirable ecological attributes, rather than result in complete collapse of ecosystem functions and services. One commonly used framework for adaptation responses to climate change consists of: (1) resistance; (2) resilience; and (3) realignment (Millar et al. 2007, Glick et al. 2011a). Under this framework, resistance actions are intended to forestall impacts to species or systems, thus maintaining status quo conditions. The term "resilience" has multiple meanings (see Box 2.1, p. 28), but in this context typically refers to actions designed to improve the capacity of a system to return to desired conditions after disturbance, or as a means to maintain some level of functionality in an altered state. Realignment in this context refers to efforts that enable or facilitate the transition of ecosystems to new functional states.

Most adaptation work to date within the biodiversity and ecosystem conservation community has focused on promoting resistance and enhancing resilience, often with the intent of achieving a persistence-oriented outcome. Indeed, enhancing resilience has become a common catchphrase among planners and practitioners, although it is most commonly invoked with a focus on the "rebound"-oriented definitions as a means to sustain status quo conditions. In the past few years, however, more scientists and conservationists have begun seriously focusing not just on retaining existing ecological conditions, but also on managing or facilitating what many now see as inevitable system transformations.

Most adaptation work to date within the biodiversity and ecosystem conservation community has focused on achieving persistence-oriented outcomes.

Although the resistance, resilience, realignment framework is widely used, because of the ambiguity of the term resilience (see Box 2.1), this guide adopts an alternate framing for this continuum that ranges from system persistence (or status quo) to system transformation. The level of change regarded as desirable, acceptable, tolerable, or inevitable will be central to the development of future-oriented conservation goals, a topic addressed in the next section and in more detail in Chapter 8.

One complication to putting the concept of managing for change and/or persistence into practice is the scale-dependent nature of these concepts. As an example, facilitating the shift of a species to a new geography would likely be viewed as a change-oriented approach at the local scale, while at a broader scale this same action could be viewed as a persistence-oriented strategy for assuring the survival of the species regionally. Similarly, there may be trade-offs among the various components of biodiversity[6] or conservation values from the perspective of managing for persistence and change. Managing for the persistence of certain ecosystem functions or services (e.g., water supply), for instance, might entail facilitating changes in the species composition or ecological structure of a particular site.

2.2.1. When Is Managing for Persistence Appropriate?

The level of acceptable change in a system (none, some, total) will depend on a variety of factors, ranging from the level of expected impacts, the costs and feasibility of ameliorating those impacts, to the social or economic value of the resource. Thus, even as managing for change increasingly will become a dominant paradigm for conservation in an era of shifting climates, there are situations where managing for persistence will continue to be appropriate, at least in the short term, and in a few instances over the longer term. Determining when and where to manage for persistence depends largely on one's conservation goals and objectives, legal responsibilities, and technical/ecological feasibility. And as described in the next section, in certain instances managers may find it appropriate to deliberately cycle between managing for persistence and change.

[6] Biodiversity components being defined as composition, structure, and function (Noss 1990).

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As discussed in Chapter 14, many laws and regulations are interpreted as obligating agencies to manage for persistence, whether in maintaining lands or waters in a particular condition, basing benchmarks for restoration and remediation on historical conditions, or managing endangered species populations. As one example, under the Stafford Act, which authorizes the federal response to natural disasters, funds currently are available only for replacing homes and other infrastructure (e.g., bridges) to pre-disaster specifications, rather than allowing for relocation or design changes that would enhance their resilience to future climate-induced disasters. This is an instance where managing for status quo conditions clearly is not appropriate, even if it is incentivized under current law.

There are, however, places and times where because of the existence of high value and/or irreplaceable resources managing for persistence may be appropriate, and "buying time" to forestall the effects of climate change may currently be the best option (Gilbert et al. 2010, Pearce-Higgins et al. 2010). Such examples might include sites containing the sole remaining populations of endangered species. In these instances, considering backup or transition plans will be important, in order to link a shorter-term emphasis on persistence with longer-term strategy for change.

In the case of some classes of "climate refugia," a focus on persistence may even be appropriate as a long-term strategy. Although the concept of climate refugia has been used in varying ways, for those areas where the effects of climate change are likely to be buffered, and therefore hospitable for the lasting survival of particular species, persistence may represent a valid long-term aspiration (Ashcroft 2010, Keppel et al. 2011).

2.2.2. Cycling Between Persistence and Change

As addressed in more detail in Chapter 8, one way to articulate the aim of managing for persistence is to prevent systems from crossing thresholds of major change for as long as possible by protecting them from stress and supporting their recovery after major disturbances (e.g., Hansen et al. 2003, Marshall and Schuttenberg 2006, West et al. 2009, Hansen and Hoffman 2011). Managing for transformation, in contrast, may involve assessing where unavoidable threshold changes in ecological systems may be about to happen, and preparing for a different management regime for the altered state. Although these are often portrayed as divergent pathways, managers may often be faced with simultaneously carrying out persistence and change-oriented strategies, and with cycling between the two based on current conditions and goals.

As an example, in managing a particular resource one might seek to buy time for as long as possible by managing the system for persistence. At a certain point this may no longer be tenable, and due to shifts in climate and other interacting stresses the system may begin approaching an ecological threshold that would cause it to transition to one of several alternate states. In advance of reaching that tipping point, management strategies might shift to actively facilitating transition to a new state that, while different, meets desired conservation goals

Box 2.1. Where does managing for resilience fit in?

Perhaps no other word has been used so extensively in the context of climate adaptation as "resilience." Indeed, because of the somewhat arcane and poorly understood nature of the term "climate adaptation" itself, many people are now using "resilience" in its place. Although the term resilience is intuitively appealing and has a positive aura about it, how does it fit with the broader concept of managing in the context of the dual pathways of persistence and change?

Part of the difficulty in answering this question is that the term resilience is used in so many different ways that it is in danger of losing clear meaning. For that reason, it is important to understand the context in which it is being used (e.g., Carpenter et al. 2001, Brand and Jax 2007, Zavaleta and Chapin 2010, Martin-Breen and Anderies 2011, Morecroft et al. 2012).

In the ecological literature, the term resilience was originally used to refer to the ability of a system to maintain or return to a particular ecological state following a disturbance (e.g., Holling 1973, Griffith et al. 2009). Similarly, it can refer to the amount of time it takes for a system to return to a prior state after a disturbance (Morecroft et al. 2012). Under these usages, the underlying conservation purpose of enhancing resilience is likely to focus on preserving particular desired, often status quo, conditions, even if climate change may cause perturbations along the way.

In recent years, the concept of resilience has been used more expansively to embrace the potential for continued functionality and self-organization in the process of ecological transitions. Folke (2006), for example, notes that resilience "is also about opportunities that disturbance opens up in terms of the recombination of evolved structures and processes, renewal of the system, and emergence of new trajectories." In this sense, managing for resilience can be considered a way to enhance the natural adaptive capacity of systems by increasing their ability to self-organize in response to change (Nitschke and Innes 2008, Magness et al. 2011, Martin-Breen and Anderies 2012).

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and outcomes. Once that new state is reached, the focus might again shift to managing that new state for persistence, at least for a period of time.

There are, or course, some important caveats. First, recognizing ecological thresholds is exceedingly difficult; oftentimes tipping points are only identified once they have been crossed. Second, there may be no realistic management actions capable of affecting the trajectory of a system's transformation, or at least not at the scale required. Finally, given ongoing climatic shifts, any new "stable state" may only be transitory. Indeed, the "new normal" will be one of continual change.

2.3. Reconsider Goals, Not Just Strategies

As conditions change, many of our current conservation goals and management objectives may no longer be achievable. Successful climate adaptation will depend not only on adjusting strategies in an effort to meet current goals, but that we reevaluate, and revise as appropriate, our underlying conservation goals and objectives (Glick et al. 2011a, Hobbs et al. 2011, Stein and Shaw 2013). Climate adaptation should not be considered as a goal in and of itself, but rather a means for achieving our conservation goals in a rapidly changing environment (Game et al. 2010). While the prospect of revising goals may be unsettling, the principles and practice of conservation have been far from static over time. Indeed, conservation goals are a reflection of human values, and there has been a continuing evolution in how society understands and values nature and ecological resources.

In the face of climate change, a central challenge for conservationists will be to determine: (1) which ecological resources—ranging from species and habitats to ecosystem services—and their associated societal values should be the focus of conservation attention; and (2) how to manage these ecological resources in ways that continue meeting societal values and expectations. In this sense, values may range from the intangible benefits that people derive from simply knowing a resource exists (i.e., "existence value") to more tangible benefits such as production of food, fiber, or fuel, provision of water, or climate regulation (Kumar 2010). Although science can inform choices about which of these values to emphasize—for instance, helping to understand the implications of managing for one set of values over another—the choices among values ultimately are made in a social and political context.

Most conservation and resource management today is focused either on the protection of biodiversity, the provision of commodities and ecological services, or the maintenance of human well-being and livelihoods, and these values are likely to endure. That said, most biodiversity conservation efforts have largely been based on a paradigm of maintaining existing conditions, or restoring species or ecological systems to some historical state. We often manage for species compositions based on an understanding of "native" ranges, and define many of our conservation goals and objectives with such terms as *natural* and *wild*, and our actions as efforts to *protect, restore, maintain,* and *preserve*. The establishment of national parks and other protected areas represents a tremendous conservation achievement, and has served as a cornerstone for the preservation of species and ecosystems around the world. Nonetheless, traditional conservation plans have resulted in static configurations of protected areas that are often too small to incorporate large-scale dynamic processes. Even where variability and ecosystem dynamics are explicitly recognized, there is a tendency to consider such variability as occurring within a given historical range that is itself unchanging (Wallington et al. 2005, Willis et al. 2009). Increasingly, managers will be challenged to come to terms with what it means to be "natural" or "wild" in an era in which virtually all lands and waters will be influenced by the effects of human-influenced climate change.

Accordingly, a third overarching theme for the practice of climate-smart conservation is the need to not only focus on modifications of strategies in efforts to continue meeting current conservation goals, but to carry out the hard work of clarifying, reconsidering, and as needed, modifying our underlying conservation goals and objectives. In this sense, conservation goals can be regarded as the "ends," and strategies as the "means."

2.3.1. Aligning Climate-Informed Goals and Strategies

To the degree that conservationists have addressed climate change in their work to date, much of the work may be thought of as at the tactical rather than strategic level. Most current adaptation efforts focus on how management practices or strategies might be altered to retain existing conditions and meet legacy conservation goals and values in the face of climate change. For instance, if warming water temperatures in a region are threatening the existence of a cold-water fish, such as eastern brook trout *(Salvelinus fontinalis),* a tactical approach to adaptation considers what actions might keep water temperatures cool enough to enable the trout to persist in the area (e.g., shading streams through restoring riparian canopy). Although such a tactical

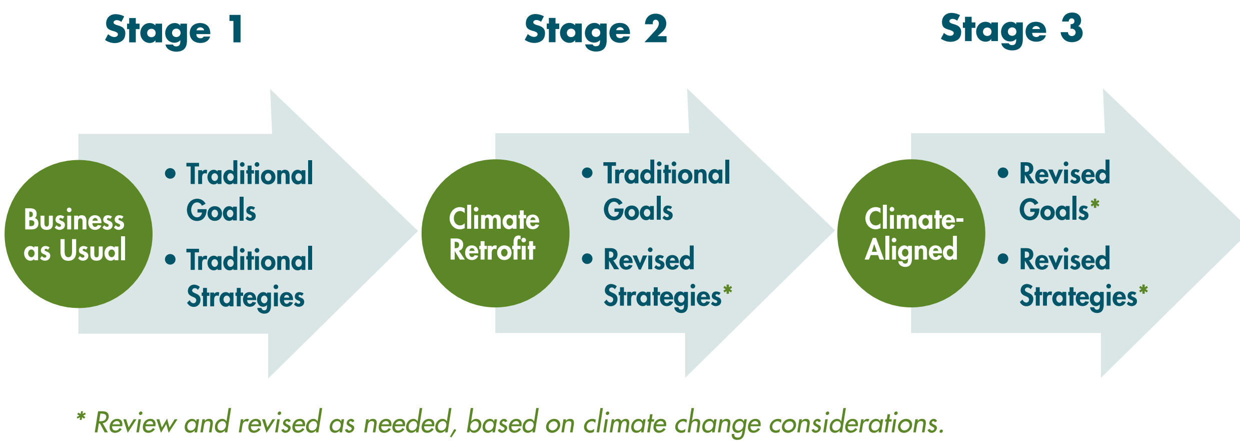

Figure 2.1. Three-stage model for aligning conservation goals and strategies in light of climate change considerations. This model reflects a shift from "tactical" adaptation to more strategic adaptation.

approach to adaptation may be a useful starting point for engaging resource managers, ultimately what will be needed is a more strategic, longer-term vision for how conservation must change given the rate, magnitude, and discontinuity of climate change. Given expected climate change, can the brook trout populations persist across its range with realistic management interventions or do we need to strategically rethink not only management options but underlying conservation goals?

Forward-looking and climate-informed goals should drive the development and selection of adaptation strategies to ensure that they are appropriate and relevant to the situation at hand. Linking climate-informed goals with supportive and relevant adaptation strategies is at the heart of our emphasis on intentionality in adaptation. But specifically, how does the concept of reconsidering goals link with strategies? Figure 2.1 describes a three-stage model for aligning goals and strategies in a climate adaptation context, and more generally for a shift from what can be thought of as tactical adaptation to strategic adaptation.

In Stage 1 of this model *(Business as Usual)* managers pursue traditional goals using traditional conservation strategies and practices, with no significant effort to assess the likely impact of climate change on resources, communities, or management actions, or to address those impacts. Stage 2 *(Climate Retrofit)* represents a tactical approach to climate change in which managers consider the likely effects of climate change on the resources of interest, with strategies or management practices adjusted in ways designed to moderate those impacts in order to continue meeting legacy goals. Stage 3 of the model *(Climate-Aligned)* takes a more strategic view, incorporating a reconsideration and, as necessary, adjustment of underlying goals along with revisions to strategies and practices needed to meet those

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climate-informed goals. As emphasized above, this does not mean that goals and objectives must be modified in all cases, but instead that there should be an intentional review and reevaluation from a climate perspective. Based on that reconsideration, one might determine that no change in goals is necessary, and that either existing strategies continue to make sense in light of projected climate impacts, or that strategies or actions will need to change to meet those climate-informed goals. Conversely, it may become apparent that original goals and objectives are no longer feasible in a changing climate, and that revised or recalibrated goals will be necessary, supported by a set of modified strategies designed specifically to achieve those climate-informed goals.

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2.3.2. Climate-Informed Goals

The result of such reconsideration should be agreement and adoption of a set of climate-informed goals and objectives, which can serve to guide the development of specific adaptation strategies and actions, as well as inform an agency or organization's broader work program. We purposefully use the term "climate-informed goals" rather than "climate-change goals" because incorporating climate considerations into the ongoing work of an agency or organization, rather than establishing separate climate adaptation goals, is essential for integrating adaptation with existing work, the subject of the next section. Such a climate-informed reconsideration may not require a wholesale revision of the goal, but as described in Chapter 7 may reveal the need to modify one or more of the following four distinct components: *what* (the conservation targets); *why* (the intended outcomes); *where* (the relevant geography); or *when* (the relevant time frame).

In summary, what is called for is not necessarily a modification of goals and objectives, but rather an intentional review of goals from a climate perspective. Based on that reconsideration, one might determine that no change in goals is necessary, and that either existing strategies continue to make sense in light of projected climate impacts, or that strategies or actions will need to be revised to meet those climate-validated goals. Conversely, it may become apparent that existing goals or objectives are no longer feasible in a changing climate, and that revised or recalibrated goals will be necessary, together with modified strategies designed specifically to achieve those climate-informed goals. Whichever is the case, linking forward-looking and climate-informed goals with strategies and actions specifically designed to help meet those goals is a foundation for achieving climate-smart conservation.

2.4. Integrate Adaptation into Existing Work

Over the past decade interest and attention to climate adaptation has increased dramatically (Bierbaum et al. 2013, Stein et al. 2013). Nonetheless, most adaptation work has focused more on planning rather than implementation (Moser and Ekstrom 2010). One of the central needs, then, is to find ways to bridge adaptation planning with implementation, and to encourage the adoption and application of climate-smart conservation on the ground. Various hurdles to adaptation implementation exist, ranging from uncertainty surrounding the type, pace, and magnitude of impacts, institutional voids in accountability, competing demands on managers, and lack of financial and other resources. Although considerable work is still required to identify means to overcome these varied hurdles to adaptation (e.g., Moser and Ekstrom 2010), at individual as well as institutional levels, one of the most promising ways to encourage implementation is to seek ways to integrate or mainstream climate adaptation into existing work, rather than have it viewed as something separate and apart (see Chapter 10).

Conservation practitioners must choose how to deploy finite resources, whether that is time, money, or staffing. In addition, they often are faced with responding to the "tyranny of the urgent," and many land managers feel constrained in their ability to focus on what they perceive as longer-term threats, like climate change. Accordingly, an important aspect of integrating adaptation into existing work is to seek approaches for tackling near-term stressors in ways that are consistent with addressing longer-term adaptation needs. Clearly, this will not always be possible, but using climate-smart criteria for choosing among alternatives for dealing with short-term threats can be an effective means of promoting the integration of adaptation with existing work.

In the absence of major new and dedicated funding sources for climate adaptation, incorporating climate-smart thinking and strategies into already-funded work also will be important for getting adaptation carried out. And to the degree that funding does become available specifically for adaptation, much of this will surely be directed toward protecting people and property from climate impacts. As a result, biodiversity and ecosystem adaptation not only must become part of the general practice of conservation, it should be integrated into planning efforts and decision-making processes that provide cross-sectoral benefits (Fazey et al. 2010, Hansen and Hoffman 2011).

Although many local, state, and federal agencies, nongovernmental organizations, and businesses have begun crafting climate change adaptation strategies and plans, adaptation has by no means become what one might consider mainstream. By this we mean that climate concerns and adaptation strategies are still not truly integrated into relevant policies, plans, programs, and projects at all scales of decision-making (Adger et al. 2005, Halsnæs and Trærup 2009). There are, however, signs of progress within government, corporate, and nonprofit sectors in institutionalizing adaptation thinking into policy and practice. Recent presidential executive orders (e.g., EO 13514 and EO 13653) require that federal departments have adaptation plans in place, and both seek to remove or reform barriers to adaptation as well as to support and encourage "smarter, more climate-resilient investments." The Department of Interior has been particularly proactive in encouraging its bureaus to address the impacts climate change on its operations and assets through adaptation planning. And the recently released National Fish, Wildlife and Plants Climate Adaptation Strategy (Box 2.2) provides a high-level road map for integrating climate considerations into many aspects of federal, state, and tribal activities and operations. Similarly, a number of federal and state agencies have begun developing and issuing guidance for incorporating climate considerations into their ongoing operations or existing planning processes (e.g., AFWA 2009, NOAA 2010, CEQ 2011a, Peterson et al. 2011, California Emergency Management Agency and California Natural Resources Agency 2012; see also Table 5.1 in Chapter 5). Nonetheless, integration of climate considerations into planning and operations at the field level is still highly variable, and often absent.

Box 2.2. National Fish, Wildlife and Plants Climate Adaptation Strategy.

The National Fish, Wildlife and Plants Climate Adaptation Strategy (NFWPCAP 2012) was developed collaboratively by federal, state, and tribal governments and outlines key steps to help natural resource managers, private landowners, and others to help safeguard the United States' wildlife and natural systems in a changing climate. The strategy identifies seven high-level goals, many of which focus on integrating climate considerations into the ongoing work of conservation practitioners:

- Conserve habitat to support healthy fish, wildlife, and plant populations and ecosystem functions in a changing climate
- Manage species and habitats to protect ecosystem functions and provide subsistence, recreational, and commercial use in a changing climate
- Enhance capacity for effective management in a changing climate
- Support adaptive management in a changing climate through integrated observation and monitoring and use of decision support tools
- Increase knowledge and information on impacts and responses of fish, wildlife, and plants to a changing climate
- Increase awareness and motivate action to safeguard fish, wildlife, and plants in a changing climate
- Reduce non-climate stressors to help fish, wildlife, plants, and ecosystems adapt to a changing climate

2.4.1. Integrated versus Stand-Alone Planning

Although integrating adaptation into existing work generally is preferred, there may be times when it makes more sense to carry out adaptation planning in a stand-alone manner. Stand-alone adaptation processes may be relevant, for instance, when an agency or organization is using climate change as the primary perspective on its planning, and/or looking at climate impacts and options outside the context of an existing decision-making process. A stand-alone process may also be appropriate when there is a need to gain technical expertise in climate analysis and adaptation planning as a means of demonstrating its feasibility and relevance to other managers and decision-makers.

Because there are times when either integrated or stand-alone approaches to adaptation planning are warranted, this guidance has been designed to support both. In particular, the climate-smart conservation cycle, around which this guide is structured, is intended not just for use in stand-alone adaptation planning. While this cycle has been optimized for use in a climate-centric planning process, the individual steps, as well as the logical sequencing, can inform and be incorporated into many existing planning processes. The ability to transfer and embed core concepts and approaches to climate-smart conservation into existing processes is, in fact, a major reason why the cycle draws from and mirrors many existing planning and implementation processes.

2.5. Recognizing the Limits of Adaptation

Even as the field of climate change adaptation has gained increasing prominence, there is a growing awareness of the limits to adaptation, which can be regarded as when adaptation actions are unable to prevent loss and damage, or avoid intolerable risks (Dow et al. 2013, Preston et al. 2013). Such limits to adaptation tend to revolve around thresholds of an ecological, economic, or technological nature (Adger et al. 2009). For example, there are ecological or physical thresholds beyond which adaptation responses will be unable to prevent climate change impacts from leading to major ecosystem disruptions or loss of biodiversity. Economic thresholds also exist, whereby the costs of adaptation may exceed the costs of the averted impacts (i.e., it is more expensive to adapt than to experience the impacts). Finally, there are technological thresholds beyond which available technologies cannot avert climate impacts (e.g., limits to captive breeding of particular species for ex situ conservation and later reintroduction). In practice, however, economic and technological thresholds are highly dependent on social constructs, and influenced by attitudes to risk, values, and ethics (Adger et al. 2009). Accordingly, the limits of adaptation should be seen as dynamic rather than static, particularly as perceptions shift regarding how much and what kinds of risks may be tolerable.

The rate, magnitude, and character of climatic changes will influence whether and when these limits are exceeded. As an example, a system may be capable of accommodating a level of change that occurs gradually, but may not be capable of accommodating the same amount of change if it takes place more rapidly. If faced with enough external change, species and systems will exceed their adaptive capacity (even with the benefit of targeted adaptation actions), and cross ecological thresholds. Depending on the extent of future climate change, even with the most aggressive adaptation strategies, society may be unable to prevent irreversible losses of biodiversity or serious degradation of ecosystems and their services.

It looks increasingly likely that the global average temperature increases during this century will exceed the 2°C target that a number of scientists and policy-makers have identified as a target threshold for avoiding “dangerous anthropogenic interference” with the climate system (Anderson and Bows 2008, Mann 2009, IEA 2011). Accordingly, the need to cope with increasing climate impacts will only become more acute with higher levels of warming. The paradox is that even as the need for adaptation becomes more intense and urgent, the effectiveness of adaptation efforts may be compromised as the aforementioned ecological, economic, and technological thresholds are exceeded (Stein et al. 2013). This paradox highlights the importance of viewing adaptation as a process rather than an outcome, and as fundamentally about managing for (and even facilitating) change, rather than resisting change.

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Chapter 3. Key Characteristics of Climate-Smart Conservation[7]

The previous chapter focused on four overarching themes for climate-smart conservation, but putting these general principles into practice requires a deeper look at what it means be climate smart. Indeed, an overall goal of this guidance is to help policy-makers and practitioners understand what constitutes "good" adaptation, and how to recognize those characteristics in existing work, as well as how to design new interventions when necessary. Determining what represents relevant adaptation is highly context specific, but there are a number of traits that can help distinguish when and whether climate considerations are appropriately being incorporated into conservation work. To assist practitioners in making that distinction, we have identified a set of key characteristics that collectively define a climate-informed approach to conservation (Box 3.1, p. 38).

This set of "key characteristics of climate-smart conservation" is not intended to capture all traits of good conservation generally. For instance, partnerships and priority setting, to name just two, are broadly recognized as important elements of modern conservation practice. Rather than attempt to encompass the broader topic of what makes for successful conservation, this set of characteristics highlights those particularly relevant from a climate adaptation perspective. Similarly, although several of these characteristics are unique to climate adaptation, others are equally applicable to conservation generally. These characteristics are intended to promote the intentional and deliberate design and implementation of climate adaptation efforts. Given the considerable uncertainties associated with climate change, these characteristics also emphasize qualities that promote agile approaches to management that can account for inevitable surprises.

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These key characteristics can be thought of as touchstones as one moves through the climate-smart conservation cycle. The characteristics have particular salience in step 5 of the cycle, which focuses on evaluation and comparison among possible adaptation options, and accordingly Chapter 9 draws from these characteristics to suggest a number of possible criteria for evaluating adaptation alternatives.

We recognize that not all adaptation efforts will meet each of these characteristics, nor that each will necessarily be appropriate in all situations. Nonetheless as a set, they offer a vision for how conservation should look to effectively address climate change. That said, we consider the first two characteristics—linking actions to climate impacts and embracing forward-looking goals—to be at the heart of climate-smart conservation and essential elements of effective adaptation.

Linking actions to climate impacts and embracing forward looking goals are at the heart of climate-smart conservation.

[7] **Lead authors: Patty Glick and Bruce A. Stein.**

Box 3.1. Key characteristics of climate-smart conservation.

Link actions to climate impacts
Conservation strategies and actions are designed specifically to address the impact of climate change in concert with existing threats; actions are supported by an explicit scientific rationale.

Embrace forward-looking goals
Conservation goals focus on future, rather than past, climatic and ecological conditions; strategies take a long view (decades to centuries) but account for near-term conservation challenges and needed transition strategies.

Consider broader landscape context
On-the-ground actions are designed in the context of broader geographic scales to account for likely shifts in species distributions, to sustain ecological processes, and to promote collaboration.

Adopt strategies robust to uncertainty
Strategies and actions ideally provide benefit across a range of possible future conditions to account for uncertainties in future climatic conditions, and in ecological and human responses to climate shifts.

Employ agile and informed management
Conservation planning and resource management is capable of continuous learning and dynamic adjustment to accommodate uncertainty, take advantage of new knowledge, and cope with rapid shifts in climatic, ecological, and socioeconomic conditions.

Minimize carbon footprint
Strategies and projects minimize energy use and greenhouse gas emissions, and sustain the natural ability of ecosystems to cycle, sequester, and store carbon.

Account for climate influence on project success
Considers how foreseeable climate impacts may compromise project success; generally avoids investing in efforts likely to be undermined by climate-related changes unless part of an intentional strategy.

Safeguard people and nature
Strategies and actions enhance the capacity of ecosystems to protect human communities from climate change impacts in ways that also sustain and benefit fish, wildlife, and plants.

Avoid maladaptation
Actions taken to address climate change impacts on human communities or natural systems do not exacerbate other climate-related vulnerabilities or undermine conservation goals and broader ecosystem sustainability.

3.1. Link Actions to Climate Impacts

Conservation strategies and actions are designed specifically to address the impact of climate change, in concert with existing threats; actions are supported by an explicit scientific rationale.

As noted in Chapter 2, linking actions to climate impacts is part of the very essence of climate-smart conservation. Clearly and transparently demonstrating such a link is an integral part of the intentionality that helps define the practice of climate adaptation. In this context, climate impacts include both direct effects, such as changes in temperature or precipitation patterns, as well as indirect effects, such as disruptions to ecological interactions or increased toxicity of contaminants. As climate adaptation increases in prominence, there may be a temptation to relabel existing practices and projects as adaptation. Climate adaptation actions—whether based on traditional practices or involving novel approaches—should therefore demonstrate an explicit understanding or hypothesis for how they are likely to reduce key climate-related vulnerabilities or take advantage of climate-related opportunities.

Developing meaningful adaptation strategies requires an understanding of the impacts, risks, and uncertainties associated with climate change, and the vulnerability of relevant natural features, and associated human values, to those changes. It also requires an understanding of how management actions and other activities may moderate or exacerbate those vulnerabilities. The emphasis here is on development of an explicit scientific rationale for the action based on an understanding (or hypothesis) of causal pathways and that specifies underlying assumptions. Developing and applying such an understanding can be facilitated through use of a structured and logical process, such as embodied in the climate-smart conservation cycle, or other climate adaptation planning frameworks referenced in Chapter 5.

3.1.1. Linking Actions to Impacts for Hawaiian Forest Birds

Hawaiian forest restoration along the slopes of Mauna Kea offers an example of linking on-the-ground adaptation actions to specific climate impacts. Native Hawaiian birds have experienced dramatic declines and widespread extinctions due to a variety of factors ranging from loss of habitat to the spread of nonnative infectious diseases. Avian malaria, spread by introduced mosquitoes *(Culex quinquefasciatus),* in particular has devastated many native Hawaiian bird populations (van Riper et al. 1986). Due to physiological thermal constraints on the mosquito vector, avian malaria generally is limited to lower and middle elevations, with cooler upper-elevation forests providing a relatively disease-free refuge for native birds. As air temperatures in the islands rise due to climate change, mid-elevation bird populations are not only projected to experience increased exposure

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to warming temperatures, but also increased exposure to these disease vectors. In response to these projected climate-related impacts, a forest restoration effort currently is underway, designed to reconnect mid-elevation mesic and wet forests of the Hakalau Forest National Wildlife Refuge with the upper-elevation woodlands of the Mauna Kea State Forest Reserve. Reestablishment of this forest corridor is designed to provide native bird populations with the ability to shift up in elevation in response to rising temperatures, and have continued access to disease-free habitats.

3.2. Embrace Forward-Looking Goals

Conservation goals focus on future, rather than past, climatic and ecological conditions; strategies take a long view (decades to centuries) but account for near-term conservation challenges and needed transition strategies.

Embracing forward-looking goals is another characteristic that is at the very core of what it means to be climate smart. As discussed in Chapter 2, rapid climate change will undermine the feasibility of achieving many existing conservation goals, and necessarily force difficult choices about how to reconcile our existing societal values with the many changes that are underway.

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Natural resources management traditionally has been implemented under the assumption that weather patterns, species and habitat ranges, and other environmental factors will remain consistent with historical trends and ranges of variability. In the context of a changing climate, the use of past conditions as the benchmark for setting conservation goals will be increasingly problematic. Accordingly, climate change adaptation will require that we focus our conservation goals and objectives on future, rather than past, climate and ecological conditions. This does not mean that historical information is irrelevant. Indeed, information from the paleoecological and historical record is essential for understanding how climate has shaped the evolution of life on earth, and how species and ecosystems have responded over time to changes in climatic variables. Recognizing how ecosystems (and societies) have responded to past climatic variability and disturbances can provide a powerful tool for understanding how such systems might respond to future changes.

With managing for change (see Section 2.3) emerging as a dominant theme in climate adaptation, conservation goals increasingly will need to be framed in the context of transformations, not just on the persistence of existing conditions or restoration to historical states. We recognize that near-term threats and urgent conservation challenges will often dominate the work of resource managers and conservation practitioners. Adoption of clearly defined, forward-looking, and climate-informed goals can serve as useful guideposts for confronting near-term challenges in ways that are consistent with, rather than divergent from, longer-term adaptation needs.

3.2.1. A Forward-Looking Conservation Plan for the Coachella Valley

With its forward-looking and climate-informed goals, the Coachella Valley Multiple Species Habitat Conservation Plan is an example of climate-smart conservation in action (Taylor and Doremus 2011). Approved in 2008, the plan is an effort to balance protection of native desert species and habitats with development in a fast-growing area of Riverside County, California. An early impetus for this regional conservation effort was the federal listing of the Coachella fringe-toed lizard *(Uma inornata)* under the Endangered Species Act, and recognition of the importance of landscape-scale processes for maintaining the lizard's increasingly scarce sand dune habitat. Specifically, these dunes depend on a long-term source of wind-blown sand that emanates from sometimes-distant mountain canyons and floodplains (Griffiths et al. 2002). The

2008 plan addresses far more than the needs of this one species, however, and was crafted as a means to both address the conservation needs of numerous at-risk species and habitats in this rapidly developing area, and to provide an alternative to cumbersome and piecemeal procedures for obtaining endangered species–related permits for development and infrastructure-related activities.

The plan lays out a vision for protecting nearly a quarter million acres of desert in a regional reserve system that incorporates multiple native ecosystem types and natural communities across their "natural range of variation," and that is designed to sustain at least 27 rare or endangered species (CVMSHCP 2007). Importantly, the plan explicitly seeks to "manage the system adaptively to be responsive to short-term and long-term environmental change and to maintain the evolutionary potential of lineages," particularly in the face of climate change. In support of this goal, a number of management actions are directly linked to climate impacts, including the potential for extreme events such as floods and drought and projected shifts in species' ranges as climate conditions change. For example, the plan recognizes the need to incorporate "a range of environmental gradients (e.g., slope, elevation, aspect) and high habitat diversity to provide for shifting species distributions" in its efforts to conserve habitat. It seeks to "provide suitable areas to act as refugia" in the event of disturbances. And it identifies target habitat in areas that are "intermediate climatically" to conditions in current habitat areas to provide effective corridors for species movements. The plan also exemplifies another key climate-smart characteristic—considering the broader landscape context (see next section)—as a way of ensuring that important ecological and evolutionary processes continue to sustain target species and habitats.

Climate-informed goals can serve as guideposts for confronting near-term challenges in ways consistent with longer term adaptation needs.

3.3. Consider Broader Landscape Context

On-the-ground actions are designed in the context of broader geographic scales to account for likely shifts in species distributions, to sustain ecological processes, and to promote collaboration.

Conservationists have long recognized the importance of taking a large landscape approach, and the emergence of the discipline of ecosystem management in the 1990s helped to institutionalize such thinking. Nonetheless, with climate-driven range shifts in species already underway, the need for considering the broader landscape context takes on an added significance from the perspective of climate adaptation.

On-the-ground adaptation actions should be designed in the context of broader spatial (geographic) scales for both ecological and sociopolitical considerations (Game et al. 2011, Groves et al. 2012, Hilty et al. 2012). From an ecological perspective, management of individual species populations or communities in static protected areas may no longer be tenable under climate change, given the strong potential for dynamic range shifts, emergence of novel assemblages, and changes in biotic interactions (Joyce et al. 2008, Monzón et al. 2011). Effective adaptation will require greater emphasis on lands and waters under varying intensities of human use as well as enhanced connectivity among protected habitats (Kostyack et al. 2011). Planning across larger landscapes will be important for managing shifts in the spatial distribution of species and habitats, as well as for underlying ecological processes.

From a sociopolitical perspective, landscape approaches promote the type of coordination and collaboration across management jurisdictions that will be especially important for successful adaptation (Hansen and Hoffman 2011). This will be necessary for turning institutional barriers, such as those related to management of shared resources, distrustful relationships, and management objectives that are at odds with one another, into opportunities for partnerships based on shared goals and trust (West et al. 2009). Private landowners will increasingly become important stakeholders in achieving climate-smart conservation based on this broader landscape perspective.

Considering the broader landscape in one's adaptation work is not necessarily the same as carrying out actions at a landscape scale. Many if not most conservation and resource management activities are localized and place based, and are not generally applied across large geographies. (There are exceptions to this, including broad-based policy prescriptions, and large-scale ecological restoration efforts, such as restoration of water flows in the Everglades.) Similarly, considering the broader landscape does not mean that conservation efforts should be focused only at higher ecological levels; there will be a continued need for both coarse-filter and fine-filter approaches to conservation, including species-level efforts (Noss and Cooperrider 1994, Stein et al. 2000). In summary, this key characteristic is not necessarily about applying conservation actions across vast acreages—although there are times when that is appropriate—but rather understanding and taking the broader landscape context into account in the design and execution of conservation projects and resource management actions, whether focused at species, habitat, or ecosystem levels.

3.3.1. Targeting Local Sites to Connect Broader Landscapes

Restoration of a riparian corridor along the upper Pajaro River of Central California is an example of a local-scale climate adaptation project designed in the context of a much broader landscape. This intensively modified agricultural area has been identified as a key ecological connector for three major coastal mountain ranges, each of which harbors globally and regionally significant biodiversity resources (Spencer et al. 2010). Enabling wildlife movement among these ranges long has been identified as an important conservation strategy, but assessments of projected climate impacts in the area, and the effect on regional biodiversity, has elevated the importance of reconnecting these landscapes as an adaptation measure (Klausmeyer et al. 2011). In response, state and private conservation partners are acquiring agricultural lands along the upper Pajaro to reestablish riparian buffers and create a functional ecological connection among these major landscape features. The Nature Conservancy, for example, recently acquired a 165-acre agricultural property that, but for its role in achieving this broader landscape-scale conservation vision, is unlikely to have merited a major conservation investment.

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3.4. Adopt Strategies Robust to Uncertainty

Strategies and actions ideally provide benefit across a range of possible future conditions to account for uncertainties in future climatic conditions, and in ecological and human responses to climate shifts.

Successful conservation in an era of climate change will require greater acceptance of decision-making under uncertainty. Managing under uncertain conditions is not new to conservation and resource management practitioners. Nonetheless, the cumulative effect of uncertainties in: (1) how the climate is changing, (2) how ecological resources are likely to respond to those changes, and (3) how human activities may respond to climate impacts, create added complexities for the development of effective conservation strategies. Perhaps because uncertainty in climate shifts—due both to different emissions scenarios as well as variation in climate models—is something relatively new for natural resource managers, it has emerged as a major impediment to engaging in adaptation planning. Finding effective ways to take uncertainty into account in the development and execution of adaptation strategies and actions will be an essential component of climate-smart conservation (Chapter 12 provides a fuller discussion of managing under uncertainty).

Some management responses are likely to be effective in meeting conservation goals under a range of potential future conditions, while others may be tailored to a specific future scenario. Wherever possible, selecting strategies that are robust across multiple plausible futures is a sound means for ensuring that management actions are buffered against future uncertainty. This is not to say that actions optimized for a single possible future should not be seriously considered or carried out. All other things being equal, however, those capable of performing well under a broader range of future conditions would be a better choice, and by some definitions can be regarded as "no-regrets" or "low-regrets" strategies.

When future conditions are fairly certain, it makes sense to ask: Which actions will produce the single best outcome? When there is significant uncertainty about future conditions, however, it may make more sense to ask: Which actions give the best chance of some acceptable outcome? This approach, called robust decision-making, is essentially a bet-hedging strategy. Rather than maximizing the chance of the single best outcome, it seeks to maximize the likelihood of an acceptable outcome.

3.4.1. Designing Fish Habitat for Uncertain Flows

Streamside restoration along the Lower Black River in Lorraine, Ohio, provides an example of how project designs can be modified to offer benefits across a range of potential future conditions. This restoration site is located in a highly industrialized area that previously was part of a steel mill. As part of a broader environmental remediation and ecological restoration effort, plans called for planting native vegetation along the shore as well as constructing in-stream habitat features, including fish shelves to provide aquatic breeding habitat. An assessment of possible climate effects on the area highlighted the uncertain nature of future streamflows in the river; in particular, concerns emerged about the ability of the constructed fish shelves to provide suitable habitat at varying, and especially low, water levels. As a result, rather than constructing the shelves at a single depth, as called for in the original plans, the design was modified to create shelves at several different depths (Inkley 2012). An analysis of the proposed modification found that construction costs did not increase substantially and accordingly, this more robust approach for addressing climate-related uncertainty at the site is now being put into place.

3.5. Employ Agile and Informed Management

Conservation planning and resource management are capable of continuous learning and dynamic adjustment to accommodate uncertainty, take advantage of new knowledge, and cope with rapid shifts in climatic, ecological, and socioeconomic conditions.

Given the pace of change confronting managers, it will become increasingly important to employ agile forms of management that can quickly respond to changing ecological and socioeconomic conditions. Doing so puts a premium on continual learning and on improved understanding of the condition and trends in resources, and on how these resources are responding to climate effects, other stressors, and any management actions. In short, there is a need for agile and climate-informed management.

Adaptive management is perhaps the best known approach for continuous learning and refinement of management practices (Franklin et al. 2007, Williams et al. 2009), but is not the only available approach for employing agile and informed management in the face of climate change (other examples include scenario-based planning and robust decision-making; see Chapter 12). Adaptive management, however, can greatly facilitate the ability of conservation planners and resource managers to respond to the uncertainty associated with climate change (Lawler et al. 2010b). This includes identifying actions that are directly tied to climate-informed management objectives, modeling potential outcomes, implementing strategies, monitoring their efficacy, and periodically adjusting strategies to better ensure achievement of goals (Heinz Center 2008). Furthermore, adaptive management facilitates a culture of continuous learning and dynamic adjustment to accommodate uncertainty, which is especially important when managers are attempting to cope with rapidly changing conditions across multiple fronts (e.g., not only climatic and ecological, but also socioeconomic) (Lawler et al. 2010b).

There are, however, limitations in the use of adaptive management in adaptation, both in terms of the conditions under which it is optimally effective, and the relative difficultly many managers have in implementing it in a rigorous form (Westgate et al. 2013). For instance, adaptive management works best under conditions with high uncertainty but high management controllability (Peterson et al. 2003). It is also important to note that while adaptive management can be an important part of climate adaptation planning and management, they are not the same thing. Unfortunately, because of their semantic similarity, adaptive management is sometimes erroneously used as a synonym for adaptation.

The ability to track how conditions are changing, as well as the effectiveness of management actions, is central to employing agile and informed management approaches. Developing and carrying out management-relevant monitoring is key to understanding when modifications or course corrections may be needed. Monitoring, however, often is an afterthought in project design and implementation, reducing its effectiveness in informing decisions. Identifying potential performance indicators during the evaluation and selection of adaptation options, as discussed in Chapter 9, can help ensure that monitoring protocols are directly supportive of management decisions. In the context of change management, well-designed monitoring protocols are particularly important for detecting when ecological thresholds might be reached, or have been exceeded, which may necessitate a change in management strategies or objectives.

3.5.1. Adaptively Managing Restoration of San Francisco Bay Salt Ponds

The South Bay Salt Pond Restoration Project illustrates how well-designed monitoring protocols can support adaptive decision-making and agile resource management. More than 85% of San Francisco Bay's tidal wetlands have been lost, with many of these marshes converted to industrial salt ponds. A major salt pond restoration effort currently is underway that aims to transform about 15,000 acres of ponds in the southern portion of the bay to a mosaic of tidal wetlands and managed pond habitats. In addition to restoring important wildlife habitat and providing recreational opportunities, the restoration project is intended to provide climate adaptation benefits through serving as a natural buffer for sea-level rise and the effects of increased coastal flooding and erosion on adjacent communities, which include portions of the high-tech region known as "Silicon Valley." As part of the project design, an adaptive management plan was developed that identifies alternative system trajectories that differ in the relative proportion of managed pond and tidal habitats (Trulio et al. 2007). To account for uncertainties in system development and trajectories, the restoration effort is being implemented in phases, with a number of applied studies and monitoring efforts linking to specific restoration and management actions. These studies focus especially on bird use of changing habitats, mercury contamination issues, and public access–wildlife interactions. Based on evaluation of performance metrics from initial project phases, managers will be able to make dynamic modifications in restoration techniques in order to calibrate the balance among restored habitat types.

Jitze Couperus/Flickr

3.6. Minimize Carbon Footprint

Strategies and projects address greenhouse gas emissions and concentrations through minimizing energy use and sustaining the natural ability of ecosystems to cycle, sequester, and store carbon.

Climate-smart conservation strategies must also take climate mitigation considerations into account. Although adaptation is about addressing the impacts of rapid climate change, adaptation actions should not aggravate the underlying problem of global warming. Indeed, minimizing the carbon footprint of adaptation actions can help society avoid the "worst-case" scenarios for climate change, which would make successful adaptation in human and natural systems difficult, if not impossible, to achieve. Ideally, adaptation efforts should contribute to meeting climate mitigation goals both by minimizing or reducing the greenhouse gas emissions from project operations, including from any construction and ongoing maintenance, as well as by managing natural systems in ways that sustain or enhance their ability to cycle, sequester, and store carbon.

Some of the most obvious synergies between adaptation and mitigation are those aimed at enhancing carbon stocks in natural forests, and carbon sequestration increasingly is becoming a major consideration in forest management. Strategies for increasing the capture and storage of forest carbon include: avoiding deforestation; afforestation (i.e., establishment of trees in areas have not been forests or where forests have not been present for some time); decreasing forest harvest; and increasing forest growth (McKinley et al. 2011). Managing natural systems to provide carbon benefits must be carefully balanced, however, with other conservation and adaptation goals. For example, although some forest management activities, such as thinning for fuel reduction or prescribed burns, may result in near-term releases of carbon, they are important for ensuring longer-term carbon capture and storage, including by reducing large pulses of carbon emissions from major wildfires (Stephens et al. 2009). Similarly, strategies for increasing forest carbon have often emphasized new plantings or younger forests, under the assumption that younger trees are more efficient at fixing carbon than older trees. Recent research, however, indicates that old trees "do not act simply as senescent carbon reservoirs" but actively fix larger amounts of carbon than smaller trees (Stephensen et al. 2014). This recognition highlights the important role that biodiversity-rich old-growth forests can play in sequestering carbon.

In addition to the obvious significance of forests for storing carbon, considerable carbon stocks exist in grasslands, shrublands, and coastal and marine habitats (sometimes referred to as "blue carbon"). Climate impacts on these diverse ecosystem types can undermine their carbon storage benefits, and adaptation efforts designed to maintain the integrity and functioning of natural ecosystems, including carbon cycling, can therefore contribute to achieving climate mitigation goals. For example, reforestation efforts that use ecologically appropriate tree species can improve habitats and reestablish landscape connectivity while at the same time providing carbon sequestration benefits. Similarly, certain agricultural practices can help replenish soil carbon and provide erosion control and other adaptation benefits (Lal et al. 2011).

Conversely, poorly designed climate mitigation projects can be detrimental to ecosystem health and undermine adaptation objectives, such as planting trees in native grasslands or promoting the use of ecologically destructive invasive species, such as giant reed *(Arundo donax),* for bioenergy feedstocks (Glaser and Glick 2012). It is not always obvious, however, when conservation and climate mitigation efforts might be in alignment or in conflict. In California, for example, the longstanding practice of flooding rice fields in the winter, which provides substantial benefit to waterfowl and other water birds, now is recognized as a significant source of methane, a potent greenhouse gas (King et al. 2010). Although there are clear synergies between adaptation and mitigation-focused activities, managers will also need to carefully consider any trade-offs. Just as adaptation actions (and conservation efforts more generally) should seek to minimize their carbon footprint, climate mitigation activities should seek to avoid compromising the adaptive capacity of natural systems and conflicting with adaptation goals.

3.6.1. Keeping Carbon in the Great Dismal Swamp

An effort designed to improve water management in the Great Dismal Swamp of Virginia illustrates how climate adaptation and climate mitigation can be mutually supportive. The Great Dismal Swamp covers more than 110,000 acres of wetland forest, which includes large amounts of carbon-rich peatlands. Climate change is projected to cause more significant periods of drought in the region, increasing stress on these wetland forests. The system's ability to cope with dry periods has been diminished, however, by a network of drainage ditches that have altered hydrological characteristics, resulting in drying of many

Mike Petruncio/USFWS

normally moist peat soils and increasing their susceptibility to wildfires. Peat fires, once started, are notoriously difficult to extinguish because they can burn underground over long periods. For example, in 2008 a peat fire in the Great Dismal Swamp burned for 121 days and covered about 4,800 acres, while a 2011 fire lasted 111 days and burned more than 6,000 acres. Peat soils are extremely rich in carbon, and peat fires are therefore a major source of carbon emissions; these two fires alone released an estimated 4 million metric tons of carbon into the atmosphere (Harball 2013). With U.S. Department of Interior Hurricane Sandy Recovery funds, the Great Dismal Swamp National Wildlife Refuge is working to install water control structures to counter the effects of the existing drainage ditches. Installation or repair of these structures is intended to help retain water in the refuge during dry weather, keeping peatlands moist and decreasing their fire risk. During wet weather, these structures will provide flood protection benefit for downstream communities, an excellent example of providing societal co-benefits (see Section 3.8, Safeguard People and Nature). In this instance, adaptation efforts focused on maintaining and restoring the health of the wetlands helps keep carbon locked in the refuge's peat soils.

3.7. Account for Climate Influence on Project Success

Considers how foreseeable climate impacts may compromise project success; generally avoids investing in efforts likely to be undermined by climate-related changes, unless part of an intentional strategy.

The threat of climate change challenges us to maximize the value of our conservation investments under both current and future climate conditions. In order to ensure that the benefits from those investments will endure, we must be

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mindful of how climate change may affect the success of on-the-ground conservation projects, and how those projects might be best designed and implemented to improve their effectiveness. Accounting for the impacts of climate change on project success applies both to projects undertaken for traditional conservation reasons, as well as to projects designed specifically to provide climate adaptation benefits.

Climate impacts may compromise project effectiveness in multiple ways ranging from changes in the underlying physical environment (e.g., sea level, water availability), modifications to the ecological context (e.g., species mixes, fire frequency), or intensification of socioeconomic pressures (e.g., land use). Determining potential climate change influences on projects entails a form of risk analysis: How likely are the climate-related impacts? How significantly would they reduce the project's ability to produce intended outcomes? Over what time frame would the impacts take effect and compromise project benefits. The timing of impacts is especially significant, since in some cases the conservation benefits provided during the functional period may continue to justify an investment. This is especially true where projects serve as a bridge or transition to a longer-term adaptation response. For example, acquisition of a salt marsh projected to be submerged in 15 years by sea-level rise may not on its own be regarded as a priority conservation investment, particularly if it is hemmed in by seawalls. If a marsh similarly susceptible to sea-level rise is adjacent to available undeveloped land, and therefore might serve as the basis for inland marsh migration, the acquisition might be have a more favorable cost–benefit ratio and therefore be a higher priority for investment.

Accounting for climate impacts on project success can result in differing responses, depending on the value and scarcity of the resource, intended life span of the project (especially relative to timing of impacts), and other ecological, social, and financial factors. One might conclude that the ecological (or social) benefits derived during the effective life span of the project are sufficient regardless of the projected reduction in benefits. Alternatively, there may be specific adaptation options available that could reduce the key climate-related vulnerabilities and enhance the likelihood of project success. Or, one might conclude that the project would be so severely compromised over the relevant timescale that conservation investments are better directed elsewhere.

3.7.1. Investing in Land Protection for Long-Term Benefit

Over the past few decades the field of private land conservation has grown dramatically, and local, state, and national land trusts have protected more than 45 million acres through acquisition or easements (LTA 2011). Many of these lands were acquired to safeguard them from development or conversion to incompatible land uses under the premise that once acquired they would be protected "in perpetuity." In the face of climate change, the permanence implied by "in perpetuity" is, at least in an ecological sense, increasingly ephemeral. One major investor in private land conservation, the Doris Duke Charitable Foundation, has made a strategic shift in its land conservation grant-making priorities to help ensure the long-term value of its capital investments. Since 1997, the Duke Foundation has invested more than $110 million dollars in land conservation grants, facilitating the protection of more than 2.5 million acres (McBryde and Stein 2011). Concerned that climate change could erode the long-term value of its capital investments, the foundation has adopted a strategy for targeting new land capital grants toward landscapes that have been identified as resilient to climate change, based primarily on work developed by Anderson et al. (2012). These "resilient landscapes" are based on the heterogeneity of topographic, geological, and microclimatic features (sometimes referred to as "enduring features"), and on high levels of ecological connectivity with other such landscapes. Investments being made in these landscapes will help protect existing suites of species and habitats, but by targeting areas believed to be less vulnerable to climate impacts these investments are also intended to provide long-term benefit even as species and ecological communities shift over time.

3.8. Safeguard People and Nature

Strategies and actions ideally enhance the capacity of ecosystems to reduce climate vulnerabilities for people as well as wildlife, and to sustain the benefits natural ecosystems provide to both.

Ideally, climate change adaptation strategies and actions will not only sustain and benefit species and ecosystems, but also provide co-benefits for people. Connecting these two will become increasingly important as climate impacts increase, and place demands on scarce financial and other resources for adaptation. This is not to say that

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providing benefit to human well-being must always be an outcome of climate-smart conservation efforts—and there undoubtedly will be places and times where this is not the case—but the provision of benefits to other sectors of society will greatly increase the opportunities for gaining acceptance for and implementing needed strategies and actions.

In recent years there has been an increasing emphasis within the conservation community on the benefits provided by natural systems to human societies, otherwise known as “ecosystem services.” The role of natural systems in providing services to society includes such things as crop pollination, provision of clean water, hydropower production, flood regulation, and carbon storage (MEA 2005, Ash 2010). While provision of such societally important services may be desirable in conservation generally, the focus of this key characteristic is more specifically on how natural systems can provide climate adaptation benefits to human communities, a concept termed “ecosystem-based adaptation.” Ecosystem-based approaches to adaptation have been defined as efforts to “harness the capacity of nature to buffer human communities against the adverse impacts of climate change through the sustainable delivery of ecosystem services” (Jones et al. 2012). Relevant services may focus especially on disaster risk reduction, sustainable water management, and food security. Ecosystem-based adaptation as a concept has seen greater adoption internationally, although it is gaining attention in the United States (Colis et al. 2009, Vignola et al. 2009, World Bank 2010).

The use of ecosystem services to provide societal benefits is often referred to as “green infrastructure.” Perhaps the most extensive application of the green infrastructure concept is for storm-water management and flood risk reduction, although the term also is used to refer to open-space conservation more generally (Benedict and McMahon 2006). Green infrastructure is rapidly emerging as a key concept for climate adaptation, particularly in urban contexts where it is viewed as having the ability to improve storm-water management, reduce the incidence of combined storm and sewer overflows, reduce urban heat island effects, decrease flood and storm-surge risks, a buffer against sea-level rise (Feagin 2008, Foster et al. 2011). Although the use of green infrastructure intuitively is more appealing than reliance on hardened structures (i.e., gray infrastructure), green infrastructure approaches vary considerably, and do not all provide significant ecological benefits.

An emerging distinction in the application of this concept is between "natural features," which are the product of natural physical, geological, or biological processes, and "nature-based features," which are engineered and constructed to emulate the functions and services of natural features (U.S. ACE 2013). Use of these approaches has been most extensive in coastal areas as a means to reduce flooding risks from sea-level rise and coastal storms (Borsje et al. 2010, Gedan et al. 2011). Evaluating the performance of natural and nature-based features in reducing risks under various conditions is still a key issue, as is determining where and when they are likely to be most appropriate and effective.

3.8.1. Reducing Erosion and Supporting Fisheries with Constructed Oyster Reefs

The use of artificially constructed oyster reefs for coastal restoration in Alabama and throughout the Gulf of Mexico demonstrates how adaptation actions can help safeguard both people and nature in the face of sea-level rise and coastal storms. With thoughtful design, these structures can provide more ecologically sound alternatives to vertical seawalls, bulkheads, and other structural armoring for protecting coastal properties from shoreline erosion by dampening wave energy, rather than deflecting it back into nearshore waters (NOAA 2007). They also provide complex, structured habitats that support many finfish and shellfish species, not just the oysters themselves. Accordingly, a coalition led by a variety of local, state, and federal partners have established the 100-1000 Restore Coastal Alabama project, which aims to build 100 miles of oyster reef and expand 1,000 acres of seagrass and marsh habitat along Alabama's coast. As part of the project, more than 500 volunteers installed the first segment at Helen Wood Park in Mobile Bay in 2011. Within 10 months of its construction, the reef was already supporting marsh grasses, fish, and birds. Furthermore, similar reefs installed in the region in 2008 proved to be highly resistant to damage from waves during major hurricane events (Heck et al. 2010). Such "living shoreline" approaches offer a promising example of ecosystem-based adaptation in action.

3.9. Avoid Maladaptation

Actions taken to address climate change impacts on human communities or natural systems do not exacerbate other climate-related vulnerabilities or undermine conservation goals and broader ecosystem sustainability.

Finally, we must work to ensure that actions taken to address climate change impacts on one system or resource (whether natural or human) do not exacerbate other climate-related vulnerabilities or undermine conservation goals and broader ecosystem sustainability. Adaptation efforts that create more problems than they solve are more aptly called maladaptation (Easterling et al. 2004, Fazey et al. 2010). Barnett and O'Neill (2010) define maladaptation as an "action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups." These authors recognize at least five distinct types or pathways for maladaptation, which include actions that, relative to their alternatives, increase emissions of greenhouse gases, disproportionately burden the most

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vulnerable, have high opportunity costs, reduce incentives to adapt, or set paths that limit the choices available to future generations (Barnett and O'Neill 2010). Maladaptation is more likely to occur when climate impacts are considered on particular system components in isolation, without assessing the net benefit within and across sectors.

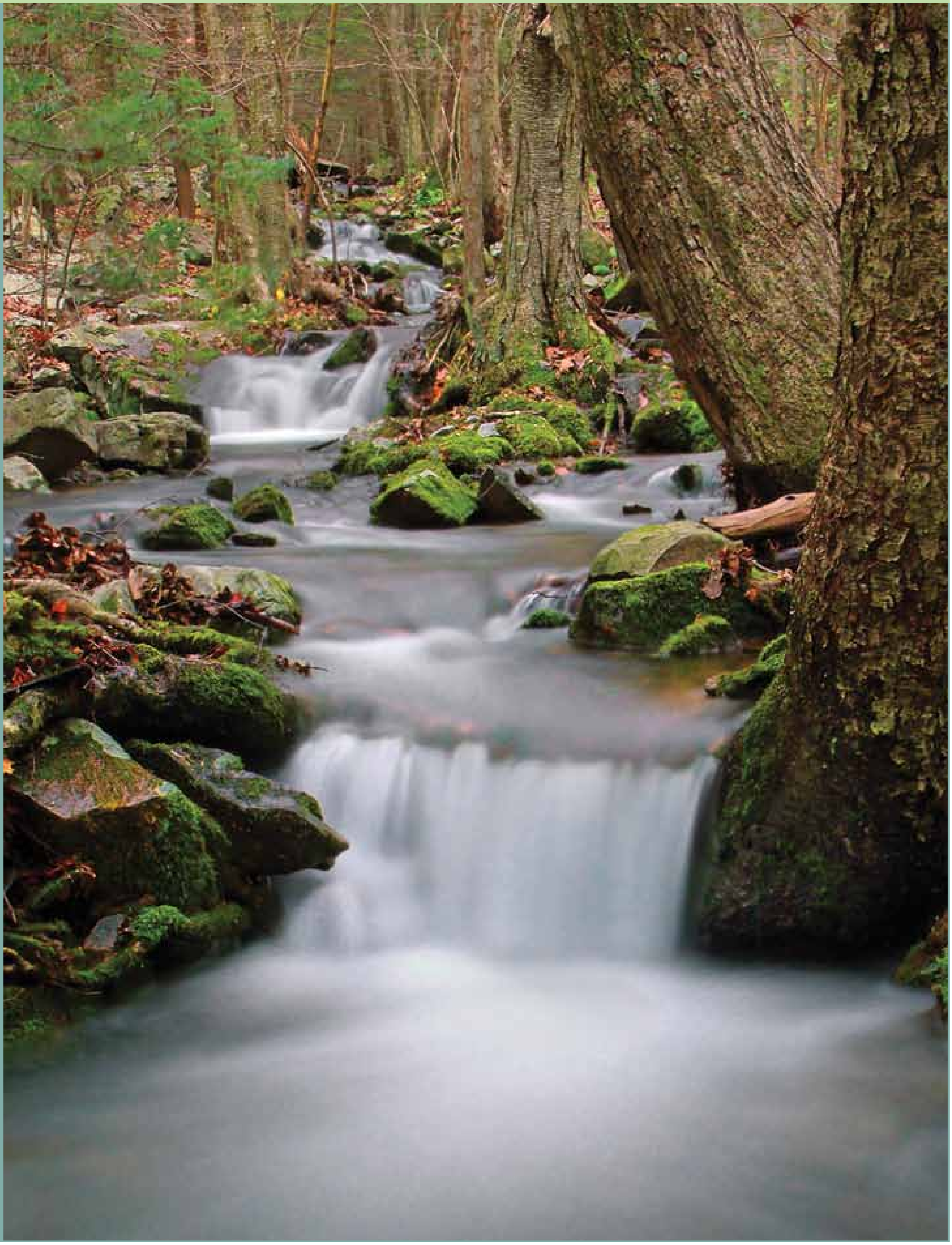
Maladaptation more generally may be thought of as a type of trade-off, something most resource managers deal with regularly. Many trade-offs involve conflict between ecological values and human interest, such as water allocations (McShane et al. 2011). There are also many examples of trade-offs between different conservation values, such as whether to emphasize management for one species or habitat type at the expense of another. It is also important to note that not taking action, and allowing certain climate impacts to proceed unimpeded, can result in other trade-offs. Accordingly, oftentimes inaction—and its attendant ecological and economic costs—can be maladaptive.

3.9.1. Unintended Consequences of Mountain Pine Beetle Control

Maladaptation can take many forms, as illustrated by the unintended consequences of mountain pine beetle *(Dendroctonus ponderosae)* control efforts in British Columbia. Western pine forests are in the midst of a massive outbreak of mountain pine beetle that is causing widespread tree mortality in the Rocky Mountains and into Canada. Although historical records indicate periodic pulses of tree mortality from this native insect species, the current infestation is unprecedented in scope and severity. Climate change is a major contributing factor to the outbreak, particularly the lack of extreme cold winter temperatures that historically have kept insect populations in check. Forests in British Columbia have been especially hard hit, and according to the Provincial Ministry of Forests, Lands and Natural Resource Operations beetles have affected more than 18 million hectares (an area larger than Vancouver Island) and killed 723 million cubic meters of timber. In an effort to control the outbreak, foresters applied an arsenic-containing pesticide (monosodium methanearsonate) to half a million trees across 14% of the province. The widespread application of this pesticide raised concerns about toxicity effects on boreal forest birds, and particularly on woodpeckers which feed extensively on the beetles. Not only did researchers document that the pesticide applications posed a significant risk to forest birds (Morrissey and Elliott 2011), but the pesticide treatments were ineffective at stemming the beetle infestation. As a result, the Provincial Ministry discontinued use of the pesticide treatments and issued policy guidance that, due to human health concerns, prohibits the harvesting and milling of treated trees (Price 2013). In this example of maladaptation, not only was the management action ineffective at addressing the underlying impact (i.e., the climate-fueled beetle infestation), but it increased the risk to forest biodiversity, created human health concerns, and undermined the economic value of the beetle-killed trees.

Dezene Huber

Maladaptation is more likely to occur when climate impacts are considered on particular system components in isolation, without assessing the net benefits within and across sectors.



Nicholas A. Tonelli

Chapter 4. A Spin Around the Climate-Smart Conservation Cycle[8]

Carrying out effective climate adaptation involves an array of activities that can at first seem bewildering in their complexity and use of specialized terminology. The intent of this guide is to help natural resource practitioners understand the fundamentals of climate-smart conservation by demystifying this process and by demonstrating how the various parts of this process fit together. To that end, we have developed a generalized framework for climate-smart conservation that breaks this process down into discrete steps (Figure 4.1). Each of the steps in this cycle, of course, has its own set of processes associated, some of which may be highly technical and complex and others less so and more conceptual. Because there is no one-size-fits-all approach to adaptation, our primary interest is in helping practitioners understand how the pieces of the adaptation process fit together, and how to recognize when various methods and approaches for carrying out the different steps are appropriate. This chapter provides an overview of this generalized adaptation framework—the climate-smart conservation cycle—and introduces the various steps in the cycle, each of which is covered in greater detail in Part II.

4.1. Overview of the Climate-Smart Conservation Cycle

Although climate change often is discussed as though it is something entirely new, the process for adaptation planning does not differ dramatically from many existing conservation planning approaches. In general, one still needs to: define the purpose and scope of the planning effort; assess the condition of, threats to, and conservation challenges of the resources of interests; identify conservation and management alternatives; select and implement suitable management strategies and actions; and monitor the results and assess management performance. What is different is the need to look at this process through a climate change lens, mindful of the four overarching themes we introduced in Chapter 2 (acting with intentionality; managing for change, not just persistence; reconsidering goals, not just strategies; and integrating adaptation into existing processes), as well as the key characteristics of climate-smart conservation described in Chapter 3.

Jim Cummins

As introduced in the first chapter, this guidance is structured around a generalized framework for adaptation planning and implementation in the context of conservation—what we refer to as the climate-smart conservation cycle (Figure 4.1, p. 56). While specific approaches to implementing this cycle will no doubt vary depending on one's particular situation, the steps put forth lay the groundwork for a process that embraces the principle of intentionality in adaptation. Although the steps of this cycle are presented in a linear and stepwise fashion, we must emphasize that depending on a project or initiative's particular

[8] Lead authors: Patty Glick and Bruce A. Stein.

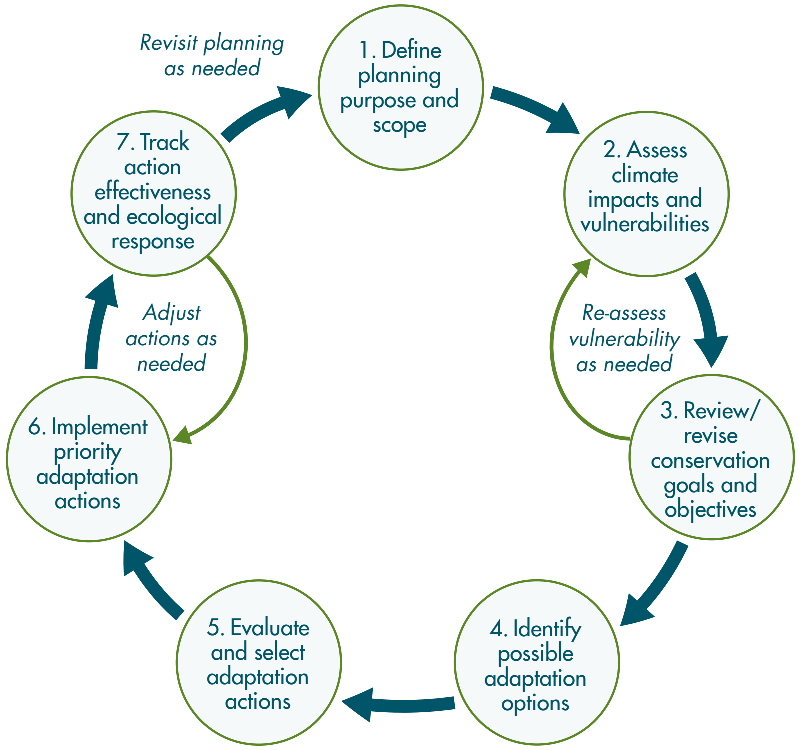


Figure 4.1. Climate-smart conservation cycle. This cycle can serve as the basis for undertaking a "stand-alone" adaptation planning effort, or can be used to help incorporate climate considerations into existing planning and decision-making processes. The steps in this cycle serve as the basis for the more detailed discussions that are the focus of Part II of this guide.[9]

needs and state of development, one may enter the cycle at various points, emphasize various aspects of this cycle, or even use an alternative sequence. There will often be more iterative steps than are reflected by the relatively few "back loops" shown in this simplified diagram.

It is also important to recognize that adaptation planning need not be a "stand-alone" process. Consistent with the theme of integrating adaptation into existing work, it will often make more sense to integrate climate-smart thinking into existing planning processes, rather than to embark on a new and separate planning effort. Indeed, by design, the climate-smart cycle mirrors many existing conservation planning processes and follows the "plan–act–check–adjust" approach of many adaptive management processes (e.g., Williams and Brown 2012). This parallel structure is intended to facilitate the incorporation of this framework into processes already in use by different organizations and agencies. This sequence of steps, however, is designed specifically with climate change in mind, particularly through an emphasis on assessing climate-related vulnerabilities (step 2) and reconsidering conservation goals and management objectives (step 3) in light of those vulnerabilities.

Regardless of the specific method used, the overarching goal of adaptation planning is to ensure that plans, strategies, and actions reflect an intentional approach to reducing climate-

[9] The climate-smart conservation cycle builds on the adaptation cycle included in our earlier guidance on vulnerability assessment (Figure 1.1. in *Scanning the Conservation Horizon* [Glick et al. 2011c]), but offers a more detailed and granular view of the steps in the adaptation planning and implementation process.

related risks by clearly articulating how the actions selected are likely to reduce key climate-related vulnerabilities or enhance a system's climate resilience. What follows is a brief introduction to each of the steps in the climate-smart conservation cycle designed to lay the groundwork for the more detailed guidance contained in Part II.

4.2. Identify Planning Purpose and Scope (Step 1)

Clearly defining the purpose and scope of the adaptation planning exercise is essential for designing an efficient and effective process and for selecting an appropriate course of action. This includes clearly articulating the purpose for developing an adaptation plan, clarifying existing conservation goals, determining such things as relevant geographic scope, time horizons, conservation targets, identifying key stakeholders and their needs, and available resources. The overall intent of this step of the climate-smart cycle, which is elaborated on in Chapter 5, is to ensure that the planning process is well aligned with users' needs, and can be accomplished with the resources (e.g., time, money, expertise, data) that are available.

Many different tools and techniques can be used at various stages of the planning cycle, and oftentimes there are strong advocates promoting one tool, technique, or approach over others, often based on familiarity, existing expertise, or other factors. Investing sufficient time up front to define the desired outcomes from the planning effort is key to selecting planning approaches and techniques that are well suited to producing a useful result and successfully implementing the selected actions. In particular, the following five linked considerations can assist in laying the groundwork for designing and executing climate-smart conservation.

Articulate planning purpose. As with any planning process, having a clearly defined purpose is paramount. What is the nature of the decision at hand? Who will be implementing the plan? Being clear about the specific decisions the plan is intended to support will help ensure that the process will lead to a successful outcome.

Clarify existing conservation goals. Having a clear understanding of existing goals and objectives, which sometimes are implied or unspoken, rather than explicit, is essential for identifying relevant conservation targets, as well as the scope and scale of the planning effort. Clarifying existing goals and objectives provides a baseline for determining later in the process (e.g., step 3) if there is a need for them to be modified or refined in light of climate change.

Identify conservation targets. Identifying the biological or ecological features that should be the target of the planning effort (e.g., particular species, ecological communities, processes, or ecosystem services) is important for appropriately designing and scoping subsequent aspects of the adaptation planning process.

Specify geographic scope and time frame. Similarly, clearly defining the relevant geography and timescale are important for determining the scope of the planning process. Taking climate change into account will often require that spatial and temporal scales be greater that what is used in many traditional planning efforts.

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Engage key participants and partners. Having an understanding of who key participants and partners are in the process (internally and externally), what their needs are, how they would act on the resulting information, and how they might expect to be engaged provides important context for designing a successful planning and implementation process.

Determine resource needs and availability. As is the case with conservation planning more generally, adaptation planning must also be scaled to available resources, which includes such factors as time, money, staff, expertise, and data.

4.3. Assess Climate Impacts and Vulnerabilities (Step 2)

Understanding the likely effect of climate changes on the systems of interest is crucial for designing effective adaptation strategies. Climate change vulnerability assessments provide an essential tool for identifying management and planning priorities, and assist in crafting effective adaptation strategies and actions (Glick et al. 2011c).

In the context of conservation, vulnerability to climate change generally refers to the extent to which a species, habitat, ecosystem, place, or project is susceptible to harm from climate change impacts. Vulnerability typically is viewed as having three basic components: (1) *exposure*, which is a measure of how much of a change in climate and associated impacts (e.g., sea-level rise or ocean acidification) the target species or system is likely to experience; (2) *sensitivity*, which is the measure of whether and how a particular species or system (natural and/or social) is likely to be affected by or responsive to particular changes in climatic variables and/or related factors (such as altered fire regimes or hydrologic cycles); and (3) a*daptive capacity,* referring to a species or system's ability to accommodate or cope with change, which includes both innate and extrinsic characteristics associated with the conservation target, as well as relevant institutional factors.

Vulnerability to climate change can be considered a relative concept, where some species, systems, individuals, or communities are more vulnerable and others are less vulnerable, or may even benefit. Vulnerability assessments typically are designed to identify which species or systems are more or less vulnerable, information that can contribute to setting priorities for adaptation and conservation investments. Vulnerability assessments on their own, however, do not define such priorities: depending on the goals of the conservation effort, priorities may emphasize the most vulnerable, the least vulnerable (what often are referred to as most resilient), or some combination. Vulnerability assessments can also help identify why the species or systems are (or are not) vulnerable. Such an understanding is especially important for linking actions to impacts, and crafting specific adaptation strategies and actions capable of reducing these vulnerabilities.

Chapter 6 describes various approaches to vulnerability assessment in greater detail, offering insights into how they support the broader task of developing climate-smart conservation strategies and actions. Of particular significance is the process of winnowing down from among the full array of identified vulnerabilities and identifying a subset of the most consequential impacts, or *key vulnerabilities.* In this regard, key vulnerabilities can be defined as those vulnerabilities that pose the greatest risk for achieving one's agreed-upon conservation goals and objectives. Adaptation planning is largely about setting priorities for action, and the identification and use of "key vulnerabilities" offers a way to provide a sharper focus to the subsequent design of adaptation options and actions.

4.4. Review/Revise Conservation Goals and Objectives (Step 3)

Assessing the climate change vulnerability of one's conservation targets may lead to a redefinition of the problems in need of attention, as well as raise questions about the continued relevance and feasibility of existing conservation goals and objectives. Because goals serve as the basis for the development and evaluation of adaptation strategies and actions, conducting a climate-informed review and reevaluation of goals and objectives is an essential aspect of *acting with intentionality,* which is at the heart of climate-smart conservation. Such a considered review may result in the validation of existing goals and objectives, or point to the need for modifications or refinements. The overall intent, as described more fully in Chapter 7, is to adopt an agreed-upon set of climate-informed goals, whether those reflect existing or revised goals and objectives.

Reconsidering goals might take place at almost any point in the process ... or even viewed as a touchstone for the entire cycle.

Using the results of a vulnerability assessment makes this (step 3) a logical place in the climate-smart cycle to carry out such a review and reevaluation of goals. This stage in the process is not, however, the only time or place that goals might be evaluated for continued relevance. Indeed, such an evaluation of goals might take place at almost any point in the process, or even viewed as a central touchstone for the entire cycle. For instance, one might discover during the identification and evaluation of adaptation options (steps 4 and 5) that there are no possible actions that could result in achieving the agreed-upon goals. Such a realization might trigger the need for another review and revision of one's goals and objectives. Based on a redefinition of goals, it may even be necessary to reassess vulnerabilities (step 2).

Reconsidering conservation goals can by psychologically challenging, but distinguishing among discrete components of goals and objective can provide a useful structure and make the task less intimidating. We identify four components of goals and objectives that may serve as a basis for conducting such a reevaluation:

- **What** (the conservation *target* or subject of the goal)

- **Why** (the intended *outcomes* or desired condition)
- **Where** (the relevant *geographic scope*)
- **When** (the relevant *timeframe*)

Crafting climate-informed goals and objectives may not require wholesale revisions to one's goals. Rather, climate-focused modifications may only be necessary to one or more of these specific components.

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4.5. Identify Possible Adaptation Options (Step 4)

With a climate-informed set of goals and objectives in hand, it is now time to turn to the development of a broad array of adaptation strategies and options designed to reduce the "key vulnerabilities" (identified in step 2 of the cycle). At this stage in the process it is important to be specific about the climate effects of greatest concern, and to think creatively and expansively about how those vulnerabilities might be reduced. Above all, this stage of the adaptation process is the time to be innovative and bold, in order to generate the broadest possible array of adaptation options. Indeed, what may not seem feasible now may look much more reasonable in the future as climate impacts intensify.

An understanding of vulnerability (and its components of exposure, sensitivity, and adaptive capacity) provides a structured means for thinking about and identifying possible adaptation options. Various mechanisms can be used for generating an array of possible adaptation options, and Chapter 8 explores in detail one approach that relies on a suite of general adaptation strategies as a springboard for generating more specific adaptation options and actions. Generating these options should be based on a line of logic or rationale that describes the mechanism by which the proposed action can be expected to reduce the vulnerability (which can include enhancing adaptive capacity) of the conservation target to the climate-related stress. At this stage in the process, the generation of options should be based primarily on their likely effectiveness from an ecological standpoint, and at the potential for helping achieve one's conservation goals and management objectives. A broader evaluation and winnowing of options, based on other factors and values is also necessary, and the evaluation, comparison, and selection among options is subject of the following stage (step 5) in the climate-smart cycle.

Development of adaptation options should also take into consideration the dual pathways of managing for persistence and change, and the potential for cycling between the two over time. For instance, in the near term relevant adaptation options may focus on addressing shorter-term and more urgent threats in order to maintain extant system types, components, or functions, while over the longer term, as system changes become increasingly inevitable and transformative, adaptation actions may need shift away from maintaining status quo conditions and toward facilitating system change.

4.6. Evaluate and Select Adaptation Options (Step 5)

The broad array of adaptation options identified in step 4 can now be evaluated and compared to determine which best meet the broad array of objectives and values brought to the table by those making and affected by the decision. While the previous step focused on identifying a range of possible options for reducing climate-related vulnerabilities, this stage of the cycle focuses on narrowing from among these possibilities to select those actions to actually carry out. Of particular interest are actions that address near-term conservation challenges in ways that simultaneously advance longer-term adaptation strategies.

Choosing among adaptation options will depend on a range of factors, depending on the particular needs, interests, and resources. Chapter 9 describes four general classes of criteria that can be useful for evaluating and comparing among alternatives:

(1) Conservation goals. How well do the alternatives help achieve agreed-upon conservation goals and objectives?

(2) Other goals/values. How well do the alternatives help achieve broader societal (e.g., social, cultural, economic) goals and objectives, or provide co-benefits to other sectors?

(3) Feasibility. How practicable or realistic is it to implement the various alternatives?

(4) Climate-smart considerations. How well do the alternatives conform to the principles and characteristics of climate-smart conservation?

The first of these focuses on how effectively possible alternatives are capable of addressing key vulnerabilities and help meet one's conservation goals and objectives, while the second addresses the broader range of societal goals and values (including possible "co-benefits"). The third set of criteria addresses various factors that might facilitate or hinder successful implementation of the adaptation action, and include such varied considerations as cost, technical feasibility, and institutional capacity. The final set of criteria is explicitly climate-centric, and draws on the "key characteristics of climate-smart conservation" (Chapter 3).

Chapter 9 describes a process for organizing and screening alternative actions or sets of actions, evaluating them against the types of criteria described above, comparing them by exploring their performance against these criteria as well as trade-offs, and then selecting the preferred

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action or sets of actions to put into practice. Key to the evaluation process is identifying a suitable set of criteria, creating metrics for measuring how well alternatives meet those criteria, and determining whether and how those criteria should be weighted. A variety of decision tools and approaches exist that can be useful for making one's selection, and balancing among the various criteria, as well as factoring in such issues as risk tolerance. Regardless of the specific decision process used—whether formal or informal—it is critical to do so in a transparent and open manner and to "show your work."

4.7. Implement Priority Adaptation Actions (Step 6)

Putting adaptation principles into practice requires that the priority strategies and actions identified through the planning process are actually carried out. To date, the number of adaptation plans that have reached the implementation phase remains limited, in part due to the relative newness of the field. This is changing as the number of adaptation planning efforts grows, and as adaptation is incorporated in a variety of other planning and decision processes. Implementing adaptation actions will be similar in many ways to carrying out other conservation and resource management projects, and accordingly can build on existing best practices for implementation. As a result, Chapter 10 does not attempt to cover general guidance for design and delivery of conservation projects generally, but instead draws from emerging adaptation examples to highlight some key barriers to implementing adaptation, and identify opportunities for overcoming those hurdles and successfully moving to project implementation.

Among the barriers to putting adaptation plans into action are concerns about the uncertainties associated with climate change, and more specifically the discomfort among some managers of basing decisions on model-based projections. Other barriers include limited conservation resources, divergent public perceptions about climate change and resulting implications for political will, and a wide variety of institutional and leadership factors.

Successful approaches to adaptation vary widely, depending on many local and context-specific factors, and there is no one best approach or "right" or "wrong" ways to move adaptation forward. Nonetheless, among the factors that can improve the outcome of adaptation implementation, and which are discussed in Chapter 10, are:

- Mainstreaming adaptation planning into existing efforts
- Focusing on cross-sector benefits and synergies
- Engaging diverse partners early on
- Demonstrating success
- Taking immediate action, but keeping sight on transformative change

4.8. Track Action Effectiveness and Ecological Responses (Step 7)

Climate-smart conservation is necessarily an iterative process, and monitoring efforts can help ensure that adaptation strategies and actions are having the desired effect, as well as help discern when and where changes in tactics might be needed. Tracking ecological change is especially important in light of the significant climate-related uncertainties confronting conservationists. Additionally, well-designed monitoring is important for putting several of the climate-smart characteristics into practice, including linking actions to impacts and employing agile and informed management practices.

As with implementation, an extensive body of best practices exists related to monitoring and evaluation, and adaptation efforts should draw from, rather than attempt to reinvent, these practices. Nonetheless, climate change introduces added complexity to the equation, and as discussed in Chapter 11, may require shifts in what to monitor (i.e., priorities and indicators), where to monitor, when to monitor, and, possibly, even who participates in the monitoring, data analysis, and reporting. In particular, designing monitoring strategies that accommodate future conditions will require much more dependence on model projections and the development of scenarios.

Although the climate-smart cycle depicts monitoring as the final stage (step 7) of the process, we must emphasize that the design of monitoring efforts begins well in advance of this, and the results of well-designed monitoring inform virtually every step in the cycle. Of particular significance are any criteria and metrics that come out of the process for evaluating adaptation options (step 5). Clearly, these criteria can help target the design and focus of specific monitoring activities.

Chapter 11 also presents a stepwise approach for integrating a climate change adaptation perspective into monitoring, which include: developing clear goals and objectives; compiling existing information; developing conceptual models; identifying and selecting relevant indicators; defining your sampling design and methods; and conducting data management and analysis. This more detailed look at the monitoring process is primarily intended for managers who will be designing and executing adaptation projects.

4.9. Fitting It All Together: A High-Level Process Map

The steps of the climate-smart cycle are designed to work together, with each step building on previous steps, and often providing input to subsequent stages in the cycle. As an aid to understanding how these steps fit together, Table 4.1 provides a high-level process map of the cycle. This process map can be viewed as a "crib sheet" for the overall cycle, summarizing the intended

Table 4.1. High-level process map. This table summarizes for each step in the climate-smart conservation cycle intended outcomes, needed inputs, and desired outputs, noting interdependencies among steps.

Climate-smart cycle step	Intended outcome	Inputs	Outputs
1. Define planning purpose and scope	Design an appropriate planning approach based on needs and resources available	Existing goals/objectives Existing plans/decision processes Resource availability/constraints	Clearly defined user needs/problem statement Identified conservation targets Identified geographic/temporal scales Appropriately scaled planning approach
2. Assess climate impacts and vulnerabilities	Identify vulnerabilities to serve as basis for designing adaptation actions	Clearly defined user needs/problem statement (from step 1) Identified conservation targets/focus (from step 1) Defined spatial and temporal scope and scale (from step 1)	Relative vulnerabilities of conservation targets Understanding of factors contributing to their vulnerability Identification of "key vulnerabilities"
3. Review/revise conservation goals and objectives	Adoption of climate-informed conservation goals and management objectives	Existing goals/management objectives (from step 1) Understanding of system/target vulnerabilities (from step 2)	Agreed-upon set of climate-informed conservation goals/management objectives
4. Identify possible adaptation options	Identify array of possible options for reducing key vulnerabilities or enhancing adaptive capacity	Key vulnerabilities (from step 3) Factors contributing to those vulnerabilities (from step 3)	Specific actions capable of reducing key vulnerabilities or enhancing adaptive capacity Explicit rationale or logic model for how identified actions link to climate-related impacts
5. Evaluate and select adaptation actions	A set of operationally feasible actions that collectively help meet climate-informed conservation goals	Agreed-upon climate-informed goals (from step 3) Array of possible adaptation actions (from step 4)	Set of preferred adaptation actions for implementation Coherent plan based on selected actions Possible performance/evaluation metrics
6. Implement priority adaptation actions	Successful implementation of selected strategies and actions	Priority actions for implementation (from step 5) Implementation challenges identified during strategy and action evaluation and selection (from step 5)	Set of actions put into practice
7. Track action effectiveness and ecological response	Inform needed adjustments in adaptation strategies and actions	Adaptation actions selected for implementation (from step 5) Possible performance metrics (from step 5)	Management-relevant changes in ecological resources documented Improved knowledge of climate impacts and ecological responses

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outcomes from each step, necessary inputs (indicating dependencies on previous steps where appropriate); and desired outputs (some of which serve as inputs to subsequent steps). As described above, and elaborated in Part II, there may be multiple approaches or methods for carrying out any particular step. Whichever specific technical approaches used for a given step, however, should be capable of achieving the intended outcomes described in this table, and producing the expected outputs.

4.10. Case Study: Climate-Smart Conservation for Coastal Impoundments in Delaware

For coastal managers across the eastern seaboard, dealing with the impacts of climate change is already a part of daily life, as a combination of sea-level rise, land subsidence, and enhanced coastal storms are contributing to inundation and erosion of both human and natural systems. The Mid-Atlantic region is an epicenter for sea-level rise, with local sea levels rising three to four times the global average (Sallenger et al. 2012). Accordingly, developing strategies to prepare for and cope with these impacts has become a priority for many natural resource managers across the region.

One issue of concern is the impact these changes are having on the region's coastal impoundments, which provide important habitat for migratory birds and other wildlife, help control mosquitoes, and support numerous recreational activities (Erwin 1986, Meredith et al. 1995). For example, since 2009, impoundments at Prime Hook National Wildlife Refuge in coastal Delaware have been breached multiple times during storms, including in 2012 by Hurricane Sandy, allowing salt water to intrude into the freshwater marshes (U.S. FWS 2012, 2013). Such breaches, and the resulting saltwater intrusion, are significantly degrading the quality and extent of bird habitat on the refuge and elsewhere in the region.

In anticipation of similar sea-level-rise-related impacts on state-managed coastal impoundments, the Delaware Division of Fish and Wildlife (DFW), a part of the state's Department of Natural Resources and Environmental Control, initiated an adaptation planning process designed to identify measures for ensuring the long-term availability of quality habitat in the face of these climate change impacts (Kane 2011). This effort to proactively manage for change along the Delaware coast provides an example of how the various elements of the climate-smart conservation cycle can be applied in practice.

Step 1. Defining planning purpose and scope. The key issue of concern is that many of Delaware's coastal impoundments are likely to be affected by both sea-level rise and the impacts from more frequent and severe storms given their low elevation and proximity to the shore. Impoundments can become flooded or even completely overtaken by seawater, forming large open-water areas with associated increased salinities. These changes can significantly alter the key habitats and wildlife values for which impoundments are being managed. Because of the multiple factors at play in managing impoundments in Delaware, ranging from construction and maintenance of infrastructure such as levees, to operations of water control devices, the planning team decided to engage in a formal "structured decision-making" (SDM) process. In addition, the National Wildlife Federation, in collaboration with the agency, convened an expert panel to identify climate-smart options that resource managers could consider for impoundment management. To guide these planning processes, the agency adopted as its overall goals to: (1) maintain a coordinated system of coastal impoundments to meet wildlife, fish, and human objectives, and (2) incorporate cost constraints and uncertainty associated with sea-level rise impacts into long-term management decisions.

Step 2. Assessing climate impacts and vulnerabilities. In 2012, the Delaware Coastal Programs and the Delaware Sea Level Rise Advisory Committee completed an assessment of the potential impacts of sea-level rise on the state's coastal resources, including impoundments, under several scenarios for eustatic sea-level rise: 0.5 meters, 1.0 meters, and 1.5 meters by 2100 (DNREC 2012). The assessment entailed five stages:

(1) *Identification of resources of concern.* Workgroups were established to identify the key issues of concern in light of projected sea-level rise.

(2) *Data collection.* Existing geographic data sets were used for this assessment.

(3) *Exposure assessment.* Locations of resources of concern were overlaid with the three scenarios for sea-level rise to identify exposure.

(4) *Impact assessment.* Based on the exposure assessment, committee members provided input about the potential direct impacts (e.g., loss of land and wetlands) and secondary impacts on economic, environmental, and social systems.

(5) *Risk assessment.* As a final step, workgroup members engaged in a risk assessment exercise to consider the combined consequences of sea-level rise exposure with the potential impacts, and those resources were then ranked as high, moderate, low, or minimal concern.

Through this assessment process, the consequences for the state's coastal impoundments were identified as a high concern. Even under a sea-level-rise scenario of 0.5 meters, 81% of the state's acreage of impounded wetlands has the potential to be inundated or lost. This could have a significant impact on important conservation targets, including habitat for birds such as red knot *(Calidris canutus),* spotted sandpiper *(Actitis macularius),* semipalmated sandpiper *(Calidris pusilla),* American black duck *(Anas rubripes),* short-billed dowitcher *(Limnodromus griseus),* mallard *(Anas* *platyrhynchos),* northern shoveler *(Anas clypeata),* Wilson's plover *(Charadrius wilsonia),* and hooded merganser *(Lophodytes cucullatus)*—all of which are Species of Greatest Conservation Need as identified in the Delaware Wildlife Action Plan (DFW 2006).

Step 3. Review/revise conservation goals and objectives. In undertaking this effort, the state's coastal managers have explicitly acknowledged the challenges that climate change poses to their existing impoundment management goals and, in turn, whether and how those goals might be revised. With saltwater intrusion and salinity increases, for example, participants on the National Wildlife Federation–led expert panel identified as a possible option abandoning some impoundments and allowing them to revert to salt marsh instead of continuing to manage them for freshwater and brackish habitat. Even as the project team recognized the need to modify some of the long-term goals and objectives, however, they validated the importance of maintaining some level of freshwater marsh habitats to support various high-value bird species.

Step 4. Identify possible adaptation options. A number of possible adaptation alternatives were identified for consideration as part of both the structured decision and expert panel processes. In particular, the SDM team developed a prototype decision model for four impoundments looking 30 years into the future. Based on those scenarios, a small team of experts identified key management objectives and predicted outcomes of different actions under different sea-level-rise scenarios. The teams particularly focused on options viewed as being flexible, transparent, and adaptive, incorporating cost constraints, and providing a suite of actions that maximize various benefits. Several options were identified involving water control structures, including: modifying existing water control structures, adding additional structures, altering dikes, and stabilizing dikes by restoring buffer areas. A number of additional adaptation options were identified, that included: adding more sediment to existing wetland areas; creating an upland impoundment; creating new brackish impoundments in place of current freshwater impoundments; and allowing existing impoundments to convert to brackish or saltwater habitat (Kane 2011).

Step 5. Evaluate and select adaptation options. To assist in selecting among the various options, participants in the SDM process used a consequences analysis (see Chapter 9) to evaluate the performance of the different alternatives against desired outcomes and goals, as well as expected costs and benefits. In this instance, the benefit of each alternative was calculated based on likely species responses and uncertainties, with the particular species receiving variable weighting. Selected actions included a variety of options designed to protect, repair, and restore existing impoundments, as well as create new upland impoundments as a means of replacing ecological functions that are expected to be lost in the future.

Step 6. Implement priority adaptation actions. Based on the evaluation and comparison of management alternatives, Delaware DFW has begun carrying out several pilot projects. One of these projects focuses on managing for future change by creating new impoundments inland and upland of existing impoundments in the Ted Harvey Wildlife Area. Figure 4.2 shows areas projected to be inundated under the various scenarios of sea-level rise. Project managers have identified two locations within the project area (outlined in black) as optimal sites for construction of new impoundments given that they appear to be less vulnerable to sea-level rise than surrounding areas, particularly under the 0.5-meter scenario. Even if this amount of sea-level rise were to occur by 2050, which would be within the DNREC (2012) midrange projection, project managers point out that the time frame is double the life span of DWF's existing impoundments. Accordingly, it is a realistic time frame to develop management and maintenance plans. This project has now entered the design and construction phase supported by state funding and a grant to the National Wildlife Federation from the Wildlife Conservation Society's Climate Adaptation Fund (supported by the Doris Duke Charitable Foundation).

Another project being carried out is designed to create a buffer wetland to protect an existing impoundment. The agency is using beneficial dredge material to repair an existing dike and enhance a barrier beach while reestablishing an internal dike more landward. Between these dikes, beneficial dredge material will also be utilized to create a tidal marsh. Once this tidal marsh has been successfully established with vegetation, the original seaward dike will be allowed to breach, permitting unobstructed tidal exchange into the newly created marsh. Several of the keys to successfully moving these adaptation efforts into the implementation phase were getting buy-in at all levels within the agency, availability of state funding, being creative and flexible, and bringing in outside partners.

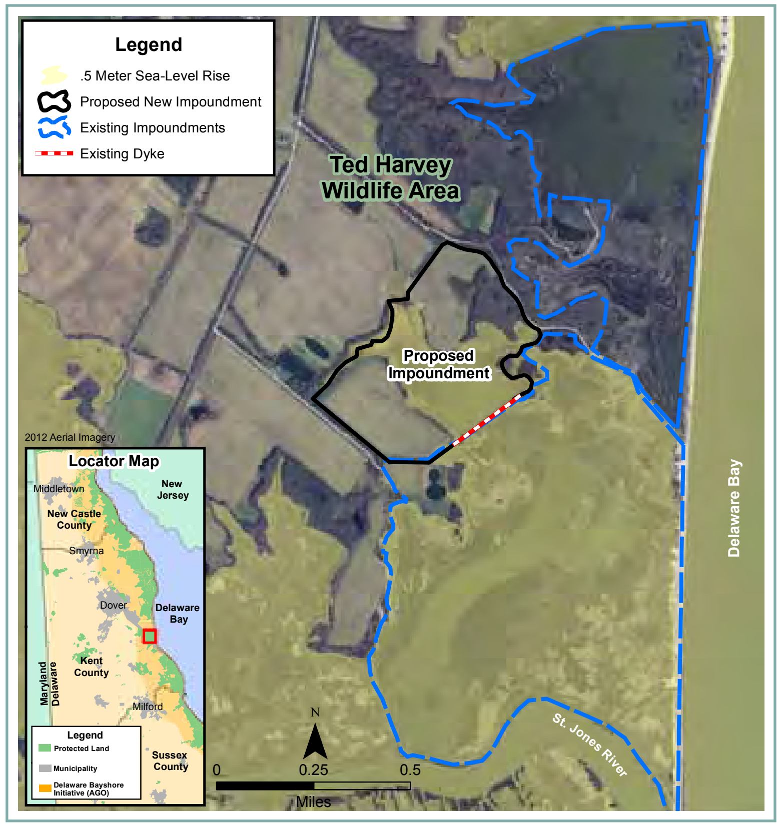

Figure 4.2. Location of new coastal impoundments being created inland and upland of existing impoundments (map courtesy Delaware Division of Fish and Wildlife).

Step 7. Track action effectiveness and ecological responses.

Although this effort is still in the implementation phase, the agency already began setting the groundwork for tracking the effectiveness of its actions. In particular, as part of the planning process, the agency identified "trigger points" for when managers may need to start considering alternative options in the management of these impoundments. In addition, given that the region is already experiencing significant relative sea-level rise, a number of monitoring efforts are also underway to track a variety of system attributes, such as salinity levels and vegetation changes.

Part 2

Putting Principles into Practice

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The next major section of this document focuses on taking the general principles of climate-smart conservation and addressing in more detail how to put these into practice. These more detailed discussions are organized around the various phases of the climate-smart conservation cycle (Figure 4.1). We begin with chapters on defining planning purpose (step 1), assessing vulnerability (step 2), and goal setting (step 3), moving on to identifying possible adaptation responses (step 4), evaluating and choosing among these options (step 5), and conclude with discussions of overcoming barriers to implementation (step 6) and tracking progress and change (step 7).

Although the steps of this cycle are presented in a linear and stepwise fashion, we must emphasize that depending on a project or initiative's particular needs and state of development, one may enter the cycle at various points, emphasize various aspects of this cycle, or even use an alternative sequence. Regardless of the specific sequence used, the most important thing is to ensure that plans and actions reflect an *intentional* approach to adaptation.

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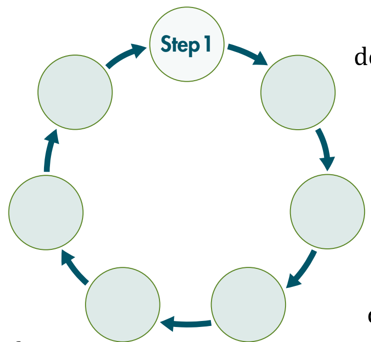
Chapter 5. Charting Your Course: Defining Planning Purpose and Scope[10]



Deciding where to start and how to structure an adaptation planning process may seem daunting. Fortunately, as attention to climate adaptation has grown, so too has thinking about how to chart the course for an appropriate and effective adaptation planning process. This chapter focuses on step 1 of the climate-smart conservation cycle (Figure 4.1, p. 56), which by clarifying and defining the planning purpose and scope, lays a solid foundation for designing and carrying out subsequent steps in the cycle. We start by identifying several important considerations for developing a process that is likely to lead to a successful outcome. The purpose here is to build on existing principles of good conservation planning, with suggestions about how they might specifically apply in a climate change context. We also provide a brief overview of several leading adaptation planning frameworks and approaches that are being used by agencies and organizations across the country. These approaches provide models for adaptation planning processes that may fit particular planning needs or be tailored to meet those needs.

5.1. Setting the Stage for a Successful Adaptation Planning Process

Developing an effective climate adaptation plan depends on designing a process that takes into account a variety of factors, including the particular decision processes the plan is to inform, the needs of intended users, and the necessary scope and scale of the effort. Taking the time up front to clearly define the planning scope and requirements greatly enhances the likelihood of a successful outcome, and can save considerable time and money later in the process. The following actions can help planning teams address important elements of project design, and provide a solid foundation and context for the climate-smart planning steps that follow:

- Articulate planning purpose
- Clarify existing goals and objectives
- Identify conservation targets
- Specify geographic scope and time frame
- Engage key participants and partners
- Determine resource needs and availability

In general, these considerations are not unique to adaptation planning—anyone who has been involved in designing and implementing conservation or resource management plans will recognize them as fundamental elements of the process. That said, in the context of climate change certain of these elements take on heightened significance, as does the need to be explicit and transparent—a key attribute of the intentionality at the heart of climate-smart conservation. Collectively, these considerations provide necessary context for the adaptation planning process, although the sequence by which planning teams consider them may vary.

[10] Lead authors: Patty Glick and Molly S. Cross.

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5.1.1. Articulate Planning Purpose

As with any planning process, being clear up front about the purpose is fundamental to designing a process likely to lead to a successful outcome. In turn, that purpose should guide the particular details of the process, including defining an appropriate focus and scope, needed participants, and relevant approaches and techniques. In particular, it is important to be clear and transparent about the specific decisions the plan is to support, and the intended audience and users.

What is the motivating force behind the planning effort? Is the need to incorporate climate considerations into an existing decision process? Or is the intent to start from a climate change perspective and develop a dedicated (or stand-alone) climate change adaptation strategy? In either case, the purpose of the planning effort will be strongly influenced by the particular user needs (see Section 5.1.5 below). If planning is part of an existing decision process, many of the scope and scale considerations may be predetermined, although there may still be need to revisit or revise some of these in the context of climate change. If the planning process is more general in nature—designed, for instance, to investigate the potential climate change consequences for a particular place or resource of interest—there may be more flexibility in how scope and scale are defined. It is also useful to identify any planning constraints, such as legal or regulatory mandates, or funding obligations. For example, if the effort is part of a formal agency decision-making process, there may be requirements for use of particular climate (or other) projections, for specific data quality assurance and review processes, or for formalized public engagement processes.

Planning processes will also vary in their thematic scope, often being focused either on a particular place, or a particular resource or set of ecological features. Whether the planning effort is place based or "theme based" will have considerable implications for determining the appropriate scope and scale of the effort, as well as for determining relevant stakeholders. Place-based efforts can range from small sites to large regions to entire geopolitical units (e.g., states, nations), while theme-based planning can focus on a particular species (e.g., an endangered species), group of species (e.g., migratory shorebirds), type of habitat, harvestable resource, or ecological service (e.g., water supply).

Finally, most planning processes are designed to address specific environmental problems, but some may be more exploratory in nature (which may mean defining the potential risks associated with climate change as the "problem"). One of the keys to effective conservation planning is to

Box 5.1. Defining terms: Goals, objectives, and targets.

Although most readers will already have some knowledge and understanding of planning concepts and terminology, usage of certain terms varies considerably among disciplines and communities of practice. In particular, there is variable usage of the terms *goals, objectives,* and *targets*, each of which is used extensively in this guide. Accordingly, we define here how these terms are used in the context of this publication.

Goals

Conservation goals, as used here, refer to the overarching vision for a conservation or management effort, and are an articulation of high-level aspirations. Generally, they describe a desired future condition and convey the underlying purpose of an effort but do not specify the means to achieve the desired outcome (Adamcik et al. 2004).

Objectives

Management objectives, in contrast, refer to more specific outcomes in support of higher-level goals, and usually articulate a measurable standard, desired state, threshold value, amount of change, or trend.

Targets

Within the conservation planning community, a "conservation target" generally refers to the specific biological or ecological features (e.g., species, habitats, ecological processes, or other entities) that are the focus of one's conservation attention. Within the resource management community generally, and in an adaptive management context specifically, the term "performance target" often refers to a specific and measurable level of an intended outcome (e.g., a specific size or number of populations in a species restoration effort) (e.g., Angelstam et al. 2004), a concept similar to our use of the term "objective." Unless otherwise specified, usage of the term "target" refers to the concept of conservation target as defined above.

define the problem being addressed as clearly as possible. By problem, we mean the underlying conservation or management dilemma or decision. Clearly identifying the problem at hand also makes it possible to break the problem into discrete parts, which can greatly facilitate structuring needed analyses and assessments, and identifying relevant management responses. Understanding the nature of the problem may evolve, however, during the course of the planning process, and in particular as a result of the climate impact and vulnerability assessments carried out during step 2 of the climate-smart cycle (see Chapter 6). Having a clear articulation of the fundamental problem to be tackled, though, provides a guidepost for keeping the planning process on track and for preventing drift and unnecessary distractions.

5.1.2. Clarify Existing Conservation Goals

Reconsidering conservation goals to ensure they are forward looking and climate informed is a core concept in climate-smart conservation (see Sections 2.4, 3.2, and Chapter 7), but a clear articulation of any existing or "legacy" goals and objectives is necessary prior to such a reevaluation. Therefore, one of the first tasks in embarking on an adaptation planning process is to clarify existing conservation goals and objectives, both to set the stage for such a reconsideration (e.g., step 3 of the climate-smart cycle) as well as to inform the design of an appropriate and relevant planning approach. (For definitions of key planning terms as used in this guidance, see Box 5.1.)

Articulating and clarifying existing goals will be especially important where climate considerations are being integrated into an existing planning process, an ongoing conservation project, or underway resource management effort. In such cases, goals and objectives should already exist and be readily available, although there may be wide variation in how up to date they are, their level of specificity, and the rigor and care with which they were developed.

Dave Menke/USFWS

Oftentimes goals are explicit, laid out in court orders, regulations, management plans, or other formal documents. In other instances, goals may be implicit or never fully articulated by their advocates. Current goals may also be vague or overly general. For instance, if "biodiversity protection" is identified as the goal, which of the various elements and aspects of biodiversity does this refer to? Of particular note is the recent emergence of "enhancing resilience" as way to impart a level of climate awareness in ecological (and other sector) goals. As noted in Box 2.1, however, without additional context (e.g., resilience of what, to what?) such a goal is so vague as to have little operational meaning.

The task at this stage in the cycle is to capture in an honest way the goals and management objectives as currently conceived and applied to the resources that are the focus of one's planning effort. Going through the process of clarifying existing goals may often reveal such a lack of clarity, and especially may highlight a lack of specificity in management objectives. There are many resources available to assist practitioners in developing sound goals and objectives, many of which follow the so-called SMART[11] framework (e.g., Adamcik et al. 2004). It is not our intent to address the general topic and philosophy of goal-setting in this document, but should note that what makes for sound goals and objectives generally, also applies to climate-informed goals.

In anticipation of reconsidering conservation goals and management objectives in light of climate change, the following four distinct elements are useful to distinguish in existing goals and objectives:

- **What** (the conservation *target* or subject of the goal)
- **Why** (the intended *outcome* or desired condition)
- **Where** (the relevant *geographic scope*)
- **When** (the relevant *time frame*)

These four components provide a framework for reevaluating the continued feasibility of goals and objectives in the context of projected climate impacts during step 3 of the climate-smart cycle. Crafting climate-informed goals, as discussed in Section 7.3, may not require wholesale revisions, but instead may only need to focus on modification of one or two of these components.

[11] The SMART framework for setting goals and objectives includes some version of the following criteria: specific, measurable, achievable, relevant, time-bound.

5.1.3. Identify Conservation Targets

Conservation targets represent the biological or ecological features that are the underlying subject of conservation attention (see Box 5.1, p. 73). Such features can range from particular species or groups of species, to specific habitats, particular ecosystems, or even ecosystem goods and services. Because so much of adaptation planning revolves around understanding and ameliorating climate impacts to one's conservation targets—and the systems that support them—being clear about those targets is essential for defining the scope of the planning process. This is especially true where overarching conservation goals are relatively vague or general (e.g., "protecting biodiversity"). In many cases, the relevant conservation targets will be predefined by existing plans, goals, or institutional mandates, and where targets already are well defined, using them as the focus for climate-smart conservation planning is a logical place to start. State Wildlife Action Plans, for instance, are designed around a set "species of greatest conservation need," which serve the role of conservation targets (AFWA 2009). In the case of the U.S. Forest Service, management efforts are focused on a range of targets relevant to its mission, such as late-successional forests that provide valued ecosystem services such as wildlife habitat and carbon sequestration (Peterson et al. 2011).

Conservation targets, as used here, should be understood as the ecological features or resources themselves.

Conservation targets, as used here, should be understood as the ecological features or resources themselves. Although in a place-based assessment, the geographic area (whether a management unit or broader geographic area) may be the "focus" of attention, conservation targets represent the biological or ecological features (or services) of interest within the area, rather than the geographic unit itself. Similarly, conservation targets typically are viewed as the underlying features of interest, as distinct from the focus of particular management actions intended to support or influence the underlying target. As an example, the underlying conservation target may be a particular declining species (e.g., a woodpecker), while the focus of management actions may be certain essential habitat features that support the target (e.g., dead snags).

The choice of which conservation targets are most appropriate, and the ecological level of those targets (i.e., species, habitats, etc.) depends largely on interests, requirements, needs, and capabilities of the institution or organization developing the plan. Indeed, as with conservation goals, the choice of which conservation targets to focus on ultimately is based on values, goals, and institutional priorities. A primary consideration in climate-smart conservation, however, is how climate change may affect the viability or health of conservation targets, and whether as part of a reconsideration of conservation goals (step 3 in the climate-smart cycle) there is a need for modifications in identified conservation targets (see Section 7.3. for further discussion).

5.1.4. Specify Geographic Scope and Time Frame

Geographic scope and scale. Determining the appropriate geographic scope is one of the most important decisions for scaling and focusing one's planning process. As noted earlier, many adaptation planning efforts will be place based (for instance, a specific park, preserve, or national forest), in which case the focal geography may at first seem relatively clear. Given the nature of climate impacts—and in keeping with the importance of considering the broader landscape context (see Section 3.3)—the geographic scope of the planning effort will often need to significantly exceed the

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specific area of concern, including accounting for nested geographies connecting local to regional scales and beyond.

Managers have long known that planning focused on a particular park, refuge, or other management unit needs to encompass an area large enough to take into account regional-scale processes (e.g., fire regimes, sediment transport) as well as risks emanating from outside the jurisdictional unit (e.g., spread of invasives, waterborne pollutants). Likewise, management actions within a unit (e.g., use of water resources, game harvest) can have an influence on adjacent areas. Climate-related shifts in the distribution and abundance of species, and changes in climatic variables, will only add to the need for expanding the geographic scope and scale of planning efforts—even when the initial management focus may be very local.

Spatial resolution. The concept of spatial resolution is related to but distinct from geographic scope and scale. Spatial resolution refers to the level of granularity of a map, image, or spatial analysis. Conservation practitioners often assume that planning would benefit from applying the highest level of resolution possible, for instance in ecological mapping or projections of future climatic conditions. Indeed, a frequently heard impediment to embarking on adaptation planning is the desire to wait for more locally specific climate projections. It is important, however, to be realistic about the level of spatial resolution necessary and appropriate for a planning process, in order to avoid costly and time-consuming "overengineering," and to avoid the trap of false precision. As is the case with most types of spatial analyses, there is an inherent trade-off between level of resolution and level of uncertainty and accuracy. In many instances, applying the most fine-scale, high-resolution projections may not contribute more to the decisions at hand then would general projections of directional change.

Time frame. Another key consideration is the relevant adaptation time frame. Most management plans and organizational strategies have relatively short time horizons (often in the 3-, 5-, or 10-

year range), although there are exceptions to this, especially where managed resources have multi-decadal harvest cycles (e.g., timber). Long-range plans (25–30 years) are also standard in certain other sectors, such as for transportation planning. Nonetheless, some natural resource managers may question the relevance (or feasibility) of looking at climate change across a longer timescale of, say, 30, 50, or even 100 years, particularly when confronted by so many near-term challenges. Considering the longer-term effects and responses to climate change is not intended to replace shorter-term operational and management planning, but rather can provide a strategic context for those near-term decisions. Planning for and addressing immediate problems (e.g., major oil spill, habitat conversion) will continue to be essential, otherwise a species or system may be irreparably damaged or lost, rendering concerns about longer-term climate change moot. Putting those near-term plans and actions in context, however, will require the longer-term perspective that adaptation planning can provide.

As with specifying geographic scope, identifying the relevant temporal scale is important for designing a successful adaptation planning process. Explicitly defining the time frame is relevant both for incorporating climate considerations into existing decision and planning processes and for crafting a dedicated, or stand-alone, adaptation plan. Being clear about timescale is especially significant in crafting climate-informed conservation goals (Section 7.3), since some goals may continue to be feasible over shorter timescales (e.g., <20 years), while other goals may be feasible over longer periods (e.g., >50 years). Specifying relevant temporal scale is also crucial for the selection of climate projections and emissions scenarios appropriate for use in vulnerability assessments (Section 6.2.1).

5.1.5. Engaging Key Participants and Partners

Engaging the right people in the right way and at the right times can be the critical factor in determining the success of conservation planning, and this is equally true for adaptation. Yet there are several considerations that are important to underscore when thinking about who to engage as climate change is incorporated into the process. One factor is the importance of enhancing the interactions between scientists and managers. Given that climate change science is likely to be new to many resource managers, having scientists engaged early on can help fill important information needs and refine the scope and focus of the planning effort. On the flip side, it is important that scientists understand the needs of managers so that scientific inquiry can be directed toward answering relevant questions in a timely manner. It is also helpful to engage relevant stakeholders early on, whether those are internal or external decision-makers, adjacent landowners, or interested individuals and organizations. Early engagement is especially important if there are likely to be difficult trade-offs emerging from the planning effort. Engagement of a variety of individuals and organizations can provide important sociopolitical context to adaptation decisions and, ultimately, help build support for and engagement in implementing those decisions (see Chapter 10).

The number and type of participants involved in developing a climate-smart conservation strategy will be influenced by the purpose and scope of the planning effort. For example, in cases where climate change issues are relatively well defined, it may not be necessary to engage people with a detailed background in climate science. In others, the active engagement of both scientists and practitioners in planning may be necessary to aid the application of best-available science while also guiding scientists toward management-relevant research. If a primary emphasis of the planning effort is to motivate the implementation of selected adaptation actions, it would be prudent to involve key decision-makers from the organizations that have the jurisdictional mandate and ability to implement those actions. The geographic extent of the planning effort also may affect the number and diversity of decision-makers involved, as well as the level of their participation. For example, if the focus is on a single management unit or land ownership, a relatively small internal planning process may be suitable. On the other hand, planning across a broader landscape controlled by diverse land management and regulatory agencies and private interests will require a more concerted focus on stakeholder engagement and collaborative processes. And as important as determining who to involve is how to engage them, and there are many existing best practices associated with stakeholder engagement and collaborative natural resource management (e.g., Schusler et al. 2003, Prell et al. 2009).

There are, however, challenges that one may encounter when planning for climate change with diverse partners, including those stemming from potentially differing missions and tolerances for climate change–related or other relevant risks among participants (Cross et al. 2010b). A key factor is whether or not planning participants come to the effort having already committed to joint decision-making or have otherwise agreed on the governance structure for how decisions will be made (Reed 2008). Participatory planning across jurisdictions is often aimed at building trust and forging partnerships, and to motivate future collaborative implementation of shared adaptation priorities.

5.1.6. Determining Resource Needs and Availability

Once the purpose and scope of the adaptation planning effort has been established, it is necessary to identify necessary resources (including available time, funding, and expertise). Yet again, this is not unique to adaptation planning, but given that adaptation is often considered a separate issue managers may be concerned that associated planning efforts will require additional staff and resources. The first thing to consider is whether the adaptation planning effort truly does need to be separate. In many cases, consideration of climate change can and should be integrated into an existing process, so addressing climate change may not significantly add to the existing planning resource requirements. Broader climate-focused efforts, on the other hand, may require additional expertise, time, and funding to gather information about multiple challenges posed by climate change, as well as climate-specific adaptation strategies and management responses. In any case, specific resource needs will depend on how participants are engaged and the level of detail and complexity of planning effort.

In project management there are well-known relationships among time, cost, and quality—the so-called “iron triangle” (Atkinson 1999). These three factors can be regarded as constraints, in which one can maximize only two at any one time. That is, projects that are carried out fast and inexpensively often must sacrifice complexity or detail, while projects that are carried out quickly but seek to achieve relatively high levels of sophistication (e.g., complex engineering design or ecological modeling) usually require a premium on cost. Adaptation planning is subject to these same constraints, which factor into defining necessary outcomes and project requirements, together with selecting appropriate (and affordable) approaches for achieving those outcomes. For example, if planning is part of a formal regulatory process and subject to legal review and challenge, credibility and defensibility may be tantamount, which has implications for the time needed, the cost required, or both. On the other hand, if the intent of the adaptation planning process is to provide a screening-level review of the palette of adaptation options that might be relevant to an organization, then a faster, less expensive process may be adequate.

5.2. A Range of Adaptation Planning Approaches

Having defined the purpose and scope of the adaptation effort, based on the above considerations, planning teams can design an adaptation planning process that best reflects these needs. The climate-smart conservation cycle provides general guidance for the steps to include in such a planning process, but there is an array of approaches (and processes) for carrying out those individual steps.

Table 5.1 highlights key features of several adaptation planning approaches that have been developed and tested by different organizations and agencies. Many of these approaches were designed with the intent of providing stepwise methods for planning for climate change, and cover some or all of the steps in the climate-smart cycle. Some of the approaches specify how climate change can be brought into an existing planning method, such as The Nature Conservancy's Conservation Action Planning process (Poiani et al. 2011) or the Open Standards for the Practice of Conservation (CMP 2013). Many of the other approaches, however, have been developed explicitly as adaptation-centric planning efforts. Even if the desire is to integrate climate change into an existing planning process, some of the more adaptation-centric approaches listed in Table 5.1 illustrate steps, methods, and tools that could be woven into an existing planning process to make them more climate smart.

The approaches vary in terms of their purpose and key features, the types of systems targeted (e.g., natural systems, human systems, or both); the geographic scales considered (e.g., site, landscape, or both); who the primary users are; and the level of time and financial resources needed. They also differ in whether they start by examining how climate, biological, and physical systems are changing, and then assess which species and ecosystems within the focal area are most vulnerable—or start with current management targets, goals, or activities and then asking how they may respond to or be affected by climate change. Despite their differences, however, the various approaches also share many similarities. While some approaches place greater emphasis on the use of modeled climate and ecological response information, most can integrate modeling results with expert-based opinion and interpretation from scientists and those with local knowledge of the system. Many also employ similar sets of

Thomas Barnes/USFWS

Table 5.1. Example adaptation planning approaches.

Approach	Purpose and key features	Spatial scale[a]	Starting point	Effort/Cost[b]	Institutional affiliation	References
Adaptation for Conservation Targets (ACT) Framework	Stepwise process for developing actions to achieve climate-informed conservation goals for specific species, ecological processes, or ecosystems	Site, Landscape	Management targets, goals, or activities	*Time:* low/moderate *Expertise:* moderate *Cost:* low/moderate	NCEAS Climate Change & Wildlife Conservation working group; Wildlife Conservation Society; Southwest Climate Change Initiative	Cross et al. 2012b, 2013
Awareness to Action (A2A)	Adaptation planning services to develop climate change adaptation plans focused on specific regions, species, or ecosystems	Site, Landscape	Either management concerns, or broad look at potential climate-related changes	Variable	EcoAdapt	Hansen and Hoffman 2011
Climate Change Adaptation Framework for Ecosystems	Stepwise process for integrating climate into natural resource management for many species and ecosystems	Landscape	Management targets, goals or activities	*Time:* moderate *Expertise:* moderate/ high *Cost:* high	Ontario Centre for Climate Change Impacts & Adaptation Resources	Gleeson et al. 2011
Climate Change Response Framework	Stepwise process for integrating climate into forest planning and management for forest species and ecosystems	Site, Landscape	Management targets, goals or activities	*Time:* low/moderate *Expertise:* low/ moderate *Cost:* low/moderate	U.S. Forest Service	Swanston and Janowiak 2012
Climate Project Screening Tool	Questionnaire-based tool to explore options for ameliorating climate effects on forest resource management projects	Site	Management targets, goals or activities	*Time:* low/moderate *Expertise:* low/ moderate *Cost:* low	U.S. Forest Service	Morelli et al. 2012
Climate-Ready Estuaries Expert Elicitation Approach	Expert elicitation approach for assessing vulnerabilities and identifying adaptation options	Site, Landscape	Management targets and goals	*Time:* moderate *Expertise:* high *Cost:* moderate/high	U.S. Environmental Protection Agency	U.S. EPA 2012a, 2012b
Climate-Smart Coastal Restoration Planning	Stepwise framework for the design and implementation of climate-smart coastal restoration projects in the Great Lakes	Site	Management targets, goals or activities	*Time:* low/moderate *Expertise:* moderate *Cost:* low/moderate	National Wildlife Federation; EcoAdapt	Glick et al. 2011b
ClimateWise	Stepwise process for developing adaptation strategies and actions coordinated across local ecosystem and human community concerns	Site, Landscape	Broad look at potential climate-related changes	*Time*: moderate *Expertise*: moderate *Cost:* moderate	Geos Institute	Koopman and Journet 2011
Conservation Action Planning for Climate Change	Stepwise process for integrating climate into existing plans developed using the Conservation Action Planning (CAP) process for specific species or ecosystems	Site	Management targets, goals or activities from an existing CAP plan	*Time:* moderate/high *Expertise:* moderate *Cost:* moderate	The Nature Conservancy	Poiani et al. 2011

Table 5.1. Example adaptation planning approaches *(continued)*.

Approach	Purpose and key features	Spatial scale[a]	Starting point	Effort/Cost[b]	Institutional affiliation	References
Decision Framework for Climate Change Adaptation	Decision tree that identifies and prioritizes actions to increase the adaptive capacity of species	Site, Landscape	Particular species and species distribution/ bioclimatic envelope model	*Time:* low/moderate *Expertise:* moderate *Cost:* low/moderate	NERC Centre for Ecology & Hydrology; UK Population Biology Network	Oliver et al. 2012
National Park Service Scenario Planning	Scenario planning process to address climate-related uncertainties in managing species, ecosystems, cultural and recreational resources	Site, Landscape	Potential climate-related changes	*Time:* moderate *Expertise:* moderate *Cost:* moderate	National Park Service	Weeks et al. 2011, Rose and Star 2013
North Cascadia and Olympic Peninsula Adaptation Partnership	Science–management partnership for assessing vulnerability and developing adaptation options for species and ecosystems across federal land management units	Landscape	Potential climate-related changes	*Time:* moderate/high *Expertise:* moderate *Cost:* moderate	U.S. Forest Service and National Park Service	Raymond et al. 2013, Littell et al. 2012, Halofsky et al. 2011
Open Standards for the Practice of Conservation	Incorporation of climate into a structured conservation planning process for specific species or ecosystems	Site, Landscape	Management targets, goals or activities	*Time:* moderate *Expertise:* moderate *Cost:* moderate	Conservation Measures Partnership	CMP 2013
Refuge Vulnerability Assessment and Alternatives	Stepwise process for spatially explicit assessment of a refuge's vulnerability to climate change and other stressors, and identification of adaptation options	Site, Landscape	Either management concerns or potential climate-related changes	*Time:* moderate/high *Expertise:* high Cost: moderate/high	NatureServe	Crist et al. 2012a, 2012b
Template for Assessing Climate Change Impacts and Management Options (TACCIMO)	Web-based tool that synthesizes published research on climate impacts and adaptation options relevant to forest planning and management	Site, State, Landscape	Potential climate-related changes	*Time:* low *Expertise:* low Cost: low	U.S. Forest Service	Treasure et al. 2014
Yale Framework	Guidance for selecting assessment and modeling strategies relevant to specific conservation and resource management needs	Site; Landscape	Matrix of adaptation options at different ecological levels	*Time:* low/ moderate/high *Expertise:* moderate/ high *Cost:* moderate/high	Yale School of Forestry	Schmitz et al. In press

[a] Site = Single management unit or jurisdiction at relatively small spatial extent. Landscape = More complex jurisdictional landscape at relatively larger spatial extent. State = Targeted at state-level planning in the United States.

[b] *Time*: low (<1 year), moderate (up to 1 year), high (>1 year); *Expertise*: low (no special technical expertise required), moderate (some technical expertise helpful), high (technical expertise required); *Cost*: low (<$10,000), moderate ($10,000–75,000), high (>$75,000).

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planning methods, such as facilitated workshops, questionnaires, worksheets, and working groups.

While no single adaptation planning approach will meet the needs of decision-makers in all situations, the examples provided here, together with the general guidance offered throughout this document, offer a useful starting point and can provide ideas for designing and tailoring a planning process that will meet context-specific needs.

5.3. Case Study: Collaborative Adaptation Planning on the Olympic Peninsula

An excellent example of cross-agency adaptation planning is on the Olympic Peninsula of Washington, where beginning in 2008 the U.S.

Forest Service and the National Park Service embarked on an effort to jointly develop climate adaptation strategies (Halofsky et al. 2011, Littell et al. 2012). Participants engaged in a three-part process that included: (1) an assessment of climate change sensitivity of key resources through a review of the scientific literature and available climate models; (2) an assessment of the capacity of Olympic National Forest and Olympic National Park to adapt to climate change given existing management and regulatory contexts; and (3) the development of adaptation strategies through science–management workshops.

While the results and recommendations established through this process are themselves notable (see Box 5.2), of particular relevance here is the collaborative planning approach used to engage scientists and managers from the start of planning to the early stages of implementation. This effort is an embodiment of many of the important considerations for adaptation planning highlighted in this chapter. Early on, representatives from both Olympic National Forest and Olympic National Park embraced the importance of a collaborative partnership given the close proximity between their respective lands, the similarities in their management goals and targets, and recognition that a broader, more collaborative approach to management would be necessary to achieve those goals in an era of climate change.

Collective problems. By its nature, climate change is a broad phenomenon. While its impacts may have highly localized consequences, they also know no boundaries—at least not to the

Box 5.2. Sample adaptation strategies for the Olympic Peninsula.

After assessing the climate change vulnerability of natural resources and infrastructure within and around the forest and park systems, participants identified a suite of possible adaptation strategies. Below are just a few examples of adaptation options put forth for the various sectors.

Hydrology and road management

- Redo culvert size analysis based on peak flow data from only the last 30 years (as opposed to the period of record) or by using a physically based hydrology model.
- Consider sediment problems in glacier-fed rivers that can make some valley bottom roads at risk or unsafe.

Fish habitat management

- Shift to a new paradigm in fish habitat management that recognizes that preexisting channel conditions may no longer be an accurate representation of the potential state.
- Restore habitat in degraded headwater streams that are expected to retain adequate summer flow.

Vegetation management

- Maintain a tree seed inventory with high-quality seed for a range of species, particularly species that may do well in the future under hotter and drier conditions.
- Consider increasing the amount of thinning and possibly altering thinning prescriptions to reduce forest drought stress.

Wildlife and habitat management

- Collaborate with neighbors about priority areas for treatments, and increase extent of protected areas.
- Conduct integrated surveys and monitoring for key species to obtain baseline information and determine when population changes are occurring.

extent that those boundaries have been selectively drawn by humans. The Olympic Peninsula is a patchwork of public, private, and tribal lands that have geographical and ecological characteristics that are unique to the peninsula, as well as characteristics that are common in the region. As an area with highly diverse topography, the impacts of climate change will be varied—coastal systems will be susceptible to changes such as accelerating sea-level rise and acidification of ocean waters, while mountainous areas will experience changes such as reduced snowpack and increased forest disturbances. Collectively, however, climate change presents a major challenge to resource managers across the region, as they can no longer rely on factors such as historical climate trends or species ranges and assemblages as baselines for conservation decisions. Rather, decisions will require a better scientific understanding of how climate change is projected to affect species and systems across the region, regardless of the managerial jurisdictions. Recognizing this collective problem was a major impetus for national forest and national park planners to develop a joint climate change adaptation strategy.

Common goals and objectives. The overarching missions of the U.S. Forest Service and National Park Service differ considerably, yet both agencies are dedicated to enhancing and protecting natural systems for the benefit of current and future generations. Although timber production and freshwater resources have historically been the charge of Olympic National Forest since its establishment in 1907, resource management has evolved to embrace a broader, ecosystem management perspective, whereby protecting ecosystems, restoring deteriorated ecosystems, providing multiple-use benefits, and organizational effectiveness have been collective priorities. In particular, the national forest is focused on several priority goals, including: managing for native biodiversity and promoting development of late-successional forests; restoring and protecting aquatic ecosystems from the impacts of aging road infrastructure; and managing for threatened and endangered species. Similarly, Olympic National Park is dedicated to protecting the natural and cultural resources of the park, with a focus on preserving physical and biological processes and preserving ecological integrity and biological diversity. Given these common goals, the national forest and national park recognized that addressing the enormous additional challenge posed by climate change warranted a collaborative strategy and associated planning effort.

Importantly, throughout the planning process, it was assumed that there would be no changes in policy mandates (e.g., land allocation designations or the Endangered Species Act) over the next 5 years. Nevertheless, participants identified a number of possible options within the existing policy realm that focus on enhancing ecosystem function and biodiversity and promoting resilience in a dynamic system, rather than assuming a "future that mirrors historical ecosystem conditions." Further, participants were mindful that it will ultimately be necessary to rethink some management goals as climate change continues.

Consistent targets, scope, and scale. The adaptation planning effort focused on four target themes considered very important to the partners' goals and objectives: hydrology and roads, fish, vegetation, and wildlife. Within these spheres, participants in the planning process assessed the vulnerability of relevant features (e.g., species, ecological systems, and infrastructure) to climate change throughout the Olympic Peninsula, not just within the individual boundaries of national forest and national park. Downscaled climate change data and scenarios provided by scientists at the University of Washington Climate Impacts Group (Mote and Salathé 2010) were used as part of this process, using scenarios for the 2020s, 2040s, and 2080s.

Commitment to collaboration. This planning process placed considerable emphasis on engagement between managers and scientists from the start. Planning participants spanned a broad spectrum of expertise and interests, including forest and park staff specialists in silviculture, forest genetics, botany, wildlife biology, engineering, fish biology, and hydrology, as well as several experts from other natural resource agencies (e.g., Washington Department of Natural Resources, U.S. Geological Survey, and U.S. Fish and Wildlife Service), watershed organizations, and tribes. Participants engaged in a series of facilitated workshops guided by scientists from the Forest Service Pacific Northwest Research Station and natural resource staff supervisors from national forest and national park, in a format that provided opportunities for open dialogue and brainstorming. The diversity of representation enabled participants to more effectively define the context for management of the various resources under each jurisdiction, highlighting both similarities and differences in their respective interests, values, and approaches, as well as the management issues of greatest concern. It also provided an opportunity to identify potential adaptation strategies that could be conducted collaboratively.

Leveraged resources. Finally, the collaborative process enabled the Olympic National Forest and Olympic National Park to achieve economies of scale by pooling information, data, and expertise into a collective planning process—an opportunity not lost on the agencies in an era of limited resources. There was also recognition that a collaborative process, such as the one undertaken here, can greatly benefit from having full-time attention from one or more individuals to facilitate the process, along with a commitment and dedicated time from key staff, supervisors, and other experts.

Jim Cummins/Washington Department of Fish & Wildlife

This planning process placed considerable emphasis on engagement between managers and scientists...in a format that provided opportunities for open dialogue and brainstorming.

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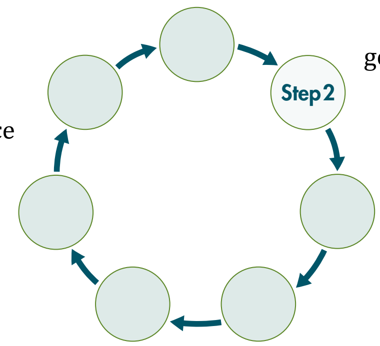
Chapter 6. Understanding Climate Change Impacts and Vulnerability[12]

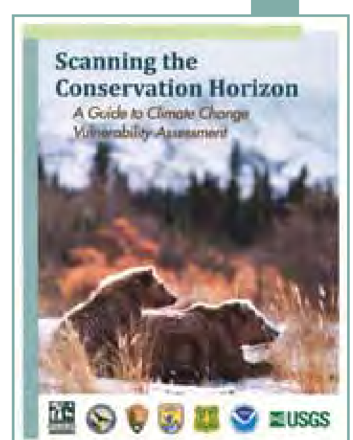


Linking adaptation actions to known and potential climate changes is the essence of climate-smart conservation. Accordingly, understanding how species and systems are likely to fare under future conditions is essential for developing meaningful adaptation strategies. Vulnerability assessment is a crucial tool for understanding the effects of climate change on natural systems, as well as human communities, and is a fundamental element of setting the stage for effective adaptation planning. For this reason, vulnerability assessment typically is carried out early in the adaptation planning process, and is the focus of step 2 in the climate-smart conservation cycle (Figure 4.1).

This chapter provides a brief summary of vulnerability assessment, drawing largely from our companion guide on this subject, *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment* (Glick et al. 2011c). In addition to summarizing the conceptual basis and fundamental components of vulnerability, the chapter includes a brief review of general steps for assessing climate change vulnerability, highlights examples of assessments in practice, and describes how the vulnerability of conservation targets can inform adaptation planning. The chapter concludes with discussion of the concept of "key vulnerabilities," an approach intended to highlight the subset of vulnerabilities that will have the greatest consequences for achieving conservation goals, and which therefore can serve as the focus of adaptation strategy development later in the climate-smart cycle.

6.1. What Is Vulnerability?

In a conservation context, vulnerability to climate change refers to the extent to which a species, habitat, ecosystem, or other conservation target is susceptible to and unable to cope with direct and indirect impacts of climate change. In concept, more vulnerable species and systems are likely to experience greater harm from climate change, while less vulnerable species and systems will be less affected, or may even benefit. In reality, linking climatic changes to possible impacts on species or system may suggest a range of vulnerabilities, depending on the climate drivers assessed, time frames, assumptions about interactions, and relevant uncertainties.



Climate change vulnerability assessments provide two essential types of information needed for adaptation planning:

- Identifying *which* species, systems, or other conservation targets are likely to be vulnerable

[12] Lead authors: John Gross, Kurt Johnson, Patty Glick, and Kimberly Hall.

- Understanding *why* they are vulnerable

Identifying which conservation targets are vulnerable is important for helping set priorities for conservation and adaptation action, while understanding the reasons for those vulnerabilities is necessary for designing strategies and actions capable of reducing those vulnerabilities. Underscoring the importance of these two types of information for adaptation planning is the very definition of adaptation as "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects" (IPCC 2007a).

Vulnerability assessments on their own do not dictate priorities for action, but rather provide an informational basis for setting such priorities. A common misperception is that carrying out a vulnerability assessment assumes that conservation actions should be focused on those species or systems that emerge from the analysis as most vulnerable. While at times that may be the case, the choice of whether to focus adaptation strategies on the most vulnerable species or systems, or on those with the greatest likelihood of long-term viability (that is, least vulnerable or most "resilient") depends on one's underlying goals and objectives. Indeed, this is the reason that identifying "key vulnerabilities," based on their consequences for underlying values and conservation goals, is important for setting priorities and targeting adaptation planning. Vulnerability assessments do not predetermine those decisions, but instead provide a basis for making informed choices about setting (or perhaps revising) those priorities and making management decisions.

6.1.1. Related Concepts: Impacts, Risks, and Hazards

Among adaptation planners, vulnerability assessment is a preferred framework for understanding the likely effects of climate change on natural resources, as well as on human communities and social assets (Turner et al. 2003, Adger 2006). While the amount of literature and tools focused on climate change vulnerability assessment has been growing rapidly, a number of related terms are used in overlapping (and sometimes confusing) ways, including impact assessment, natural hazard assessment, and risk analysis. While there are no universal definitions for vulnerability, hazard, impact, and risk, we provide some general distinctions below to help frame vulnerability assessments in the context of these other assessment frameworks, each of which has its own techniques and communities of practice (Sarewitz et al. 2003, Jones and Boer 2004, Downing and Patwardhan 2005, Thomalla et al. 2006, Romieu et al. 2010).

Impact assessments, such as documentation of changes in phenology, changes in species distributions, or changes in wildfire frequency, have dominated much of the literature on climate change effects on ecological resources. Impact assessments, as the concept often is used in the literature, focus largely on observed, modeled, or projected changes in species or systems or in response to climatic factors (Jones 2001, Jones and Boer 2004, Füssel 2007). Although the term "impact" has the connotation of negative effects, in practice, many impact assessments focus on detecting or projecting change without attribution of either harm or benefit. Vulnerability, in contrast, is generally understood to incorporate the concept of susceptibility to adverse effects, or harm, and its implications for the sustainability of target resources or systems.

The term "natural hazard" generally refers to the inherent potential of a natural event (e.g., wildfire, storm, flood, hurricane, earthquake) to cause harm to people (Jones and Boer 2004, van Aalst 2006). Accordingly, *natural hazard assessments* are typically carried out from the perspective of the effect of such events on human interests, whether people or property (U.S. Department of Homeland Security 2012). As this focus on harm suggests, the concept of "hazard" is more akin to vulnerability than many uses of "impact." There is an entire community of practitioners and first responders focused on natural hazard mitigation, with legal, policy, and administrative frameworks spanning the range of disaster preparedness, response, and recovery. Given the growing recognition of the role of well-functioning ecosystems in reducing natural hazard risks to people and property, there are likely to be increasing opportunities for natural resource managers to engage with hazard mitigation practitioners in use of these frameworks.

Hazard assessments traditionally have focused on acute, or pulse events (e.g., floods, fires, etc.) based on historical patterns. In the context of climate change, a key challenge is to understand changing patterns and frequencies of such pulse events. Vulnerability assessments, in contrast, typically consider not only such acute or extreme events, but also more gradual, or "press-style" changes. These two types of changes are not independent of course: for example, long-term sea-level rise—a gradual process—had the effect of amplifying the height of storm surge and flooding—a pulse event—during Hurricane Sandy in 2012.

Within all of these contexts, "risk" generally refers to the probability and consequences of something being harmed by a particular agent (i.e., natural hazard or climate change impact). *Risk analysis,* therefore, combines the probability that an impact or event will occur with the magnitude of the impact and its consequences (Sarewitz et al. 2003, Jones and Boer 2004, Carter et al. 2007, Jones and Preston 2010, Cardona et al. 2012). We explicitly apply such a risk-based framing to vulnerability as the basis for defining what can be referred to as "key vulnerabilities" (see Section 6.5).

6.2. Components of Vulnerability

Vulnerability assessments have a rich history and have been guided by a similarly rich set of conceptual frameworks (Füssel and Klein 2006, Füssel 2007). Here, we follow the general framework adopted by the Intergovernmental Panel on Climate Change (IPCC 2007b) and elaborated on in *Scanning the Conservation Horizon* (Glick et al. 2011c). Vulnerability, in this context, is understood to consist of three primary components: exposure, sensitivity, and adaptive capacity (Figure 6.1). Exposure and sensitivity interact to determine potential impact,[13] with adaptive capacity representing the ability of the species or system to accommodate or cope with

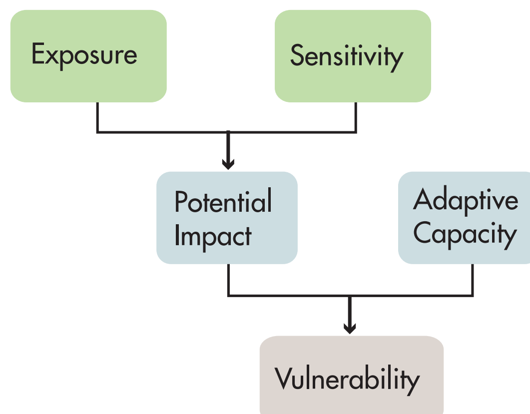


Figure 6.1. Relationship among the three major components of vulnerability: exposure, sensitivity, and adaptive capacity.

that impact. Understanding the fundamental elements of these components can help managers gain specific insights into the reasons why a particular species or system is vulnerable to climate change and, in turn, can inform potential management responses that address specific elements of vulnerability (Foden et al. 2013). While climate change vulnerability assessments

[13] Note that use of the term impact here implies negative consequences, in contrast to use in some "impact assessments" described above, in which it simply refers to deviation from existing conditions.

Table 6.1. Examples of physical factors for assessing exposure.

Level of change	Exposure factors	Examples
Primary climate change drivers[a]	Air temperatures	Average annual/seasonal temperatures; extreme values (e.g., daily minimum or daily maximum temperatures); timing (e.g., fall frost/spring frost-free dates)
	Precipitation	Average annual/seasonal totals; extreme values (e.g., extent and/or duration of heavy downpours); type of precipitation (e.g., rain vs. snow)
Associated changes	Drought	Temperature and precipitation can influence drought frequency, duration, and/or severity
	Hydrologic changes	Soil moisture associated with altered precipitation, water runoff, and evapotranspiration; timing and volume of streamflows
	Water temperatures	Average annual/seasonal lake, stream, and ocean temperatures; changes in temperature extremes; changes in associated processes such as stratification and upwelling
	Natural fire regimes	Timing, intensity, and frequency of wildfire events
	Snow/ice cover	Snow water content and timing of snowmelt; extent, timing of ice cover in lakes/streams/ oceans
	Sea-level rise	Sea-level rise due to thermal expansion of the oceans and melting of land-based glaciers and ice fields
	Decrease in ocean pH	Acidification of ocean waters associated with absorption of atmospheric CO_2
	Storm frequency and intensity	Frequency and magnitude of intense storms

[a] Other primary climate drivers include wind, humidity, cloud cover, and solar radiation.

focus on consequences of climate change, they are most useful when they incorporate effects of key non-climate stressors, or are developed in a way that promotes integration into broader threat assessments. Pollution, habitat degradation or loss, invasive species, altered fire regimes, and other factors may strongly interact with climate-related impacts, and for conservation strategies to be most effective, these interactions should be addressed in an assessment. The integration step can be iterative, with the full complexity of interactions explored for a smaller subset of priority conservation targets or "key" vulnerabilities.

6.2.1. Exposure

Exposure is a measure of the character, magnitude, and rate of climatic changes a target species or system may experience. This includes exposure to changes in direct climatic variables (e.g., temperature, precipitation, solar radiation) as well as changes in related factors (e.g., sea-level rise, water temperatures, drought intensity, ocean acidification) (Table 6.1). In addition to such physical factors, species and systems may be exposed to climate-related changes in ecological factors that may contribute to their vulnerability.

The principal way to assess exposure to climate change and related factors is through an understanding of historic and current observed climate (retrospective assessment) combined with the use of modeled climate projections (prospective assessment) (Hayhoe et al. 2011, Lawler et al. 2011). Most projections of future climates are based on the use of sophisticated global circulation models (GCMs), which because of the complexity of their calculations produce results at a coarse geographic scale. Although there is continuous progress in increasing the resolution of these global models, they are not sufficiently detailed for most conservation applications. As a result, vulnerability assessments usually use "downscaled" products derived from the underlying GCMs that can account for regional dynamics and factors such as the effects of local topography to produce regionally specific forecasts. Over the past few years there has been a tremendous effort to develop better downscaled climate projections at ecologically meaningful scales. In general, there are two approaches for producing such downscaled projections: *dynamical downscaling,* which uses a process-based high-resolution climate model centered over a relatively small region and driven by global climate model output fields at its boundaries; and *statistical downscaling,* which relies on historical instrumental data for calibration of global climate models at the local scale (Hayhoe et al. 2011). The two approaches are complementary, and a number of studies evaluate their performance and appropriateness under a range of climate change-related concerns (Mearns et al. 2003, Wilby et al. 2004, Hayhoe 2010). An increasing number of data products that provide historical climate information and/or future projections are available through such venues as the ClimateWizard Web site, Department of the Interior Climate Science Centers, and the National Oceanic and Atmospheric Administration's (NOAA) Regional Integrated Service and Assessment program (see Chapter 13).

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Determining what climatic exposure data may be appropriate to use in an assessment depends on many factors, ranging from the geographic scope and scale of the vulnerability assessment, the required levels of spatial and temporal resolution, the availability of regionally specific climate projections, and the level of expertise available to the planning team to apply and interpret the climatic data (Daniels et al. 2012). Indeed, many of these factors reflect decisions about planning purpose and scope made during step 1 of the climate-smart cycle. Additional considerations include the specific sensitivities of one's conservation targets (i.e., is a species sensitive to minimum winter temperatures, maximum summer temperatures, first frost dates, etc.), the level of uncertainty in projections, and any guidance or constraints from institutional policies (e.g., sanctioning of certain projections, such as for sea-level rise). The need for ecologically relevant climatic variables, as distinct from many of the standard climate values (e.g., averages) readily available in data products, highlights the importance of collaboration among conservation users of these data products and their developers.

Determining whether and how to use downscaled climate data is a key decision in assessing exposure. Frequently, there is a desire to use the highest-resolution climate projections possible in planning efforts, and the lack of very local-scale projections often is perceived as a major impediment for embarking on climate adaptation planning. Apart from cost implications and the potential for high-resolution projections to provide a false sense of precision, one also needs to be realistic about the sensitivity of the analyses and decisions at hand to the resolution of climatic variables. Having detailed and quantitative projections of the rate and magnitude of certain key changes may be necessary at times, but other times it may be sufficient simply to know the directionality and range of likely changes (e.g., warmer water, increased spring streamflows, or higher sea levels). This is particularly the case when using multiple general scenarios as the basis for planning (Chapter 12).

Even when using high-resolution projections there is a need to consider variation within and across models (e.g., Rupp et al. 2013) and the relative importance of uncertainties in model structure, emission scenarios, and natural climate variation (Hawkins and Sutton 2009, 2011). Given the inherent uncertainties in projecting future climates, best practices for application of climate models in ecological analysis emphasizes the use of multiple projections or ensembles of models (Mote et al. 2011).

6.2.2. Sensitivity

Sensitivity refers to the degree to which one's conservation target is or is likely to be affected by or responsive to climatic change. Sensitivity can be thought of as attributes that are intrinsic to the conservation target (e.g., life-history traits of a species), whereas exposure refers to factors that are typically external (see Table 6.2 for sensitivity examples). Species-level sensitivities may be characterized by physiological factors, such as maximum temperature tolerances among cold-water fish species (Eaton and Scheller 1996, Dunham et al. 2003), turtles with temperature-dependent sex ratios (Janzen 1994), and moisture requirements for amphibians or trees (Blaustein et al. 2010, van Mantgem et al. 2009); or ecological linkages such as dependence on certain disturbance regimes like wildfire for seed germination (Dale et al. 2001). Similarly, some ecological systems may be directly sensitive to changes in temperature or precipitation (e.g., ecosystem processes such as decomposition or nutrient transport [Wang et al. 2012]); or indirectly sensitive (e.g., rivers in which flow regimes are tied to snowpack and snowmelt timing, which are sensitive to temperature and/or precipitation [Kalra et al. 2008]).

Sensitivity assessments are likely to be most accurate when projected climate change information is integrated with deep knowledge of how a system functions, or the life history and dependencies of a given species (Lawler et

Table 6.2. Examples of factors for assessing sensitivity.

Biological level	Sensitivity factors	Examples
Species	Physiological factors	Temperature for fish (Eliason et al. 2011); moisture for amphibians (Carey and Alexander 2003); CO2 concentrations for plants (Keenan et al. 2013); pH for calcareous marine organisms (Chan and Connolly 2013)
	Dependence on climate-sensitive habitats	Low-lying coastal areas for migratory shorebirds (Iwamura et al. 2013); vernal pools for crustaceans (Pyke 2005); sea ice for polar bears *(Ursus maritimus)* and other species (Post et al. 2013; Stirling and Derocher 2012)
	Phenological changes	Leafing and flowering of plants (Cook et al. 2012); emergence of insects (DeLucia et al. 2012); migration of birds (Jones and Cresswell 2009); reproduction by forest pests (Mitton and Ferrenberg 2012)
	Ecological linkages	Disruptions to predator–prey linkages for marine fish (Hunsicker et al. 2013); to pollinator–plant relationships for butterflies (Bedford et al. 2012)
Habitats and ecosystems	Component species	Changes in woody species vs. grasses (Cornwell et al. 2012); in ecosystem engineers for coral reefs (Wild et al. 2011); in keystone species such as ringed seals *(Pusa hispida)* (Ferguson et al. 2005)
	Ecosystem processes	Decomposition rates (Ise et al. 2008); net primary production (Zhao and Running 2010); nitrogen and carbon cycling (Field et al. 2007)

al. 2011). Thus, vulnerability assessments often are most successful when species or ecosystem specialists work together with climate specialists to iteratively consider how systems might change, and to identify the most appropriate climate data to answer questions that arise about possible impacts. In this iterative process, developing a conceptual ecological model for how a system functions can be particularly useful in helping reveal inherent sensitivities, and potential interactions between climate change and other key stressors. In many cases, managers will also have a general sense of whether and how conservation targets are likely to respond to particular changes, and they can work with local experts or other partners that are familiar with various climate data sources to focus on likely sensitivities and useful data sets for exploring change.

Elements of exposure are often considered first and then applied to species or systems that are likely to be sensitive to those changes. But some understanding of the inherent sensitivities of target species or systems from the start will help refine the types of climate change exposure variables to consider. For example, if a particular target species is highly sensitive to temperature, but responses to precipitation shifts seem unlikely, then it may not be necessary to find or develop data on projections for precipitation in later steps of the assessment. Conversely, if the target system is very sensitive to factors such as snow cover and timing of spring snowmelt, it may be necessary to acquire or develop outputs not typically available from global climate models.

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6.2.3. Adaptive Capacity

Adaptive capacity refers to the ability of a species or system to accommodate or cope with climate change impacts with minimal disruption.[14] Adaptive capacity is often likened to the concept of "resilience," and the two terms are sometimes used interchangeably. As discussed in Chapter 2, however, the term resilience is used in a wide variety of ways, although in ecological terms generally refers to the ability of a system to bounce back from a disturbance and maintain or return to a given functional state (Gallopín 2007, Carpenter and Brock 2008).

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For natural systems, adaptive capacity can be associated with both intrinsic traits and extrinsic factors (see Table 6.3 for examples). Among species, intrinsic adaptive capacity can be described by three main categories: life-history traits, including dispersal and colonization ability; genetic diversity and evolutionary potential; and phenotypic plasticity (including acclimation). Life-history traits such as strong dispersal capability, broad habitat requirements, flexible diets, ability to shift behavioral patterns, and wide physiological tolerances are all intrinsic traits associated with high adaptive capacity (Nylin and Gotthard 1998, Running and Mills 2009). Some species and populations within species may also have evolutionary potential to adapt to climate change, based on traits such as generation time, genetic diversity, and population size (Bradshaw and Holzapfel 2006, Skelly et al. 2007, Berg et al. 2010, Hoffmann and Sgrò 2011). Heritable, genetic changes in populations of Yukon red squirrel *(Tamiasciurus hudsonicus)* (Réale et al. 2003), the European blackcap *(Sylvia atricapilla)* (Bearhop et al. 2005), and the great tit *(Parus major)* (Nussey et al. 2005) have been observed in response to climate change, most often associated with adaptation to the timing of seasonal events or season length. Genetic variation has been well quantified in many species, and where available may be an influential factor in assessing adaptive capacity. At an ecosystem level, such attributes as redundancy and response diversity within functional groups may be useful for assessing adaptive capacity (Nyström et al. 2008, Petchey and Gaston 2009).

One thing to note is that many of these intrinsic traits (e.g., plasticity, dispersal ability) could plausibly be considered elements of sensitivity. Indeed, some vulnerability assessment approaches (e.g., the NatureServe Climate Change Vulnerability Index, described in Section 6.4) assess only sensitivity and exposure. When conducting

[14] In this chapter, we discuss adaptive capacity as it pertains specifically to natural systems (species, habitats, and ecosystems). However, adaptive capacity also may refer to socioeconomic or institutional factors that determine one's ability to implement climate change adaptation measures. This guidance addresses the latter in chapters on selecting and implementing adaptation options (Chapters 9 and 10).

Table 6.3. Examples of factors for assessing adaptive capacity.

Biological level	Adaptive capacity factors	Examples
Species	Plasticity	Variability in ecophysiological traits among populations of tree species at different elevations/latitudes (Grulke 2010); flexibility in behavior such as choice of nesting sites with different thermal characteristics among turtles (Refsnider and Janzen 2012)
	Dispersal ability	Long-distance dispersers such as birds (Trakhtenbrot et al. 2005) may have greater ability to move to climatically suitable habitats than poor dispersers such as belowground organisms (Berg et al. 2010)
	Evolutionary potential	As affected by generation time (van Asch et al. 2012]); genetic variation (Hoffmann and Sgrò 2011); population size and inbreeding (Futuyma 2006)
Habitats and ecosystems	Landscape permeability	Barriers to dispersal and/or seasonal migration such as fragmented or naturally patchy environments (Trakhtenbrot et al. 2005)
	Redundancy and response diversity within functional groups	Redundancy in primary producers, herbivores, carnivores, decomposers, etc. are more likely to maintain key processes with changing conditions and/or species losses (Fry et al. 2012, Cadotte et al. 2011)
	Ecological processes	Processes such as sediment transport in coastal marsh systems (Stammermann and Piasecki 2012); flooding in riverine systems (Hulea et al. 2009), and other processes and disturbances can be important for maintaining ecosystem functionality

vulnerability assessments, the key is to ensure that such factors are considered—whether they are labeled as sensitivity or adaptive capacity is less important. That said, failure to explicitly consider adaptive capacity can lead to overlooking significant external factors that can influence vulnerability by facilitating or inhibiting adaptive response. For instance, habitat fragmentation or incompatible land uses may limit the ability of a species or system to move across the landscape (Vos et al. 2002); or, overharvest may reduce the genetic diversity of species and inhibit the potential for evolutionary adaptation (Thorpe et al. 1995). Similarly, reduction in riverine sediment loads (i.e., due to sediment deposition behind dams) can limit the capacity of downstream coastal wetlands to accrete sediment and keep pace with sea-level rise. As discussed in greater detail in Chapter 8, addressing external factors associated with adaptive capacity is likely to be a central focus for generating possible adaptation options.

One emerging approach to understand and think about adaptive capacity is to use an extension of the ecological concept of *niche*, as originally developed by Hutchinson (1957). Under this concept, the full range of abiotic conditions under which the organism can survive is referred to as the "fundamental niche." Biotic forces acting on the species, such as interspecific competition or predation, narrow the conditions under which the species actually exists, resulting in a "realized niche." In the same way, one can think of an organism or system as having a "fundamental adaptive capacity" based on the breadth or narrowness of its intrinsic traits. External stresses, such as physical impediments to dispersal (i.e., habitat fragmentation), loss of interspecific symbionts, or disruption of key ecological processes (e.g., fires, floods, sediment transport), can result in a restriction of adaptive capacity, resulting in what might be thought of as the "realized adaptive capacity." Extension of niche

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theory to adaptive capacity has more than just theoretical interest. Understanding the external stresses responsible for reducing a species or system's adaptive capacity can become logical targets for adaptation actions resulting in enhanced adaptive capacity. For example, adaptation measures, such as removal of dikes or seawalls, may serve to enhance the adaptive capacity of a coastal marsh by reestablishing the capacity for inland migration in the face of sea-level rise. Similarly, reestablishing natural sediment levels into the waters nourishing the marsh can enhance its adaptive capacity through encouraging vertical accretion of sediments.

6.2.4. What about Non-Climate Stressors?

Of course, the impacts of climate change are not isolated from existing stressors on the system. Rather, climate change can both exacerbate and be exacerbated by many of the factors that long have been of concern to conservation practitioners, from habitat fragmentation and water pollution to the spread of invasive species. Understanding the synergies and linkages among multiple stressors is a necessary element of climate-smart conservation. However, if climate change is treated separately from other fish and wildlife management issues, which might occur if it is considered in a stand-alone adaptation planning process, other relevant conservation challenges (or opportunities) may be underrepresented or overlooked altogether.

One way to bring non-climate stressors into climate change vulnerability assessments is to consider them in the context of the components of vulnerability. Non-climate stressors can themselves be relevant factors in determining the degree to which a species or ecological system is sensitive to climate change. For example, research suggests that exposure to pollutants, such as heavy metals, oil, and pesticides, may increase the sensitivity of some corals to increasing sea surface temperatures and associated bleaching events (Brown 2000, Ateweberhan et al. 2013). Clear-cutting forests along riparian areas may increase the exposure of stream systems to higher temperatures (Studinski et al. 2012). The presence of exotic invasive, flammable grasses may make a shrubland system more sensitive to wildfires (Bell et al. 2009). Furthermore, climate change may exacerbate other conservation problems managers must deal with. Heavier downpours, for instance, may increase nutrient loadings from agricultural areas into aquatic habitats, leading to algal blooms and hypoxia (Baron et al. 2013). And, as discussed above, a variety of anthropogenic stressors (e.g., the existence of roads, dams, invasive species, coastal armoring, overexploitation, etc.) can play a role in reducing the adaptive capacity of a system or species. Coastal Louisiana illustrates how a variety of natural and anthropogenic factors can reduce the adaptive capacity of an ecological system and result in the loss of coastal wetlands (Yuill et al. 2009, Couvillion et al. 2011). Isolation of wetlands from inputs of riverine sediments (due to flood-control infrastructure) has reduced the capacity of marshes to keep pace with rising water levels through accretion, and extensive areas have succumbed to a combination of subsidence (often due to oil extraction and pipeline infrastructure) and sea-level rise (Day et al. 2011).

Box 6.1. Steps for assessing vulnerability to climate change.

Determine objectives and scope

- Identify audience, user requirements, and needed products
- Engage key internal and external stakeholders
- Establish and agree on goals and objectives
- Identify suitable assessment targets
- Determine appropriate spatial and temporal scales
- Select assessment approach based on targets, user needs, and available resources

Gather relevant data and expertise

- Review existing literature on assessment targets and climate impacts
- Reach out to subject experts on target species or systems
- Obtain or develop climatic projections, focusing on ecologically relevant variables and suitable spatial and temporal scales
- Obtain or develop ecological response projections

Assess components of vulnerability

- Evaluate climate sensitivity of assessment targets
- Determine likely exposure of targets to climatic/ecological change
- Consider adaptive capacity of targets that can moderate potential impact
- Estimate overall vulnerability of targets
- Document level of confidence or uncertainty in assessments

Apply assessment in adaptation planning

- Explore why specific targets are vulnerable to inform possible adaptation responses
- Consider how targets might fare under various management and climatic scenarios
- Share assessment results with stakeholders and decision-makers
- Use results to advance development of adaptation strategies and plans

6.3. Assessing Vulnerability

This section provides a summary of the general steps for carrying out a climate change vulnerability assessment and some key considerations for designing the assessment. The following section highlights some of the tools and approaches for getting the job done.

There are four general steps for carrying out a climate change vulnerability assessment, each of which has a number of components, as described in detail in Glick et al. (2011c): (1) determining objectives and scope; (2) gathering relevant data and expertise; (3) assessing the various components of vulnerability; and (4) applying the assessment in adaptation planning and resource management (see Box 6.1, p. 97).

6.3.1. Considerations for Conducting Vulnerability Assessments

Before designing and conducting a vulnerability assessment, consideration of several key issues can help ensure that the assessment will be as useful as possible. Many of these considerations will have been addressed in defining the purpose and scope of the overall adaptation planning process (step 1 of the climate-smart cycle), and aligning these will be important for ensuring the vulnerability assessment will effectively support subsequent planning steps.

Be clear about purpose and audience. Climate change vulnerability assessments are, first and foremost, intended to support decision-making at some level, and as such they should be designed from the start with an eye toward the needs of end users—whether they are on-the-ground managers, policy-makers, or others in the management or scientific community. As with defining the purpose for adaptation planning overall, being clear about the intended use of a vulnerability assessment, including who will be using it and why, is a critical first step in determining an appropriate scope and scale (Bizikova et al. 2009). For example, some vulnerability assessments may be intended to provide an overview of the various ways in which climate change may affect certain species or systems of general interest to policy-makers or the public. In such cases, it may be sufficient to conduct a relatively broad, general assessment across a range of sectors and geographical scales. Others may have the more specific purpose of informing detailed management decisions, such as whether and where refugia from high temperatures are expected to persist in a park or refuge and how to manage those areas. In such cases, more detailed, quantitative assessments may be warranted. Ultimately, the sophistication of the vulnerability assessment should match the sophistication of possible uses of assessment results. While more detailed assessments may take longer and cost more, they are not necessarily "better."

There is no one-size-fits-all approach. As discussed in greater detail in the following section, approaches to conducting vulnerability assessments differ widely, and the scope and level of detail of an assessment need to match an organization or project's needs. There is no single "best" approach to conducting an assessment—the task is to use an approach that generates useful and actionable information. While stand-alone assessments may be appropriate and useful, results are sometimes more appropriate or useful when climate vulnerability assessments are integrated into existing planning efforts and they provide a synthetic assessment in the context of the full suite of relevant stressors (e.g., CMP 2013). Importantly, the purpose and objectives of the assessment should drive the selection of tools and data, not vice versa.

Tolerance for uncertainty varies. Assessing the vulnerability of species, habitats, or ecosystems to climate change is complex, and there are different levels of uncertainty and confidence associated with each piece of scientific information and expert knowledge that flow into an assessment. While no one knows exactly how climate may change or how ecological or human systems may respond to that change, management decisions can be made in the face of uncertainty, as they have been throughout history. Climate change vulnerability assessments can both help fill significant information gaps, as well as highlight areas where further analysis or research may be necessary. Ultimately, being transparent about areas of uncertainty and clearly describing the range of possible values allows managers to articulate and justify the rationale for making specific decisions. Chapter 12 provides additional insights into incorporating uncertainty in assessments and decision-making.

6.4. Tools and Approaches for Vulnerability Assessment

There are many tools and approaches for assessing the climate change vulnerability of species, habitats, ecological processes, and other resources. Some of the more commonly used methods include vulnerability indices, quantitative ecological models, spatial analyses of current and predicted distributions, multi-disciplinary models, and expert elicitation processes. Vulnerability assessment tools usually include analyses of sensitivity and exposure, and many also incorporate an assessment of adaptive capacity. Outputs and results from these tools can range from a determination of relative vulnerability (e.g., low, medium, high), to numeric scores with uncertainty bounds, to narratives detailing underlying assumptions, conceptual models, and conclusions. The level of detail in assessments varies considerably, but ideally the detail of the analysis should align with the level of detail needed to inform possible management decisions and actions. The level of analysis is also dependent on the availability of suitable data. For instance, without detailed and accurate data (e.g., on species habitat requirements and distributions), quantitative model-based assessments may not provide any more useful information than expert opinion-based assessments. And unless uncertainties are well characterized, highly detailed assessments may even be misleading in suggesting greater precision than warranted.

Selection of an appropriate vulnerability assessment tool or approach depends on numerous factors, including, perhaps most significantly, the management question of concern, but also the conservation targets (species, habitat, community, etc.), geographic scope, and available data, technical expertise, financial resources, and time available for carrying out the assessment. What follows is a survey that highlights some of the more common approaches and vulnerability assessment methods that are used at a range of organizational scales and levels of detail.

6.4.1. Species Assessments

Despite the acknowledged need for landscape-scale conservation, many policy and legislative mandates (e.g., the U.S. Endangered Species Act, many State Wildlife Action Plans) focus at the species level. Additionally, even when conservation interests may be at broader ecosystem levels, species represent the constituent components of higher ecological levels, and accordingly are often appropriate units of assessment. As a result, species are one of the most common targets for vulnerability assessments. Table 6.4 summarizes a sampling of commonly used approaches for assessing the climate change vulnerability of species.

Two general approaches to evaluate the vulnerability of species are: (1) index-based assessments that often combine multiple information types; and (2) model-based assessments that are often based on spatially explicit analyses. Two commonly used indices are the NatureServe Climate Change Vulnerability Index (CCVI) (Young et al. 2010), which applies to both plant and animal species, and is intended for use in conjunction with NatureServe conservation status ranks, and the U.S. Forest Service System for Assessing Vulnerability of Species (SAVS) (Bagne et al. 2011), which applies to terrestrial vertebrates. The University of Washington's Climate Change Habitat Sensitivity Database represents another index-based assessment approach, although this tool addresses just the sensitivity component of vulnerability. Lankford et al. (2014) offers a review and comparison of this and the previous two index-based assessment protocols. Other vulnerability assessment indices have been developed for particular taxonomic or geographic sets of species, such as California birds (Gardali et al. 2012), California native and alien freshwater fish (Moyle et al. 2013), and coral reef fish (Graham et al. 2011). Vulnerability indices generally are designed to accept varying levels of available information, including expert-based opinion, and therefore can be used to relatively rapidly assess tens to hundreds of species across multiple taxonomic groups. Where detailed modeling data are available for a given species, however, that data can be incorporated into the assessment and inform the resulting vulnerability rank.

Table 6.4. Example species vulnerability approaches.

Approach	Attributes	Examples
	Index based	
NatureServe Climate Change Vulnerability Index, CCVI (Young et al. 2010)	Uses a scoring system that integrates projected exposure to climate change with three sensitivity factors: (1) indirect exposure to climate change; (2) species-specific factors; and (3) documented response to climate change	Breeding birds in Arctic Alaska (Liebezeit et al. 2012); Florida (Dubois et al. 2011); Illinois (Walk et al. 2011); New York (Schlesinger et al. 2011)
U.S. Forest Service System for Assessing Vulnerability of Species, SAVS (Bagne et al. 2011)	Uses 22 predictive criteria to create six vulnerability scores: an overall vulnerability score, four categorical scores (habitat, physiology, phenology, biotic interactions) indicating source of vulnerability, and an uncertainty score	Barry M. Goldwater Range, Arizona (Bagne and Finch 2012); Coronado National Forest, Arizona (Coe et al. 2012, Davison et al. 2012); Fort Huachuca, Arizona (Bagne and Finch 2010)
	Model based	
Modeling of individual species (e.g., population, physiological)	Generally highly detailed and focused on well-studied species; often involve population or physiological models	Joshua tree *(Yucca brevifolia)* (Cole et al. 2011); Trout species (Wenger et al. 2011); Polar bears in southern Beaufort Sea (Hunter et al. 2010); Tidal marsh birds (Nur et al. 2012)
Species distribution or "climate envelope" models	Spatially explicit models that rely on geospatial species and environmental data. Can be mechanistic (e.g., Niche Mapper) or correlative (e.g., Maxent); can be single or multiple species	Pika *(Ochotona princeps)* (Calkins et al. 2012); European mammals (Levinsky et al. 2007); North American trees (McKenney et al. 2011); Appalachian salamanders (Milanovich et al. 2010)

Model-based assessments involve either spatially explicit models of species distributions and/or application of detailed physical or population models. For well-studied species, detailed population or physiology-based models can be used to assess climate-related vulnerabilities (Cole et al. 2011, Wenger et al. 2011). Such assessments require considerable amounts of detailed, species-specific information, and can be computationally intensive. More frequently, model-based vulnerability assessments make use of species distribution models as the basis for analysis, either for multiple species (Iverson et al. 2008, Lawler et al. 2010a, Sinervo et al. 2010) or in a more detailed manner for one or a few species (Copeland et al. 2010, Cole et al. 2011, Calkins et al. 2012). The models in these vulnerability assessments generally make use of associations between environmental variables (e.g., elevation, temperature, precipitation) and known species' occurrence records in order to identify a "climate envelope," that is, potentially suitable environmental conditions for the species.[15] Vulnerability in such assessments generally reflects the difference between the current distribution of a species, and the projected distribution of suitable future climatic conditions. There is a rich and growing literature on species distribution and bioclimatic models, including several assessments of the pros, cons, and limitations of the approach (Franklin 2009, Araújo and Peterson 2012). As noted above, index-based and model-based approaches can be complementary, and planners may choose to use a fairly rapid screening-level assessment approach to identify species for which a more detailed model-based analysis could yield management-relevant results.

6.4.2. Habitat and Ecosystem Assessments

Habitat-scale assessments are well suited to support landscape conservation efforts, such as identifying and preserving key movement corridors, identifying risks to high-priority habitats, supporting buffers, ecological restoration, or protection of priority habitats. By identifying not only which habitats are vulnerable, but the reasons for vulnerability, a habitat-level assessment can help address threats that are most immediate or that pose significant long-term danger. Habitat-level vulnerability assessment approaches include indices (e.g., Comer et al. 2012, Manomet and NWF 2012) as well as spatially explicit mapping approaches (e.g., Bachelet et al. 2001, Notaro et al. 2012, Rehfeldt et al. 2012). Some habitat methods are more taxon specific, such as a recently developed decision tool for assessing the vulnerability of coastal shorebird habitats to climate change.[16]


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As highlighted in Table 6.5, a number of habitat- and ecosystem-specific vulnerability assessment methods have been developed, including a general framework for assessing the vulnerability of wetlands to climate change (Gitay et al. 2011), a manual to help practitioners assess the vulnerability of mangrove ecosystems to climate change (Ellison 2012), an approach to marine ecosystem vulnerability in the California Current (Teck et al. 2010), and an approach for forest ecosystem vulnerability in northern Wisconsin (Swanston et al. 2011). There also are several tools and approaches for assessing coastal vulnerability,

[15] Suitable environmental conditions for a species may be characterized by using either a mechanistic approach or a correlative approach (Pearson and Dawson 2003), with correlative approaches typically referred to as bioclimatic envelope models (Rowland et al. 2011)
[16] Climate Change Vulnerability Assessment for Shorebird Habitat, http://www.whsrn.org/tools/climate-change-tool.

Table 6.5. Example habitat/ecosystem vulnerability approaches.

Approach	Attributes	Examples
Index based		
Northeast Association of Fish and Wildlife Agencies (NEAFWA) Regional Habitat Vulnerability Model (Galbraith 2011)	Excel spreadsheet-based, the model comprises four modules used to produce an overall evaluation and score of habitat vulnerability to climate change and non-climate stressors	Fish and wildlife habitats in the northeastern United States (Manomet and NWF 2012); New York (Hilke and Galbraith 2013)
NatureServe Habitat Climate Change Vulnerability Index (HCCVI) (Comer et al. 2012)	Three to five separate analyses produce sub-scores used to generate an overall score for sensitivity (from direct effects) vs. resilience (indirect effects + adaptive capacity)	Mojave and Sonoran deserts (Comer et al. 2012)
U.S. Geological Survey Coastal Vulnerability Index (CVI)	Ranks six factors in terms of their contribution to sea-level-rise-related coastal change	22 National Park Service sea- and lakeshore units (Pendleton et al. 2010)
Model based		
Dynamic vegetation models and climate envelope models	Various modeling approaches for simulating the response of terrestrial vegetation distribution to climate change scenarios	Sagebrush in Nevada (Bradley 2010); Appalachian ecosystems (Jantz et al. 2013); American Southwest vegetation (Notaro et al. 2012)
The Sea Level Affecting Marshes Model (SLAMM)	Simulates dominant processes in coastal wetland conversion and shoreline modifications due to sea-level rise	Prime Hook National Wildlife Refuge, Delaware (Scarborough 2009); Waccasassa Bay, Florida (Geselbracht et al. 2011); southeastern Louisiana (Glick et al. 2013)
WETLANDSCAPE (www.wetlandscape.org)	A process-based deterministic model that simulates wetland surface water, and vegetation dynamics of wetland complexes	U.S. Prairie Pothole wetland complexes (Johnson et al. 2010)

particularly to sea-level rise, including indices (e.g., the U.S. Geological Survey Coastal Vulnerability Index [Thieler and Hammer-Klose 1999]) and spatially explicit mapping approaches (e.g., the Sea Level Affecting Marshes Model of SLAMM [Clough et al. 2010]). In addition, the U.S. Environmental Protection Agency (U.S. EPA) and collaborators have developed a process to assess climate change effects on specific ecosystem processes—sediment retention in salt marshes and community interactions in mudflats—using expert elicitation approaches (U.S. EPA 2012a, 2012b).

6.4.3. Place-Based Assessments

Vulnerability assessments are often targeted toward a specific geographic place or region, which can range from specific management or jurisdictional units—such as parks, refuges, national forests, tribal lands, counties, or entire states—to naturally defined features such as watersheds or regional landscapes. Typically, place-based assessments use a combination of species-, habitat-, and ecosystem-based assessment approaches, and may also include approaches that focus on relevant socioeconomic or cultural resources.

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6.4.4. Multi-Sectoral Assessments

Several multi-sectoral approaches are available that can facilitate assessment across ecological and socioeconomic systems (Kuriakose et al. 2010). Bergström et al. (2011), for example, applied a multi-sectoral approach to assess the vulnerability of several key sectors of the Finnish society/economy, including watersheds and water bodies, urban areas, coastal areas, ex situ plant conservation, forestry, fisheries, and tourism. They assessed the threats and challenges posed by climate change to ecosystem services and livelihoods, and suggested methods for adapting to changing conditions. Another approach is that developed by the Advanced Terrestrial Ecosystem Analysis and Modelling (ATEAM) project, which integrates results of different ecosystem models covering biodiversity, agriculture, forestry, hydrology, and carbon sequestration across multiple scales into a multidisciplinary vulnerability assessment (Metzger et al. 2005). Outputs include vulnerability maps and an adaptive capacity index, which allow for comparison of relative vulnerabilities across the relevant study region.

6.5. Identifying "Key Vulnerabilities" to Inform Adaptation Planning

As part of the climate-smart planning process, vulnerability assessment is intended to provide a context for linking adaptation actions with climate impacts. However, as noted previously, vulnerability assessments do not dictate what the priorities for adaptation attention should be, but rather provide context for making such a determination. Accordingly, a critical stage in adaptation planning is winnowing down from the broad array of concerns that may have been revealed during the course of the vulnerability assessment, to those vulnerabilities that are most critical to address during subsequent steps of the adaptation planning cycle. We refer to these priorities for subsequent adaptation attention as "key vulnerabilities."

The concept of key vulnerabilities was introduced by Schneider et al. (2007), who characterized them as those climate impacts that "merit particular attention by policy-makers because they endanger the lives and well-being of people or other valued attributes of climate-sensitive systems." Building on the notion that these are the vulnerabilities meriting "particular attention," we consider key vulnerabilities as the critical connection linking conservation goals with needed adaptation strategies and actions. In this context, key vulnerabilities can be defined as those vulnerabilities that pose the greatest risk to achieving one's agreed-upon conservation goals and objectives. In essence, they reflect those risks that, unless addressed through subsequent adaptation actions, would undermine one's ability to achieve enduring adaptation benefits. In the face of many possible targets for adaptation actions, identification of key vulnerabilities provides a structured means for setting priorities in the development, evaluation, and selection of adaptation strategies and actions in steps 4 and 5 of the climate-smart cycle.

As discussed above, vulnerability assessments help identify *which* species, systems, or other conservation targets are likely to be vulnerable, as well as understand why they are vulnerable. The identification of "key vulnerabilities" in any particular situation should encompass both of these attributes. For instance, selecting key vulnerabilities may start with determining which resources are of greatest concern based on their relative vulnerability (or lack thereof) and centrality to meeting one's conservation goals, followed by a determination of the most critical climate-related impacts affecting those resources. Where the subject of conservation attention is predetermined, identification of key vulnerabilities may instead start with the climate-related impacts of greatest concern. In either case, defining key vulnerabilities necessarily includes articulating both the subject of adaptation interest (i.e., *which*) as well as the critical climate-related concerns affecting those resources (*why*).

Our use of the concept of key vulnerabilities reflects an explicit integration of risk management in the application and use of vulnerability assessment results. As noted in Section 6.1.1, risk reflects the probability that an impact will occur with the magnitude and consequence of the impact. In this sense, the use of key vulnerabilities in focusing adaptation strategies and actions recognizes that not all identified vulnerabilities have the same level of consequences. As an example, on a particular wildlife management area a wetland species might be determined to be extremely vulnerable to certain climate impacts (e.g., sea-level rise), but that vulnerability may have little or no consequence for achieving conservation goals that focus on the area's upland systems. In contrast, an upland species might have a lower relative vulnerability, but due to its role as an ecosystem engineer, be regarded as critical to sustaining ecological processes in that upland system. Accordingly, the more moderate threats to the latter species might be regarded as representing a "key vulnerability," and serve as the focus of subsequent adaptation planning, even though overall it is less vulnerable to climate impacts than the wetland species. Such an approach to setting priorities is consistent with more traditional conservation planning where actions do not always focus on those species with the highest absolute extinction risk, but take into account broader values and conservation goals.

The process for identifying key vulnerabilities can vary considerably, and different planning teams will wish to choose the criteria they find most relevant. From a climate-smart conservation perspective, the following general criteria may be especially applicable:

- **Implications for conservation goals.** Perhaps the most important reason for selecting particular vulnerabilities as a priority for adaptation action is the degree to which they could affect the ability to achieve existing, or climate-informed, goals and objectives.

- **Implications for other relevant societal values.** The choice of key vulnerabilities may also take into consideration the extent to which they affect other social and economic values, from mitigating climate risks to human communities to maintaining valued historical or cultural resources.

- **Ecological significance.** Is the vulnerable species or system particularly significant for ecological reasons (e.g., listed as threatened or endangered, keystone species, or ecosystem engineer), or for cultural reasons (e.g., provides a valued ecosystem good or service; contributes to local traditions or customs)?

- **Magnitude of impacts.** What is the scale and intensity of the impact likely to be and would the consequences be especially harmful (e.g., cause cascading extinctions)? Would the relevant impact affect an extended geographical area or large number of species?

- **Likelihood of impacts.** Are the impacts already being observed, or projected to occur with high certainty, or are they based on more uncertain future projections with multiple assumptions?

- **Reversibility of impacts.** Are the potential impacts likely to be persistent or irreversible (e.g., result in species extinction or system collapse), or could actions taken later still be effective? Is there potential for the system to reach an ecological threshold or tipping point of concern?

- **Timing of impacts.** Are the impacts already occurring or expected to occur in the near term, or are they only expected to manifest in a longer time frame? Near-term impacts may be more likely to rank as key vulnerabilities, in part because people tend to discount future values (both costs and benefits). However, even where impacts may be further in the future, opportunity costs might be incurred by failure to act in the near term.

- **Potential for successful adaptation.** Although this should not be the primary criterion for identifying key vulnerabilities, particularly since one may not at this point have a sense for what adaptation options might be available, opportunities for successful adaptation can be relevant.

The choice of criteria will depend on the breadth of one's particular goals and the diversity of stakeholders involved in the decision. For example, a forest manager operating in a multiple-use management framework with diverse goals (e.g., maintaining timber production, enhancing wildlife habitat, providing clean water) may need to weigh multiple trade-offs to identify those key vulnerabilities that should serve as the basis for developing adaptation strategies and actions. Linking the identification of key vulnerabilities to agreed-upon goals and objectives, however, connects this process back to any broader stakeholder engagement process that might have been used in defining or clarifying those underlying goals. In more focused management contexts, such as where protection of a particular species is legally mandated, key vulnerabilities may be more predetermined. Reflecting the iterative nature of the climate-smart cycle, it is also possible that the key vulnerabilities identified early in the adaptation process may change, particularly in light of any modifications in the overarching conservation goals or management objectives that occur during step 3 of the climate-smart cycle, or even after adaptation strategies have been developed and implemented.

As noted earlier, climate change vulnerability assessment can help identify relative vulnerability among conservation targets, and identify the mechanisms causing their vulnerability, but these assessments on their own do not prescribe which targets or mechanisms to focus on, or what management actions to take. Going through the process for evaluating the full array of vulnerabilities to identify "key vulnerabilities" is an explicit way to accomplish the key climate-smart characteristic of "linking actions to impacts."

NPS

6.6. Case Study: Badlands National Park Vulnerability Assessment

Recognizing the considerable threat that climate change poses to the natural and cultural resources at the heart of America's national parks, the National Park Service (NPS) has embraced climate change vulnerability assessment as a useful tool to help the agency better understand the scientific understanding of the impacts, risks, and uncertainties it faces. In 2012, NPS completed a vulnerability assessment at Badlands National Park in South Dakota, focusing on potential impacts to species and plant communities, sacred sites, and archaeological artifacts (Amberg et al. 2012).

The assessment encompassed many of the elements highlighted within this chapter. The effort began through collaborative meetings with relevant partners, including NPS staff, analysts from Saint Mary's University of Minnesota GeoSpatial Services, surrounding land managers (e.g., U.S. Forest Service), tribal representatives, and stakeholders. This broad group discussed the proposed project boundary, the resources to be considered within Badlands National Park and surrounding areas, availability of data, expertise, and other informational resources, the pertinent time frame for climate change projections, and the desired role of relevant stakeholders throughout the assessment process. This scoping effort enabled the assessment team to define the relevant resource targets, geographic and temporal scale, and desired level of complexity for the assessment moving forward. For example, participants agreed that the assessment could include resources outside of park boundaries given that many of the ecological systems and associated biodiversity within the park extend beyond those boundaries.

Project partners also addressed whether to focus the assessment on ecological communities or individual species, based on the premise that if a particular community is highly vulnerable to climate change, then species dependent upon that community would also be affected. Because resource managers in national parks focus both on individual species and ecological health and processes, as well as cultural resources, a multi-scale assessment was determined to be most useful. The group decided to specifically assess:

- Dominant plant communities in Badlands National Park and surrounding areas
- Selected wildlife species
- Primary disturbance processes (e.g., fire, erosion, grazing)
- Paleontological resources
- Cultural resources (e.g., archaeological resources, historic structures, and landscapes)

The Badlands National Park assessment focused on both: (1) identifying *which* specific species, plant communities, and other resources are likely to be most affected by climate change; and (2) understanding why these resources are likely to be vulnerable, based on the needs and interests of the multiple stakeholders involved. It also explicitly identified the factors associated with the three components of vulnerability—exposure, sensitivity, and adaptive capacity—using both historical and projected climate changes to the year 2100.

At the plant community level (woodlands, shrublands, sparse badlands, seep/springs, and grasslands), project partners used the expert-driven assessment approach developed by Hector Galbraith (Manomet and MDFW 2010a, 2010b, 2010c) for six specific variables:

1) Location in geographical range of the plant community
2) Sensitivity to extreme climatic events
3) Dependence on specific hydrologic conditions
4) Intrinsic adaptive capacity
5) Vulnerability of ecologically influential species to climate change
6) Potential for climate change to exacerbate impacts of non-climate stressors

Based on available scientific literature, data, and expert opinion, each variable was assigned a "best estimate" score from 1 (least vulnerable) to 5 (most vulnerable) based on the likely vulnerability of the particular plant community to climate change and non-climate stressors, which enabled a comparison of relative vulnerability across the various communities. They also were given certainty scores (i.e., 6–10 = low, <30% certainty; 11–14 = moderate, 30–70% certainty; and 15–18 = high, >70% certainty) to document how confident analysts were in assigning the relevant vulnerability scores. Finally, detailed narratives were developed for each variable assessed to explain the specific reasons why the particular vulnerability scores were established and to provide transparency to users. A similar process was applied for relevant variables associated with Species Level and Cultural Resource vulnerabilities, the results of which are available in the full assessment report.[17]

Table 6.6 summarizes results for the relative vulnerability of plant communities in the assessment study area. The assessment results indicate varying degrees of vulnerability among plant communities. Woodlands were identified as highly vulnerable, primarily due to their high moisture requirements and projected exposure to more frequent droughts, while grasslands were categorized as least vulnerable due to low sensitivity to extreme climatic events and relatively high intrinsic adaptive capacity. On the whole, the experts generally concluded that the impacts to plant communities in the park are likely occur over a period of decades or longer, ultimately resulting in altered plant composition. While the system is expected to retain its overall structure, however, the devil is in the details in terms of management considerations. For example, even though grasslands as a whole are considered least vulnerable, climate change is projected to favor warm-season grasses, which in some cases are less valuable forage for the park's wildlife. In response to projections for increasing temperatures that favor warm-season grasses, one adaptation strategy that managers could consider would be to conduct prescribed burn treatments at times of year that favored the cool-season grasses.

Table 6.6. Summary of ecological community vulnerability in Badlands National Park.

Plant community	Climate change vulnerability	Confidence
Woodlands	High	Moderate
Shrublands	Moderate	Moderate
Sparse Badlands	Moderate	Moderate
Grasslands	Least	High

[17] https://irma.nps.gov/App/Reference/Profile/2184543.


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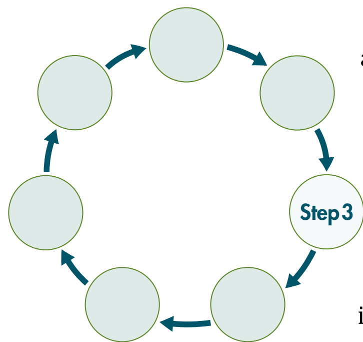
Chapter 7. Reconsidering Conservation Goals in Light of Climate Change[18]



Successful conservation requires clear goals and objectives and likewise, these are imperative for climate adaptation. Goals provide the framework within which to design, implement, and measure conservation efforts, and setting appropriate goals and objectives is critical to ensure actions are likely to produce the desired outcomes.[19] Because goals reflect shared values, the process for setting them must necessarily be collaborative, incorporating input and engagement of key stakeholders. Articulating and agreeing on goals also facilitates moving from adaptation planning to implementation. The bottom line is that making conservation efforts climate smart will be successful only if clear and appropriate goals are established.

Conservation practitioners are often eager to move immediately from an assessment of climate impacts and vulnerabilities to deliberation about strategies and management actions that might ameliorate those impacts. Without pausing to reconsider whether existing goals and objectives continue to make sense given the projected impacts, the resulting actions may not produce meaningful and enduring climate adaptation benefits, or may even be counterproductive. Revising goals—whether in subtle or substantial ways—may or may not be needed; asking the question, however, is essential.

Goals figure prominently in at least two parts of the climate-smart conservation cycle—steps 1 and 3 (Figure 4.1). Clarifying existing (or legacy) goals and objectives during step 1 provides an essential context for designing an adaptation or conservation planning process. The process of articulating existing goals and objectives may reveal inadequacies even apart from a lack of climate considerations. Existing goals may be vague and unclear, while objectives often lack specificity. Thus, quite apart from a concern with climate issues, there is an overarching need for conservation and resource management efforts to have well-crafted goals and objectives. Step 3 of the cycle, in contrast, focuses on the need to reevaluate goals and objectives in light of climate change and is the focus of this chapter.

Although we highlight a specific focus on goals in steps 1 and 3 of the cycle, reexamining the appropriateness of goals from a climate change perspective may also be appropriate elsewhere in the climate-smart cycle, such as during the development and evaluation of strategies. For example, as one develops specific adaptation options and actions (step 4 of the cycle), it may become apparent that no strategies or actions exist that could achieve the agreed-upon goals. In this instance, another review of goals and objectives may be necessary before attempting to identify possible adaptation options. This may also occur elsewhere in the process, from the evaluation of adaptation options (step 5) to the implementation (step 6) and monitoring (step 7) phases. Indeed, the need to review and possibly modify goals

[18] Lead authors: Bruce A. Stein, Cat Hawkins Hoffman, and Patty Glick.

[19] See Box 5.1 for definitions of the terms goals, objectives, and targets in the context of this guidance.

and objectives can be thought of as an iterative process throughout the entire climate-smart cycle. Nonetheless, we consider a purposeful review of goals during step 3 to be particularly important in light of the availability of climate impact and vulnerability information developed during the preceding step.

Ultimately, we should seek agreement on a set of *climate-informed* conservation goals and objectives. By this, we mean forward-looking goals that bridge existing conservation and resource management values to new realities and challenges resulting from a shifting climate. As discussed in Chapter 2, we deliberately use the term "climate-informed" goals rather than "climate change goals." While there may be instances in which goals specifically focus on climate change, in most cases the best approach will be to incorporate climate change considerations into existing decision processes and conservation efforts. This type of integration occurs most successfully if managers view adaptation as part of and crucial to their work, rather than as appended to and imposed on it. Well-articulated, climate-informed goals are the foundation to identify, evaluate, and select alternative adaptation and management options, and to measure progress in implementing management actions.

7.1. Conservation Goals and Human Values

Goals reflect human values, and thus are not preordained or static. Conservation goals are a product of societal, cultural, and ethical preferences and norms, including the relative acceptability of various trade-offs. In turn, evolving scientific knowledge and understanding can influence these values and preferences. In many instances, legal requirements, which themselves are based on shared societal values, may establish conservation goals. In essence, conservation goals reflect how people value natural resources and express what matters most to them.

Multiple and conflicting goals may apply to the same places or resources, reflecting the perspectives and values of different people, communities, or institutions. Conservation goals can focus on such diverse concerns as preventing species extinctions, sustaining the maximum diversity of species, maintaining intact and fully functional ecosystems, sustaining key ecosystem services (e.g., pollination, water supply, hazard risk reduction), and maintaining sustainable levels of harvestable resources (e.g., waterfowl, timber, forage). As a result, setting goals and objectives requires an understanding of the values that stakeholders bring to the table.

Divergent and conflicting values are particularly stark when comparing preservation-oriented goals with resource use and/or extraction goals, but conflicts and trade-offs exist even within the conservation community. Management of national parks, for instance, must often weigh values and goals focused on resource protection with those associated with public access, use, and enjoyment. Similarly, fish and wildlife managers often balance goals related to biological resources and those focused on hunting and fishing opportunities. And there are many examples where sustaining or enhancing one environmental benefit is at odds with maintaining other environmental benefits. For example, in the southwestern United States, the goal of restoring native riparian vegetation through removal of tamarisk (*Tamarix* spp.), an invasive shrubby tree, is at odds with the goal of recovering populations of the endangered southwestern willow flycatcher (*Empidonax traillii extimus*), which in the absence of native riparian canopy now uses tamarisk for nesting (Shafroth et al. 2005).

Like a prism refracting light, then, a single landscape may represent divergent and overlapping values. Depending on these varied perspectives, a landscape may be valued as a source of raw materials, location for recreational opportunities, provider of ecosystem goods and services, spiritual sanctuary, refuge for biodiversity broadly, or

Ryan Hagerty/USFWS

habitat for a particular endangered species. And as social and cultural norms shift over time, so do our values and goals for the natural world. Values and their expression in policy objectives that may have been suitable for the social, ecological, and technological context of one time period may be ill suited, undesired, or untenable in a different time and context (Cronon 1996, Hagerman et al. 2010).

7.2. Implications of Climate Change for Conservation Goals

Conservation and natural resource managers will not face a choice of whether to reconsider conservation and management goals; rather, it will be a matter of when, how much, and in what ways these should change (Glick et al. 2011a). CCSP (2008a) noted that "for virtually every category of federal land and water management, there will be situations where currently available adaptation strategies will not enable a manager to meet specific goals, especially where those goals are focused on keeping ecosystems unchanged or species where they are." Camacho et al. (2010) summarized the range of possible conservation goals in the context of climate change by asking "whether we want to be curators seeking to restore and maintain resources for their historical significance; gardeners trying to maximize aesthetic or recreational values; farmers attempting to maximize economic yield; or trustees attempting to actively manage and protect wild species from harm even if that sometimes requires moving them to a more hospitable place?"

Several key themes and issues emerge from the literature associated with rethinking conservation goals in the context of climate change. What is apparent is there are no easy answers and, of necessity, there will be trade-offs among long-held values. As highlighted above, such trade-offs are not new, although often these occur in the background without clear articulation. Decisions associated with climate adaptation will likely accentuate certain trade-offs, however, bringing them more clearly into the open.

Among the most common suggestions for modifying conservation goals is to shift from goals focused on maintenance of existing ecological patterns (e.g., for composition or structure) to goals focused on processes[20] that underlie those patterns. Specifically, conservation efforts may need to shift from an emphasis on preserving current patterns of species at particular locations, toward maintaining ecological and evolutionary processes (Harris et al. 2006, Pressey et al. 2007, Prober and Dunlop 2011, Groves et al. 2012). Process-oriented goals are not new in conservation; managers long have known that maintaining ecological processes is fundamental to achieving desired conditions. What is new is the suggestion that a focus on process might be required to ensure the continuation of diverse and functioning ecosystems, even if the particular compositional and structural attributes of that system may be strikingly different.

Goals focused on compositional attributes of biodiversity[21] will still be relevant, but may need to be considered at different spatial and temporal scales. For example, rather than retaining the full diversity of species at localized sites, compositional goals may need to be restated as maintaining that full diversity across larger landscapes. In fact, much of the emphasis on habitat corridors and landscape connectivity implicitly recognizes the need to take this broader geographic perspective as a means for sustaining species and genetic-level diversity across a region.

To the degree that managers already address process goals, though, these tend to focus more on ecological processes than evolutionary processes. The latter, however, will likely become increasingly important. If managing biodiversity under climate change will largely be about "facilitating nature's response" (Prober and Dunlop 2011), then having explicit goals to promote evolutionary adaptation to proceed will be important (Hoffmann and Sgrò 2011). One approach to retaining evolutionary potential that is gaining acceptance in the literature focuses on protecting geophysical settings as important drivers of biodiversity (Anderson and Ferree 2010, Beier and Brost 2010). In this view, setting goals to conserve unique geophysical "stages" may play an important role in sustaining overall diversity even if the individual "actors" or species will be different.

An overarching conservation goal for many agencies and organizations currently focuses on the concept of "naturalness" (Cole and Yung 2010). As species shift in response to climate change, existing ecosystems disaggregate, and novel ecosystems (composed of both native and nonnative species) emerge, what will be viewed and accepted as the "new natural"? Managers of U.S. national parks, for example, currently seek to maintain "natural conditions," a term used to describe the condition of resources that would occur in the absence of human dominance over the landscape (NPS 2006). The dilemma of managing for "naturalness" in an era of climate change is particularly stark with regards to federally designated wilderness areas. Future trade-offs will be inevitable between two defining characteristics of wilderness—"untrammeled" quality and historical fidelity (Stephenson and Millar 2012). Untrammeled nature, a core concept in the Wilderness Act of 1964, refers to areas unencumbered by humans. The concept of historical fidelity alludes to the primeval character of these areas. Paradoxically, efforts to retain historical fidelity will likely require increased human intervention that contravenes the notion of untrammeled nature.

[20] These can include physical (e.g., disturbance regimes), biogeochemical (e.g., nutrient cycling), biological (e.g., seed dispersal networks), and evolutionary (e.g., gene flow) processes.

[21] Biodiversity can be characterized as consisting of three major attributes: composition, structure, and function (Noss 1990). Composition refers to the identity and variety of biological elements that exist in an area, such as the diversity of different species, genes, or ecological communities.

7.2.1. Persistence and Change in Conservation Goals

Acknowledging and planning for system change (see Section 2.3) is especially important for climate-informed goals. As discussed earlier, many conservation and resource management goals currently focus on maintaining status quo conditions, or conditions of some historical state, even if this intent is not always explicit. Nonetheless, by their very nature most management activities intend to facilitate change, either through reducing stresses to the system, or through enhancing system attributes that reflect particular stakeholder values and interests. Against that backdrop, embedding visions for ecological change in conservation goals and management objectives is not new or unusual. What is different is the need to embrace forward-looking goals that encompass future conditions that may be strikingly different from current or historical conditions. Additionally, there is a need to recognize that non-stationarity extends into the indefinite future. Forward-looking goals are not necessarily about transitioning from one stable state to a new stable state, but rather about managing for continual change.

Addressing persistence and change in conservation goals and objectives will vary relative to conservation targets, as well as geographic scope and temporal scale. In a particular area, for instance, one might define as a priority the maintenance (i.e., persistence) of a particular ecosystem service, while being open to facilitating shifts (i.e., change) in the site's complement of species in order to maintain that ecosystem function. Similarly, a priority may be to maintain the full diversity of native species across a broader landscape (i.e., persistence), while accepting modified species compositions (i.e., change) at a particular site. Or, as described in more detail in Chapter 8, one may define as a priority maintenance of existing habitat conditions at a site over a defined time period (or until the system approaches some ecological threshold), at which point the goal may switch to managing the system for transition. Given the interplay among these various factors, defining goals and objectives entirely in terms of either persistence or change is incomplete; including the relevant temporal and spatial scales is also necessary. It will be increasingly important to be explicit in one's goals about how desired outcomes (near and longer term) relate to this continuum of change.

7.2.2. Psychological Challenges

Psychological challenges are among the most pervasive obstacles to reconsidering and modifying conservation goals or objectives in light of climate change (Gifford 2011). Hagerman et al. (2010) emphasize that many conservationists find it difficult to move beyond the familiar goals of restoring and protecting existing patterns of biodiversity and a priori–selected conservation targets due to strong resistance to making trade-offs—a concept described in the psychology literature as "protected values" (Gregory et al. 2006). The notion of adaptation as picking winners and losers (i.e., triage) is troubling to some, who are concerned that climate change may "blow conservation off course" (Tingley et al. 2013). In fact, numerous factors influence the outcome of conservation efforts, including those beyond the control of managers. Thus, a more appropriate view of triage is that of efficient allocation of scarce resources for conservation (Bottrill et al. 2008). In that sense, triage is not new to climate adaptation, and instead commonplace in conservation and resource management. Oftentimes, however, these choices and trade-offs are unstated, implicit, and or not fully recognized. Reconsidering goals relative to climate change will oblige managers to engage in the psychologically demanding task of being explicit about these difficult choices.

7.3. Reconsidering Goals and Objectives in Practice

How should planning teams go about the process of reevaluating goals and objectives? First, it is important to determine the appropriate level for review. Goals and objectives can occur from levels of overarching agency or organization mission to specific desires for a particular program, project, or place. Consequently, they can vary considerably in formality and rigidity; project-level goals, for instance, may be easier to modify than institutional goals embedded in legislation or hardened as part of institutional culture. In fact, there may be multiple layers of goals relevant in any particular situation, ranging from those at the highest level of abstraction and aspiration, to those that are very pragmatic and operational in nature.

Similarly, there may be a difference in the ability of managers to modify conservation goals versus management objectives. As described in Box 5.1, goals are often visionary and directional in nature, and reflect higher-level outcomes and aspirations, while objectives tend to be more specific and operational in nature. Accordingly, setting goals often requires broad collaboration and agreement across multiple internal and external stakeholders. On the other hand, since objectives support achievement of agreed-upon goals, there is generally more discretion for project or planning teams to modify objectives. However, if higher-level goals no longer make sense in light of climate change, simply adjusting program or project objectives will probably be insufficient.

Setting clear goals and objectives is an art, and there are many resources available that describe best practices for doing so. We will not restate such guidance here, but note that one of the more widely used approaches focuses on application of the so-called SMART framework (Doran 1981, Adamcik et al. 2004). In this approach, each letter refers to a key quality: specific, measurable, achievable, relevant, and time-bound. Below we offer suggestions for reconsidering existing conservation goals and objectives in light of climate change, intending that this climate-focused reevaluation should complement, not replace, application of existing frameworks (such as SMART) in developing sound goals and objectives. However, in reconsidering goals and objectives in the context of climate change, we consider one SMART criterion—achievable—to be of particular relevance.

Considering whether the goal or objective is still *achievable* or feasible in light of climate change is important for ensuring that they are climate smart. Achievability should be considered from both an ecological and technical perspective. Given the type and direction of climate change projected for an area and the vulnerability of a species or habitat, does the goal or objective still make sense? Be sure to consider whether the goal or objective may create barriers to adaptation or even be maladaptive. An honest assessment of achievability can also help distinguish between those goals that are aspirational, but unattainable, and stretch goals that may be possible through innovation, commitment, and hard work.

What is technically achievable may, however, be different from what might be realistic to expect, based on projected financial resources, institutional capacity, legal authorities, community support, or political opposition. Many factors that determine whether a goal or objective is realistic can change over time, and one should exercise caution in permanently dismissing a goal or objective based on economic or cultural context at a single juncture. For example, strategies designed to enhance adaptive capacity (especially from an institutional perspective) may have a significant role in changing the context to support achieving particular adaptation goals and objectives. Additionally, increasing knowledge and shifting cultural and political values and norms will influence what may and may not be realistic. Twenty years ago, for example, goals assuming the retreat and abandonment of shoreline structures in the face of rising sea levels and associated storm surge

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may not have been considered realistic; such approaches are now being openly discussed, and in a few places actually carried out.

7.3.1. Reevaluating the What, Why, Where, and When

The idea of reevaluating, and possibly modifying, existing goals can be intimidating, but breaking the task into discrete components can make it less daunting. Accordingly, we identify four components of goals and objectives that may serve as a basis for conducting such a reevaluation. Crafting climate-informed goals may not require wholesale revision; instead, climate-focused modifications may only be necessary to one or two of the following four components.

- **What** (the conservation *target* or subject of the goal)
- **Why** (the intended *outcomes* or desired condition)
- **Where** (the relevant *geographic scope*)
- **When** (the relevant *time frame*)

What. Are existing conservation targets still appropriate, or is a change needed in which ecological features or processes should be the focus of attention? Conservation targets can range from individual species, particular species assemblages, habitat or ecosystem types, ecological processes, or suites of ecosystem goods or services. Modifications might be either within these categories (e.g., shift from focusing on one species to another), or across categories (e.g., shift from focusing on particular species or habitats to underlying ecological processes).

Why. Are intended outcomes or desired conditions for the conservation targets still relevant and feasible, or is a change warranted to reflect biological or ecological realities, or changing values? Where emphasis is on the persistence of a particular species or ecosystem trait, does this continue to make sense, or is there a need to consider alternatives that look to transition-oriented outcomes? "Desired future condition" is a familiar and widely used concept in ecosystem management (e.g., Kessler et al. 1992), and will have particular applicability for describing outcomes in a climate change context.

Where. In what places or over what area is the goal or objective still appropriate? Will it continue to be feasible in some portions of the area but not others? Modifications might be appropriate to specify a different area, or more clearly describe differing outcomes or time frames in goals and objectives across the geography of interest.

When. For how long might existing goals or objectives continue to make sense, or is there a need to better specify or modify relevant time frames. Many current goals explicitly or implicitly assume a time frame of "in perpetuity." Modifications might be appropriate to distinguish among shorter-term and longer-term goals and objectives, and to clearly identify relevant time periods (e.g., 5–10 years, 20 years, >50 years). Goals that are only feasible over shorter time frames (often thought of as "buying time" goals) are not necessarily inappropriate, particularly if they are considered in the context of an intentional transition strategy.

Application of these four components can be illustrated through an analysis of the following goal for management of Bonneville cutthroat trout *(Oncorhynchus clarkii utah)* in Idaho (Teuscher and Capurso 2007):

Ensure the long-term viability and persistence of Bonneville cutthroat trout within its historical range in Idaho at levels capable of providing angling opportunities.

This statement clearly addresses the four goal components (what, why, where, and when) as follows: conservation target/focus (Bonneville cutthroat trout); desired outcome or condition (viability/persistence at levels capable of providing angling opportunities); geographic scope (historical range in Idaho); and time frame (long-term/indefinite). The question, then, is how and to what degree does current and future climate change affect the feasibility of achieving this goal, and more specifically what does climate change mean for each of these four components?

Given likely changes in water temperatures in Idaho, is long-term viability across the *entire* historical range realistic? It is possible that adjustments may be needed in geographic scope to focus on maintaining viability in drainages expected to better retain suitable water temperature profiles. Alternatively, if persistence across the entire historical range is regarded as a priority, there may be a need for adjustment in time frame. For example, long-term persistence may be feasible in certain drainages (e.g., cold-water strongholds) but persistence over a shorter period (e.g., 20 years) more appropriate for areas expected to experience substantial water temperature increases. Another possibility would be to consider a shift in the desired outcome. In regions expected to experience more substantial increases in water temperature, for example, persistence of the trout species might be possible (at least for a certain period), but perhaps not at levels capable of sustaining a recreational fishery. Yet another possibility would be to consider a change in conservation targets, at least in portions of the historical range. Many fisheries departments already are considering the need to shift from managing for cold-water species, like trout, to warmer-water fish. The bottom line is that distinguishing among these four goal components provides a structured means for identifying various ways that climate change may affect existing goals and objectives, and facilitate development of tailored and climate-relevant modifications.

7.4. Case Study: Revising Goals for Northwoods Restoration

The storied history of natural resource management and conservation in the Northwoods of Minnesota provides a compelling backdrop for an example of reconsidering and revising conservation goals in practice. A broad partnership consisting of The Nature Conservancy, Northern Institute of Applied Climate Science, University of Minnesota-Duluth, Minnesota Forest Resources Council, and Sustainable Forests Education Cooperative has been working to apply the paradigm of "adaptation forestry" to the region's forests (Kahl et al. 2011). Adaptation forestry can be described as forest management applied through a climate change lens, whereby greater emphasis is placed on restoring the ecological processes fundamental to a dynamic, resilient system, rather than re-creating a snapshot from the past. This approach embodies many of the elements of climate-smart conservation highlighted in this guidance.

In the Northwoods, the "snapshot of the past" captures a diverse forest mosaic of boreal and subboreal forest types, including conifers such as white spruce (*Picea glauca*), balsam fir *(Abies balsamea),* and pine (*Pinus* spp.), northern deciduous species such as paper birch *(Betula papyrifera)* and quaking aspen *(Populus tremuloides)*, and hardwoods such as sugar maple *(Acer saccharum)* and yellow birch *(Betula* *alleghaniensis)*. It also reflects a community that was long a hotbed for the logging and paper industries, epitomized by legendary lumberjack Paul Bunyan. Today, many fewer long-lived conifers remain, and the forest ecosystem has been greatly reduced in complexity. Following customary practice, restoration efforts in the region have largely used historical conditions (e.g., "range of natural variability") as a benchmark for regenerating hardwoods and restoring long-lived boreal conifers such as white spruce (Cornett and White 2013). The Conservancy and its partners have come to recognize that in light of climate change the traditional approach to restoring this forest system is likely to be increasingly ineffective, and that a new, climate-informed approach was necessary, which required them to fundamentally reevaluate and adjust the goals of their restoration efforts.

This effort began with an assessment of the climate change vulnerability of existing management goals under existing forest management strategies for the region (Cornett and White 2013). The project team developed simulation models to project future habitat suitability across the region for a range of forest types under changing climate conditions and under a variety of potential management treatments (Ravenscroft et al. 2010). Results of the analysis suggest that, in general, forest composition in northeast Minnesota will change significantly under future climate scenarios, especially over the longer term (100+ years). Many of the historically common tree species, such as boreal conifers, will experience increasingly unsuitable habitat conditions and likely will be lost regardless of management treatments. In contrast, more southerly species such as maples are projected to increase in dominance and thrive. As Kahl et al. (2011) state, "over the long term, climate change may be working in *direct opposition* to the management actions designed to achieve [current restoration] goals."

Based on this assessment of future conditions and likely ecological responses, the project partners have revised their conservation goals and management objectives, shifting from a focus on managing to restore historical species composition, to a focus on increasing ecosystem complexity and enhancing forest resilience to climate change. The revised goals are explicitly designed to manage for change, rather than restore historical species assemblages. Retaining boreal species in the landscape will continue to be included in the work, but restoration efforts will not prioritize increasing their numbers, as was the case previously. The adaptation work will instead emphasize a mixture of species projected to thrive in the region over the longer term.

The project partners have modified their management strategies to reflect and support these revised goals, nicely illustrating the climate-alignment of goals and strategies depicted by Stage 3 of Figure 2.1. These strategies include selecting species for seeding and planting that represent an array of life-history traits, using genetic material from a broader geographic range, encouraging structural diversity (e.g., coarse woody debris for seedbeds), and managing for a full range of forest growth stages. With support from the Wildlife Conservation Society's Climate Adaptation Fund, The Nature Conservancy is beginning to implement these strategies on 2,000 acres in northeastern Minnesota, putting these revised goals and strategies "on the ground."

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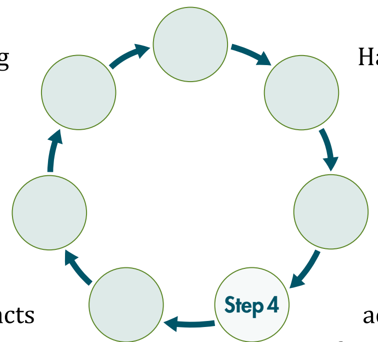
Chapter 8. The Art of the Possible: Identifying Adaptation Options[22]



Armed with an understanding of climate vulnerabilities in the context of climate-informed goals, the next step is to identify a full range of possible adaptation responses. Bridging the gap between vulnerabilities and potential options to address those impacts is at the heart of climate-smart conservation, through linking actions to climate impacts. This challenging task requires a concerted effort to consider knowledge gleaned from vulnerability assessments in the context of one's relevant decision-making processes and goals (Mastrandrea et al. 2010).

While the general toolbox of conservation and management approaches may remain fairly constant, it is not sufficient to simply apply the same practices "better" (more effectively) or "more" (in greater amount). Rather, the risks associated with climate change may require changes to some of the assumptions that go into conservation project design, as well how these approaches and strategies are used in given situations. For example, climate change may require managers to re-prioritize which existing stressors to focus on and which options to use to address them. Existing management practices and approaches may need to be adjusted for place, time, technique, or other aspects in order to be effective at meeting climate-informed goals. There may also be some entirely novel management approaches that emerge, which may either complement or supplant current-day "best practices."

Having a good list of options available is central to effective conservation priority setting and natural resource decision-making (Game et al. 2013). Step 4 in the climate-smart cycle (Figure 4.1) is the stage at which the broadest array of possible adaptation options should be generated for subsequent evaluation (step 5) and possible implementation (step 6). An important aim should be to avoid constraining identified adaptation options to a limited set of "popular" or familiar choices, without regard to whether they are really the most appropriate or sufficient for the particular need in question. At this stage in the process it is more useful to be creative rather than prescriptive, and to embrace innovative thinking. Even if some policy or management approaches may not currently be viewed as technically, financially, or socially feasible, what may be impossible today may change in the not-too-distant future. For example, while planning for managed retreat and abandonment of coastal areas in response to sea-level rise generally was considered unthinkable just 20 years ago, such approaches are now becoming a reality in certain early-adopter coastal states (NOAA 2013).

This chapter focuses on a process for using vulnerability information as the basis for generating specific adaptation options. The chapter also considers the applicability of these options in the context of the dual pathways of managing for change and persistence, and the interrelationship and cycling between the two. The concentration

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at this stage is on generating management options suitable primarily from the perspective of achieving ecological outcomes. A broader evaluation that brings in social, political, financial, institutional capacity, and other factors is also necessary, and the subject of step 5 in the climate-smart cycle (Chapter 9). In contrast, this chapter focuses on generating a broad array of options, or the "art of the possible."

8.1. Moving from Vulnerability to Adaptation

Climate change vulnerability assessments, conducted in the context of established goals, form an important basis for generating adaptation options. The link between vulnerability and adaptation is clearly evident in the IPCC (2007a) definition of adaptation as "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects." As discussed in Chapter 6, vulnerability assessments can help managers identify *which* of their conservation targets are most vulnerable, as well as *why* they are vulnerable. Understanding the "why" of vulnerability is of particular importance for generating relevant adaptation options. Vulnerability assessments may also reveal beneficial or positive changes that adaptation strategies and actions might take advantage of (such as the fact that invasive cheatgrass is likely to be stressed in portions of its existing range) (Rivera et al. 2011). Vulnerability assessments thus provide critical inputs for thinking about and identifying adaptation options. In particular, adaptation can be a means of addressing one or more of the three components of vulnerability (i.e., exposure, sensitivity, and adaptive capacity), either explicitly or implicitly. And while vulnerability assessments provide the context for identifying the scientifically important issues to consider in designing adaptation strategies, identification of "key vulnerabilities" can focus the generation of adaptation options even further on the most critical issues for meeting agreed-upon conservation goals.

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8.2. Identifying Adaptation Strategies and Options

How does one move from an understanding of vulnerabilities to specific and actionable adaptation options? This section describes an approach based on a set of general adaptation strategies that can serve as a framework for brainstorming more specific adaptation options and management actions (other types of framing approaches will be touched upon in Section 8.2.3). Next, a series of case studies, focused on different levels of ecological organization, illustrate how these adaptation strategies and options may be used to address specific climate change vulnerabilities. Ultimately, however, the options generated in this way will need to be assessed against context-specific "climate-smart design considerations" to ensure that they address relevant impacts and vulnerabilities, or take advantage of appropriate opportunities.

8.2.1. General Adaptation Strategies

As a framework for generating adaptation options in this chapter, we use a modified version of the adaptation framework developed by the U.S. Climate Change Science Program (CCSP 2008b). The strategies that comprise the original CCSP framework have been updated and further refined based on a number of more recent contributions to

Table 8.1. General adaptation strategies. While these general strategies also apply to traditional conservation efforts, "climate-smart" application takes into account future as well as current conditions and makes explicit links to climate-related impacts and vulnerabilities in order to generate specific adaptation options.

Adaptation Strategy	Definition
Reduce non-climate stresses	Minimize localized human stressors (e.g., pollution) that hinder the ability of species or ecosystems to withstand or adjust to climatic events
Protect key ecosystem features	Focus management on structural characteristics (e.g., geophysical stage), organisms, or areas (e.g., spawning sites) that represent important "underpinnings" or "keystones" of the current or future system of interest
Ensure connectivity	Protect, restore, and create landscape features (e.g., land corridors, stream connections) that facilitate movement of water, energy, nutrients, and organisms among resource patches
Restore structure and function	Rebuild, modify, or transform ecosystems that have been lost or compromised, in order to restore desired structures (e.g., habitat complexity) and functions (e.g., nutrient cycling)
Support evolutionary potential	Protect a variety of species, populations, and ecosystems in multiple places to bet-hedge against losses from climate disturbances, and where possible manage these systems to assist positive evolutionary change
Protect refugia	Protect areas less affected by climate change, as sources of "seed" for recovery (in the present) or as destinations for climate-sensitive migrants (in the future)
Relocate organisms	Engage in human-facilitated transplanting of organisms from one location to another in order to bypass a barrier (e.g., urban area)

the field (e.g., Galatowitsch et al. 2009, Heller and Zavaleta 2009, Joyce et al. 2009, West et al. 2009, Groves et al. 2012, Yale Working Group 2012).

A few words about terminology: there are various terms used to describe different types and levels of adaptation efforts, including approach, strategy, option, action, and tactic, with varying applications (Janowiak et al. 2011). There is no consensus on a hierarchy for such terms, and for purposes of this guidance, we generally refer to adaptation "strategies" as those at the broadest level, with adaptation "options" at the next level of specificity. Ultimately, both strategies and options will need to be translated to specific actions for implementation (Game et al. 2013).

Table 8.1 presents seven general adaptation strategies ranging from very familiar approaches for which managers already have a large degree of experience and confidence (e.g., reducing non-climate stressors) to those for which there is less experience and greater uncertainty about effectiveness (e.g., relocating organisms) (West et al. 2012). Note that most of these strategies represent existing "best practices" derived from the management community's long history of experiences with non-climate stressors such as pollution, habitat destruction, and invasive species, as well as unpredictable and extreme events such as hurricanes, floods, pest and disease outbreaks, and wildfires. As such, many are important for conservation regardless of climate change. The key question is how effective the strategies will be for meeting particular goals given the magnitude and timing of climate change impacts on the system. Even though multiple benefits may result from continuing with today's practices using these strategies, it is not enough to simply continue their use in a business-as-usual way. Rather, it is necessary to consider how climate change will affect both the need for and effectiveness of each adaptation option within the context of all relevant stressors. This should include what adjustments in timing, location, and intensity of effort may be necessary for the greatest positive (i.e., desired) effect on the management target. Note that each of these general strategies may be applicable whether one is focused on managing for change or for persistence. The relationship between these general strategies and the dual pathways is discussed in more detail in Section 8.3.

Reduce non-climate stressors. Reducing "non-climate" stressors (i.e., existing threats that are not specifically related to climate change) is a commonly cited adaptation approach, largely because climate change is not happening in isolation from the many other challenges we face in conservation (Hansen et al. 2003, Lawler 2009, Mawdsley et al. 2009, West et al. 2009, Hansen and Hoffman 2011). In fact, it is the combined effects of climate change and other problems, such as habitat fragmentation, pollution, and invasive species that ultimately pose the greatest threat to natural systems and the fish, wildlife, and people they support (Root and Schneider 2002, Glick et al. 2009, Staudt et al. 2013). This does not mean that addressing non-climate stressors *writ large* will be appropriate or sufficient in all cases. Rather, understanding where and how climate change may exacerbate (or may be exacerbated by) non-climate stressors is necessary to help identify relevant management actions. As described in Chapter 6, non-climate stressors can themselves be important factors in determining the degree to which a species or ecological system is sensitive to climate change. For example, management practices such as fire suppression may increase the sensitivity of a forest system to drought and disturbances associated with climate change. And, often, other anthropogenic stressors (e.g., the existence of coastal armoring) are important factors in reducing a system's or organism's adaptive capacity. Climate change is also likely to exacerbate some of the other problems managers must currently deal with, such as heavier downpours that increase pollutant loadings into aquatic habitats. In each of these cases, asking the climate question (i.e., showing your work) is essential.

Protect key ecosystem features. Within ecosystems, there are likely to be a number of key features that will be especially important for enhancing resilience to climate change (West et al. 2009). For example, there is clear scientific evidence that maintaining biological diversity across a range of functional groups can improve the ability of many ecological systems to recover from disturbances such as wildfires and disease outbreaks—in other words, because such systems have greater functional redundancies, they may be less sensitive to climate change and/or have greater adaptive capacity (Elmqvist et al. 2003, Luck et al. 2003, Folke et al. 2004, Worm et al. 2006, Kareiva et al. 2008, Peters 2008). Another key feature can be geophysical land facets or "enduring features" that, because they are likely to remain relatively static over time in contrast to predicted species distribution shifts, will support future diversification (Hagerman et al. 2009, Anderson and Ferree 2010, Beier and Brost 2010). Here, the focus is on protecting the ecological "stage" (e.g., distinctive combinations of geophysical features, such as elevation, slope, and substrate), not just particular "actors" (e.g., particular plant and animal species). Beier and Brost (2010), for example, cite numerous studies that found a strong correlation between species distributions and topographic features; understanding these key features can assist in the design of migratory corridors (see below) that are more likely to support range shifts under climate change.

Ensure connectivity. Maintaining or enhancing habitat connectivity is another adaptation strategy that has received considerable attention in recent years (Heller and Zavaleta 2009). Traditionally, habitat connectivity has been fostered as a way to enhance gene flow among isolated populations and promote recolonization of species into historical habitat areas (Krosby et al. 2010). Interest in connectivity in the context of climate change is both because of these capabilities as well as to facilitate species movements over the landscape in response to changing conditions—again, a factor that can be associated with the adaptive capacity of a species. Many approaches to maintain or enhance habitat connectivity focus on expanding protected area networks and protecting or restoring corridors

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among these protected areas (Monzón et al. 2011). Mapping corridors among currently suitable habitat patches to areas with similar conditions may be insufficient for the purpose of addressing climate change since those currently suitable conditions may change (Cross et al. 2012a). Rather, managers should take projected climate change into consideration when identifying and designing potential corridors for species movement. Various studies have suggested using: (1) projected shifts in habitat suitability (Williams et al. 2005); (2) identification of locations where climate is expected to remain within species' tolerances (Rose and Burton 2009); and (3) modeling of spatial temperature gradients along with land-use changes (Nuñez et al. 2013) to map potential routes and stepping-stone "refugia" that species might take to track shifting climates (see also discussion of refugia below). In addition to focusing on corridors, managers may also consider increasing the permeability of the landscape through actions focused on improving the suitability of human-dominated lands and waters, such as farms, grazing lands, and urban areas, to better support populations of native species (Manning et al. 2009, Mawdsley et al. 2009, Schloss et al. 2012).

Restore ecological structure and function. Climate-smart conservation necessitates greater emphasis on biodiversity processes and ecological function in the context of dynamic threats, recognizing that climate change will make it increasingly difficult to maintain or control species composition (Harris et al. 2006, Pressey et al. 2007, Hagerman et al. 2010, Prober and Dunlop 2011). Here the focus is on preserving processes that ensure the continuation of diverse and functioning ecosystems, even if the particular compositional and structural attributes may be strikingly different. Traill et al. (2010) suggest that a logical approach is to focus on the specific mechanisms by which climate change is likely to affect a host of factors, including "species behavior, physiological and evolutionary response, population- and species-level interactions, and consequent effects for species diversity, system resilience, and function." Based on this information, fundamental functions such as primary productivity, gene flow, decomposition, and nutrient cycling can be targeted for management, either through restoration of the original system, or through transformation to a new system state that fulfills the same functions. Although the term "restoration" conjures images of an emphasis on historical conditions or species assemblages, modern restoration ecology recognizes the importance of maintaining or restoring those processes and functions that will confer resilience even with shifts in system state or composition (Harris et al. 2006, Jackson and Hobbs 2009).

Support evolutionary potential. If managing biodiversity under climate change will largely be about "facilitating nature's response" (Prober and Dunlop 2011), then having explicit strategies for allowing adaptation in an evolutionary sense to proceed will be important, as will maintaining the distinctive evolutionary character of regional plants and animals. Evolutionary processes have been, and will continue to be, a significant factor influencing the patterns and rates of species' responses to climate change (Parmesan 2006). Indeed, preliminary evidence indicates that populations of some species are already demonstrating genetic changes (e.g., in traits that contribute to increased temperature tolerance) in response to climatic shifts (Parmesan 2006, Skelly et al. 2007, Berg et al. 2010, Hoffmann and Sgrò 2011). Managers can help improve the evolutionary adaptive potential of target species through actions that conserve or increase genetic diversity. This can include enhancing the abundance and genetic diversity of individual species, protecting diverse populations of species within and across habitat ranges (i.e., increasing redundancy), facilitating gene flow, and actively managing genetic composition of species (e.g., such as plants in forest management or restoration projects) (Harris et al. 2006, Millar et al. 2007, Joyce et al. 2009, Kremer et al. 2012).


USFS Kaibab National Forest

Protect refugia. The term "refugia" in the context of climate change adaptation typically refers to areas that are likely to experience relatively less change than others and thus serve as "safe havens" for species, either currently or in the future (Noss 2001, West et al. 2009, Keppel et al. 2011). For example, tributaries fed by glaciers may offer cold-water refugia for aquatic species when other parts of their stream habitat become adversely warm (i.e., it can help reduce exposure to climate change impacts). Refugia can be within a species' current distribution (in situ refugia) or outside of a species' current distribution but likely to be suitable in the future (ex situ refugia) (Ashcroft 2010). For management purposes, identifying and protecting in situ refugia may be especially important for species with limited dispersal ability. Yet, it also may be useful to protect potential ex situ refugia, even if associated species ultimately might need to be translocated to those areas (see below). Identifying and protecting potential refugia in the near term can help ensure that they will not be lost to land-use change or other factors before climate change comes into play. For both in situ and ex situ refugia locations, an important consideration is whether human structures such as dams or cities might restrict the ability of species to access otherwise available refugia, necessitating managed relocation (see below).

Relocate organisms. One of the more controversial climate change adaptation strategies is the translocation or, more specifically, "managed relocation" of species (i.e., actively moving a species from its current range into a novel area expected to have more suitable climate conditions in the future) (Schwartz and Martin 2013). This could be considered an option, for instance, for species with limited dispersal capabilities, whose ranges have become highly fragmented, and whose current habitats are disappearing (Hoegh-Guldberg et al. 2008, Thomas 2011). While some scientists (e.g., Ricciardi and Simberloff 2009, Seddon et al. 2009) cite risks such as the potential that the newly introduced species may erode biodiversity and disrupt ecosystems, others argue that those risks need to be weighed against the likelihood that, without such action, the target species may become extinct (Hoegh-Guldberg et al. 2008, Schwartz et al. 2009). It is important to note that translocation of species is not an entirely new concept. Species reintroductions generally follow a similar process, although usually those are intended to replenish species within their historic range (Lawler 2009, Green and Pearce-Higgins 2010). Yet even those native habitats may have changed over time due to anthropogenic stressors, so reintroductions may well be creating different species assemblages than had occurred before those target species had been extirpated. Ultimately, decisions about which adaptation approaches to take, from reducing existing stressors to relocating organisms, will require consideration of a range of values-based criteria, as discussed further in Chapter 9.

8.2.2. Generating Specific Adaptation Options

The set of general adaptation strategies described above can be used as a structure for identifying and discussing a wide array of more specific adaptation options using the climate-smart lens. Here the aim is to be creative and expand the range of possible options beyond those that are commonly used or already underway. Box 8.1, presents some available techniques and methods to help with the brainstorming and idea generation process. All of these require participatory processes in recognition of the valuable information and insights that come from engaging stakeholders and resource users with local or traditional knowledge. Most emphasize the need to engage people from

Box 8.1. Techniques for generating adaptation options.

Expert elicitation. A range of techniques to systematically elicit judgments from experts (either individually or in groups), usually through the use of some form of conceptual modeling that aids in structuring a series of questions about the system of interest. See example applications by McDaniels et al. (2012) and Doria et al. (2009), and a methods review by Martin et al. (2012).

Brainstorming groups/buzzing groups/ideation. A process for generating ideas in a participatory manner, often through workshops, using a mix of individuals with different backgrounds and roles to develop and propose ideas. "Buzzing groups" refers to smaller subgroups broken out from a larger group. "Ideation" typically involves intense preparation prior to a session to develop ideas. For a general guide to brainstorming, see Baumgartner (2005).

Analysis of Interconnected Decision Areas (AIDA). A structured format in which decision areas are identified (along with corresponding options) and compatibility is explored across decision areas in order to generate a list of possible option portfolios. Decision areas and options may be visually depicted (e.g., through circles and dots within circles) as an aid to check for interactions or incompatibilities. See Sayers et al. (2003) for an example for flood management.

Charrettes. A group-based approach that employs a period of intensive, collaborative problem solving to quickly generate appropriate options using groups of people with diverse disciplinary backgrounds, abilities, and interests. Typically, charrettes are held over multiple days and are conducted on or near the site for which planning is occurring. For example, see San Francisco Public Utilities Commission (2010).

Focus groups. An approach for gathering feedback from people with a variety of backgrounds who all have a stake in the issue at hand. Participants are provided with detailed information and asked to respond through a particular exercise. A trained moderator then analyzes participant responses and the internal dynamics of the group to identify the central elements of the issue and the reasoning behind different viewpoints. See Carmody (2010) for an example application.

Literature/case study reviews. Use of literature or case study databases for summaries of analogous management situations that illustrate selection and application of adaptation measures or that provide lists of adaptation options to consider. Online repositories such as the Climate Adaptation Knowledge Exchange (CAKE; http://www.cakex.org/) and the U.S. Forest Service's TACCIMO (www.forestthreats.org/taccimotool) provide access to such resources from which adaptation options can be drawn.

Linda Killam

different backgrounds, abilities, and interests to collaborate in the option development sessions. Expert elicitation is an exception in that only individuals with specific knowledge are engaged. This approach is suitable when very specialized information is needed from an idea generation session. Other aspects that distinguish the different methods can include: whether to use large groups or smaller breakout groups or some combination; whether the format is a workshop or focus group; and the types of visual tools used. Selecting a method or technique may be as simple as going with the one that is most familiar. However, if a range of methods and techniques is possible, it is worth spending time to consider which is most appropriate given the characteristics of the problem and people involved in the planning process.

For adaptation options to be considered climate smart, a clear line of logic must be drawn that begins with the conservation target and its key vulnerabilities, and describes the mechanism by which the implementation of an option can be expected to reduce the vulnerability of the system or species to the climate-related stress. For example, salmon (the conservation target) is threatened by warming water (the exposure), which leads to greater mortality of eggs given critical temperature thresholds (the sensitivity). Adaptation options developed in response to this critical threat would need to demonstrate how each specifically designed action would either decrease exposure, decrease sensitivity, or increase adaptive capacity of salmon eggs in light of these changes. Table 8.2 provides a few example adaptation options for each general adaptation strategy that could arise from a brainstorming session.

8.2.3. Alternative Frameworks for Generating Options

The application of these general adaptation strategies in designing adaptation options for specific places and systems is elaborated on and illustrated in Section 8.4. It is important to note, however, that alternative frameworks are also in use for generating adaptation options in conservation planning efforts. In addition to the "general adaptation strategies" approach described above, other adaptation framings for generating adaptation options make use of "components of vulnerability" and "intervention points" as underlying structures. Table 8.3 provides descriptions of alternative frameworks along with example applications. These different approaches are not mutually exclusive, and can be used either individually or in concert to help structure the exploration of a full array of potential adaptation options. Indeed, step 4 of the climate-smart cycle focuses on identification of an array of possible adaptation alternatives to use as the basis for subsequent steps in the cycle (i.e., evaluation selection [step 5] and implementation [step 6]).

Table 8.2. Illustrative adaptation options. For any particular option to be considered climate-smart, it would need to explicitly address vulnerabilities of the conservation targets. More detailed and specific examples of how to apply such climate-smart considerations to the design of options are presented in Section 8.4.

General Adaptation Strategy	Example Adaptation Options
Reduce non-climate stressors	• Work with watershed coalitions to promote best practices for agricultural and stormwater management to reduce non-point sources of pollution • Institute flexible zoning in marine protected areas to minimize tourism and fishing impacts • Remove structures that harden the coastline to allow inland migration of sand and vegetation
Protect key ecosystem features	• Update protections for key biogeochemical zones and habitats as their locations change with climate • Maintain natural flow regimes to protect flora and fauna in drier down stream river reaches • Manage functional species groups (e.g., grazers) necessary for maintaining the health of coral reefs and other ecosystems
Ensure connectivity	• Design marine protected area networks of resilient habitats connected by currents • Remove barriers to upstream migration in rivers and streams • Create linear reserves oriented longitudinally
Restore structure and function	• Restore the natural capacity of rivers to buffer climate-change impacts through land acquisition around rivers, levee setbacks to free the floodplain of infrastructure, and riparian buffer repairs • Restore estuarine habitat in places where the restored ecosystem has room to retreat as sea level rises • Favor the natural regeneration of species better-adapted to projected future conditions
Support evolutionary potential	• Manage for a variety of species and genotypes with tolerances to low soil moisture and high temperatures • Distribute species over a range of environments according to modeled future conditions • Facilitate evolution by managing disturbances to initiate increased seedling development and genetic mixing
Protect refugia	• Create side-channels and adjacent wetlands to provide refugia during droughts and floods • Restore oyster reefs along a depth gradient to provide shallow water refugia for mobile specie during climate-induced deep water hypoxia/anoxia events • Identify areas that supported species in the past under similar conditions to those projected for the future and consider those sites for establishment of "neo-native" plantations or restoration sites
Relocate organisms	• Move isolated populations of species of interest that become stranded when water levels drop • Relocate or re-introduce captively bred species to restored habitats and refugia • With sufficient information, move germplasm in the anticipated adaptive direction

Table 8.3. Alternative frameworks for identifying adaptation options. Several different framing approaches currently are in use for generating possible adaptation options, including the three broad frameworks detailed here. These general approaches can be used in combination to assist in thinking through and generating sets of potential adaptation strategies and actions.

Framework	Description	Example application of framing approach	Other examples for approach
General adaptation strategies	Use a list of "general" adaptation strategies to identify specific adaptation options that would help achieve goals and objectives	Using the U.S. Forest Service Climate Change Response Framework Adaptation Workbook (Swanston and Janowiak 2012), adaptation options such as the following can be identified for retaining paper birch stands where possible, and regenerating white pine (*Pinus strobus)* when paper birch regeneration is not possible as climate changes: • *Reduce the impact of existing stressors (e.g., invasives):* Ensure adequate overstory is retained so as not to encourage the establishment of sun-loving invasives • *Maintain and enhance species and structural diversity:* Employ silvicultural techniques (e.g., shelterwood harvest) to encourage growth of white pine in overmature paper birch forests • *Sustain fundamental ecological functions:* Adjust rotation age to achieve age class distribution goals and increase ability of forests to resist pests and pathogens	SAP 4.4 (West et al. 2009); TACCIMO (Treasure et al. 2014); Conservation Action Planning for Climate Change (TNC 2009); Yale Framework (Schmitz et al. In press)
Components of vulnerability	Using the three components of vulnerability, target actions toward one or more of the following: reduce exposure, reduce sensitivity, enhance adaptive capacity	Using a guide for the design and implementation of climate-smart restoration projects for the Great Lakes region (Glick et al. 2011b), adaptation options such as the following can be identified to restore fish habitat along the Black River of Ohio (see Section 3.4.1., Chapter 3): • *Reduce exposure:* Restore riparian tree canopy to provide shading over open water to moderate exposure to warmer air temperatures • *Reduce sensitivity:* Select more southerly tree species for use in site restoration to decrease sensitivity to future temperature increases and precipitation changes • *Enhance adaptive capacity:* Construct fish shelves at multiple levels to increase availability of breeding habitat at variable water levels	Application of Climate Change Vulnerability Index by Defenders of Wildlife (Dubois et al. 2011); Adaptation for conservation reserves by Magness et al. (2011); Mangrove adaptation by World Wildlife Fund (Ellison 2012)
Intervention points	Use conceptual models or other methods to identify "intervention points" (components of the target system that can be influenced through conservation actions) to identify possible adaptation options	Using the Adaptation for Conservation Targets (ACT) Framework (Cross et al. 2012b), adaptation options such as the following can be identified for managing stream flows for native cold-water fish as temperatures warm and flows decline: **Intervention points** — **Potential Adaptation options** • Withdrawals — Reduce withdrawals by leasing in-stream water rights • Snowpack management — Build snow fences to retain snow in key areas for longer • Riparian vegetation — Restore riparian areas that provide shading to streams	Conservation Action Planning (CAP) for Climate Change (TNC 2009); Open Standards for the Practice of Conservation (CMP 2013); NOAA (2010)

It does not, however, prescribe the process for generating those options, and adaptation planning teams may elect to use one or more of these framing approaches as appropriate.

Regardless of the framing approach used, all options would then be designed according to whether the intent is to: (1) preserve the current set of system conditions (e.g., maintain natural flow regimes to protect flora and fauna in drier downstream river reaches), or (2) facilitate system changes in a desirable direction (e.g., manage for a variety of species and genotypes with tolerances to low soil moisture and high temperatures). In practice, even if the current intent is to "manage for persistence," experience indicates that change is inevitable and it will be necessary to think about and prepare to "manage for change" as well.

8.3. Adaptation for Persistence and Change: Dual Pathways

As discussed in Chapter 2 and above, climate change will increasingly necessitate that the conservation community move from a paradigm of not just preservation and restoration to historical conditions (i.e., managing for persistence), but one that is simultaneously open to anticipating and actively facilitating transitions (i.e., managing for change). This notion has previously been described in the adaptation literature in the form of a continuum of strategies that move from resistance, to resilience, to transformation (Millar et al. 2007, Glick et al. 2009). Here we choose to focus on "outcomes" (change/persistence) rather than "strategies" (resistance/resilience/transformation) because any particular adaptation action could contribute to change or persistence depending on context, scale, and application.

In the case of managing for persistence, the aim generally is to prevent systems from crossing thresholds of major change for as long as possible by protecting them from stress and by supporting their recovery after major disturbances (e.g., Hansen et al. 2003, Marshall and Schuttenberg 2006, West et al. 2009). This remains a viable goal where: (1) there is potential for long-term success; or (2) a high priority is placed on "buying time" to prepare for longer-term changes (Hansen et al. 2003). However, managing for persistence will become an increasingly difficult challenge as climate change progresses. In some cases changes in the mean and extremes of precipitation and temperature already have led to ecological transitions. For example, threshold behaviors have been documented in grasslands throughout arid and semiarid areas as woody plants have encroached into perennial grasslands (Zavaleta et al. 2003, Sherry et al. 2011, Yang et al. 2011) and in coral reef ecosystems as seawater temperatures and ocean acidification have increased (Marshall and Schuttenberg 2006, Hoegh-Guldberg et al. 2008).

Thus, equally as important as persistence is the concept of managing for change, which involves assessing where unavoidable changes in ecological systems may be about to happen and preparing for a different management regime for the altered state. Since thresholds will continue to be crossed as climate change progresses, it will be necessary to revisit and sometimes revise conservation goals and objectives, as covered in Chapter 7. For example, a national wildlife refuge established to protect a particular species might see that species' habitat range shift farther north outside of refuge boundaries, while more southerly species move in. Accordingly, the refuge may need to reconsider its goal of maintaining the original species (Griffith et al. 2009).

Based on the existing or revised goals, there are two primary approaches to managing for change. The first is to allow regime shifts to occur without management interference (which may be unavoidable where there is not enough information to know a shift is occurring); and the second is to anticipate potential shifts, establish the new goal of the desired future state, and manage to affect the trajectory toward that state as climate changes. The second approach is still in the realm of the experimental since there are significant uncertainties associated with trying to project regime shifts. This is where sustained research, monitoring, and evaluation will be critical in order to continuously improve the knowledge base about system dynamics (see Chapter 11). In the meantime, managers and researchers have already begun to explore ways to anticipate and manage transitions using existing information and theory, with the same techniques that are used to manage for persistence, but applied differently to manage for change.

For example, management techniques involving manipulation of genetic composition of communities (e.g., forests) can be used to preserve the existing type of system; or they can be used to manage succession to a different type of system (Joyce et al. 2009). As another example, one could imagine that for cold-water fish, we might maintain natural flows and riparian buffers to support persistence of current species; but if invasion/replacement by warm-water fish becomes unavoidable, we might use the same techniques (e.g., manipulation of flows) to now manage for the new species assemblage. The challenge is deciding when it is time to shift to a new objective, either based on some indicator of impending transition or in rapid response to an observed transition as it is occurring. In the meantime, it will be important to practice the climate-smart characteristic of "employing agile and informed management" by brainstorming and designing options for both persistence and change simultaneously, as a dual pathways approach to planning.

8.4. Examples of Linking Adaptation Options with Impacts

Below, we highlight this dual pathways concept through four case studies of specific management options for targets representing a range of ecological scales: individual species; ecosystems; protected area networks; and multi-ecosystem mosaics (Tables 8.4–8.7). Each table provides a specific example of a management target and associated conservation goal, along with an identified set of key climate change vulnerabilities that are specific to the targets (and could affect attainment of the goal). An explicit understanding of the mechanism by which a key vulnerability relates to an impact on the target is needed to make the link from vulnerabilities to specific options that address those vulnerabilities. Each option must then be subjected to "climate-smart design considerations" in order to determine how, when, and where a conservation action can be applied to be truly effective for adaptation (this is where to "show your work"). Some of the questions surrounding these design considerations can be difficult to answer, particularly in cases where current data and scientific knowledge are incomplete. Yet it is not in society's best interest to put off adaptation while waiting for perfect information. The key is to couple available information (whether meager or abundant) with logical reasoning to shed new light on today's management choices, while also being open to adjusting this reasoning through time as new information becomes available.

These examples are meant to be illustrative rather than comprehensive. Each case study table presents one example of a specific option under each general strategy, along with a set of climate-smart design considerations for that option. The case studies illustrate the crosswalk from target, to vulnerabilities, to strategies, to options to actions. In order to generate a complete

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table of options, however, one would need to examine each key vulnerability—and consider it from the perspective of each general strategy—in order to systematically brainstorm a full list of possible options in response.

8.4.1. Species Level: Chinook Salmon on the U.S. West Coast

In this example, the conservation goal is to ensure viable spawning habitat to maintain populations (i.e., support the persistence) of Chinook salmon *(Oncorhynchus tshawytscha)* on the U.S. West Coast (Table 8.4). Under the "restore structure and function" general strategy, one option is to increase spawning habitat containing clean gravel beds through restoration. Looking at the identified key vulnerabilities, the line of logic is that climate change will cause increased sedimentation rates, increased temperatures, and decreased flows in salmon spawning habitats—all of which will be detrimental to the survival of eggs given their sensitivity to changes in those variables. This is where the essential application of the climate-smart design considerations comes into play. Restoring clean gravel beds may only make a positive difference if they are strategically located based on questions such as: How will climate change affect temperature, flow, and sedimentation rates in historic locations of spawning habitats versus other locations (i.e., are there areas where exposure to relevant climate change factors can be reduced or eliminated)? What are the best locations for restoring clean gravel beds in terms of their long-term viability as salmon spawning habitat given climate change? Besides location, climate-smart adjustments for other options may also involve timing and intensity. For example, under the "maintain key ecosystem features" general strategy, water temperature and flow can be managed through scheduled dam releases to maintain suitable habitat conditions during spawning and migration. Yet, this will only be effective if implementation is based on asking: How will climate change affect the timing and magnitude of peak temperatures and low flows during spawning and migration? What volume and timing of water releases will maintain temperatures and flows within tolerance ranges?

Besides looking at adaptation options individually, it is also helpful to consider them in concert. In some cases it may be necessary for multiple actions to be combined in order for any individual

Table 8.4. Species-level example of adaptation options and climate-smart considerations: Chinook salmon, U.S. West Coast.

Target, goal, and key vulnerabilities	General adaptation strategy	Specific management option (example)	Key climate-smart design considerations
Conservation Target Chinook salmon **Conservation goal:** Ensure viable spawning habitat to maintain salmon populations on the West Coast **Key climate-related vulnerabilities:** • Increased stream temperatures - Lethal temperatures - Reduced dissolved oxygen **• Altered flows** - Erosion/sedimentation - Habitat fragmentation	Reduce non-climate stressors	Reduce withdrawals and remove infrastructure to maintain minimum flows during spawning to ensure sufficient oxygenation of eggs	How will climate-related alterations in hydrology, together with changing water demands, affect flows during spawning? What combination of reduction in withdrawals and removal of infrastructure will maintain minimum flows during spawning?
	Protect key ecosystem features	Schedule dam releases to maintain suitable habitat temperatures during spawning and migration	How will climate change affect timing and magnitude of peak temperatures during spawning and migration? What volume and timing of water releases will maintain temperatures within tolerance ranges?
	Ensure Connectivity	Re-establish side channel connections with freshwater and estuarine wetland habitats to improve low flows and lessen the negative impacts of peak flows	How will climate change continue to affect hydrology in historic floodplains? Where are the locations for re-establishment of side channels that will be most viable in the long term given climate change?
	Restore Structure and Function	Restore spawning habitat containing clean gravel beds in areas with suitable temperatures and flow s (also see refugia example below)	How will climate change affect sedimentation rate, temperature and flow in historic locations of spawning habitats? Where are the best locations for restoring clean gravel beds that will be viable in the long term given climate change?
	Support Evolutionary Potential	Maintain diversity (genetic replicates) within and across populations	How will climate change affect the genetic diversity of native salmon populations? What is the best way to identify, capture, breed and restock appropriate genotypes within and across populations?
	Protect refugia	Create streamside riparian vegetation to provide shaded areas (thermal refugia) and buffer gravel beds from sediment runoff	How will climate change affect temperatures, flows and land-based sedimentation of existing gravel spawning beds? Taking into account flows, what kind and how much vegetation should be placed in what locations to provide effective thermal refugia, free of excessive erosion and sedimentation?
	Relocate Organisms	Relocate hatchery-bred fry to most appropriate stream habitats	How will climate change affect the relative likelihood that natal streams will become intermittent and disrupt native salmon runs? From which streams should salmon be captured and bred in hatcheries, and in which streams should the fry be released?

Based on Battin et al. (2007), Yates et al. (2008), and Beechie et al. (2013).

action to be fully effective. For example, projects to restore clean gravel beds for spawning habitat may only be worthwhile if carried out in concert with other activities such as creation of refugia through planting streamside riparian vegetation to provide shaded areas. Note that these activities could span both managing for persistence (since natural populations of salmon are being preserved) and managing for change (since refugia may need to be created in entirely new areas where viability of conditions such as temperature limits can be maintained). Thus we are managing for persistence (of salmon) at the scale of the overall river reach, while at the scale of individual habitat patches we are managing to account for unavoidable change.

8.4.2. Ecosystem Level: U.S. East Coast Salt Marshes

The issue of scale invokes another key climate-smart characteristic that is relevant to this discussion: considering the broader landscape context. This refers to how best to design on-the-ground actions in the context of broader geographical scales to account for likely shifts in species distributions and to sustain ecological processes. We illustrate this using an ecosystem-level case study for salt marshes (Table 8.5). Here, the conservation goal is to maintain healthy, functioning salt-marsh ecosystems along the U.S. East Coast. Based on the identified list of vulnerabilities, the logic model is that climate change will lead to altered hydrology and increased sea level, with consequent negative impacts on salt marshes due to altered inundation regimes and marsh "drowning." Under the "protect refugia" general strategy, one option is to identify and acquire (or acquire easements for) areas in the upper estuary that will serve as locations where favorable conditions are anticipated as sea-level rise continues. This requires modeling and planning at the scale of the entire watershed to identify appropriate upper estuarine habitat, even though salt marshes are currently present only in the lower estuary.

Similarly, under the "ensure connectivity" general strategy, considering the broader landscape context may also apply to actions aimed at maintaining appropriate inundation regimes in areas where marshes currently are present, through manipulation of tidal connectivity. For example, it

Table 8.5. Ecosystem-level example of adaptation options and climate-smart considerations: U.S. East Coast salt marshes

Target, goal, and key vulnerabilities	General adaptation strategy	Specific management option (example)	Key climate-smart design considerations
Conservation target: East coast salt marshes **Conservation goal:** Maintain healthy, functioning, East coast salt marsh ecosystems **Key climate-related vulnerabilities:** • Sea level rise - Marsh drowning - Saltwater infiltration • Altered hydrology - Increased nutrient runoff - Altered inundation regimes	Reduce non-climate stressors	Work with watershed coalitions to reduce non-point sources of pollution that favor invasive *Phragmites*	How will climate change affect inputs of non-point source pollution (e.g., through effects on timing and flashiness of precipitation)? Given the nature of these effects, what are the best options (e.g., permeable pavements, rain catchers, sewer system upgrades) for reducing runoff of pollutants onto the marsh?

(continued on p. 134)

Table 8.5. Continued.

Target, goal, and key vulnerabilities	General adaptation strategy	Specific management option (example)	Key climate-smart design considerations
	Protect key ecosystem features	Modify ditches to re-establish natural hydrology and maintain appropriate salinities and sediment transport	How will climate change affect salinities and sediment transport through effects on hydrology? How many, what type, and what locations of ditch modifications will enable sufficiently "natural" hydrology for appropriate salinities and sediment transport?
	Ensure Connectivity	Reinstate tidal connections to support appropriate inundation regimes	How will climate change affect tidal inundation regimes through sea level rise and changes in hydrology? What number and locations of restored tidal connections will be sufficient to support appropriate inundation regimes?
	Restore Structure and Function	Plan timing of restoration projects (i.e., incorporate known climatic oscillations) to maximize likelihood of success	How will climate change have implications for the success of restoration projects, in terms of the need to take into account inter-annual (e.g., El Nino/La Nina) or seasonal (e.g., wet/dry season) oscillations? What is the optimal timing for restoration projects in order to maximize successful establishment of restored salt marsh?
	Support Evolutionary Potential	Ensure high clonal diversity of salt marsh plants used in restoration	How will climate change affect or change the top stressors of salt marshes? What is the clonal diversity of salt marsh plants found at sites that already experience these stressors to a high degree, and how do we ensure a high diversity of these types of clones for use in restoration?
	Protect refugia	Model, identify, and acquire (or set up easements for) areas in the upper estuary that will serve as refugia, i.e., locations where favorable conditions such as tidal inundation are anticipated as sea level rise continues	How will climate change shift the future locations of appropriate salt marsh habitats in the upper estuary based on sea level rise projections? Where do these locations correspond with areas that are available or can be acquired/set aside as refugia? What preparations (e.g., installation of larger culverts) can be made to ready these locations for unimpeded tidal inundation?
	Relocate Organisms	Not applicable	Not applicable

Based on Richards et al. (2004), Erwin (2009), Derwent Estuary Program (2011), and U.S.EPA (2012a, 2012b).

may be possible to support/enhance the adaptive capacity of marshes to keep pace with sea-level rise by enhancing sources of sediments to the marsh from upstream and/or tidal sources. Asking how climate change will affect engineering of hydrology and tidal inundation regimes is a watershed-scale question. In short, whether the intent is to enable existing marshes to stay in their current locations (managing for persistence) or facilitate the migration of marshes to new locations up-watershed (managing for change), success will not be possible without proper modeling and analysis at the broader landscape scale.

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8.4.3. Network Level: Central Flyway

Looking across adaptation options also helps with identifying potential conflicts and trade-offs. This is the "avoid maladaptation" key climate-smart characteristic: ensuring that actions taken to address climate change impacts do not exacerbate other vulnerabilities or undermine conservation goals and broader ecosystem sustainability. An illustration can be found in the case study on networks of protected areas (Table 8.6). This case study focuses on the conservation goal of ensuring appropriate Central Flyway feeding habitats to sustain waterfowl populations during migration.

One line of thinking or logic model is that climate change will cause altered precipitation patterns that will in turn result in increased runoff of nutrients into wetland feeding habitats, with consequent negative impacts due to eutrophication. Accordingly, under the "reduce non-climate stressors" general strategy, one option would be to work with farmers to reduce agricultural runoff into wetland-feeding habitats through the use of riparian buffers or improved irrigation scheduling. Yet at the same time, under the "protect key ecosystem features" strategy, a possible option for maintaining key feeding habitats is to mimic natural disturbance regimes (e.g., through controlled burns) in order to counteract the negative effects of climate change on the natural processes that shape these ecosystems. A problem arises in that controlled burns can have the negative side effect of increasing runoff during rain events, which could negate the nutrient reductions made under the other strategy through sheer volume of flow. In other words, even if nutrient concentrations have been reduced through riparian buffers or improved irrigation scheduling, the volume of runoff may be so great during intensified rain events that total nutrient inputs are just as high or higher. Therefore, part of the calculation in using these options might be to time controlled burns so that they will not coincide with periods of greatest fertilizer use in adjacent portions of the watershed.

Table 8.6. Network-level example for adaptation options and climate-smart considerations: Central Flyway.

Target, goal, and key vulnerabilities	General adaptation strategy	Specific management option (example)	Key climate-smart design considerations
Conservation target: Central Flyway feeding habitats for migratory waterfowl **Conservation goal:** Ensure appropriate Central Flyway feeding habitats to sustain migratory waterfowl populations **Key climate-related vulnerabilities:** • Changes in precipitation - Altered flows - Increased runoff - Eutrophication - Reduced extent and number of wetlands and lakes • Increases in temperature - Species distribution shifts - Asynchronous phenological changes and shifts in resource availability	Reduce non-climate stressors	Work with farmers to reduce agricultural runoff into wetland feeding habitats to improve water quality, groundwater recharge, and hydrologic function	How will climate change affect runoff of non-point source pollution from agricultural lands into feeding habitats? What are the best options (e.g., riparian buffers, improved irrigation scheduling) for reducing runoff of pollutants into water bodies, and when and where should they be implemented?
	Protect key ecosystem features	Maintain disturbance regimes (e.g., controlled burns, pasture rotation, periodic flooding) to augment natural processes and mimic natural patterns	How will climate change, in combination with other human activities, alter historic disturbance regimes (e.g., distribution, frequency, area disturbed) that shape ecosystems providing feeding habitat for waterfowl? How, when and where can human-assisted practices be used to best mimic natural patterns?
	Ensure Connectivity	Conserve corridors and transitional habitats between ecosystem types through land exchanges, conservation easements and other approaches	How will climate change affect species with special connectivity needs (e.g., area-, resource-, dispersal-limited)? Where will the connectivity gaps in the landscape be, and how can priority areas be conserved to maintain transitional habitats and corridors, considering ecosystem functions and physical barriers?
	Restore Structure and Function	Restore or enhance areas that will provide essential feeding habitat and ecosystem services during ecosystem transitions under a changing climate	How will climate change affect ecosystems that have been identified as providing key food resources for migratory waterfowl under the current climate? What areas, if restored, will provide the necessary feeding habitat to sustain waterfowl species as ecosystems change, and where and when should they be restored?
	Support Evolutionary Potential	Conserve areas representing the full range of geophysical settings (e.g., bedrock geology, soils) to maximize future biodiversity	How will climate change affect the full range of habitats and associated land cover and geophysical settings that support migratory waterfowl species? What areas need to be conserved that will maintain that full range under climate change?
	Protect refugia	Identify/protect wetland habitats that will serve as refugia, i.e., where precipitation is projected to stay the same or increase	How will climate change affect wetland water levels and extent? Which wetland areas in or near feeding habitats are projected to persist or increase in size? What should the placement and size of buffer strips be to maintain/protect these areas from development?
	Relocate Organisms	Assist in the translocation of limited-dispersal species to repositioned habitats	How will climate change affect food sources such as fish and submerged aquatic vegetation, and are their dispersal capabilities sufficient for them to adjust? Which species should be moved, and to which sites according to projections of favorable future conditions (see refugia discussion above)?

Based on information from CCSP (2008b), Griffith et al. (2009), and NFWPCAP (2012).

Identifying such trade-offs in order to avoid maladaptation should be a consideration not only for maintaining current feeding sites (managing for persistence) but also when considering selecting from among a list of potential new sites/refugia (managing for change). In the case of managing for change, it is important to note that over time, migratory waterfowl are likely to have range shifts in their nesting areas and/or may not go as far in migration (or even need to migrate); and this will have implications for where to locate climate-smart efforts to restore, protect, and manage feeding habitats of the future.

8.4.4. Multi-Ecosystem Mosaic: Alligator River National Wildlife Refuge

Currently, one of the best examples of a place where managers have fully embraced the dual pathways concept of managing for both persistence and change is the Alligator River National Wildlife Refuge in North Carolina (Table 8.7) (Gregg 2010, Tucker 2010). In this refuge, which consists of bogs, freshwater and brackish marshes, and hardwood and Atlantic white cedar *(Chamaecyparis thyoides)* swamps, climate change impacts already are being seen. The refuge is experiencing greater rates of shoreline erosion, saltwater intrusion into the interior via ditches, a rising water table, some disintegration of peat soils, and more frequent inundation events. In response, managers have begun planning and implementing adaptation options for both persistence and change simultaneously, in order to preserve the extant system for as long as possible while also preparing for inevitable shifts. For the near term, in an effort to preserve refuge area for as long as possible while also adjusting to ongoing changes, the U.S. Fish and Wildlife Service and The Nature Conservancy have joined with other partners to among other things: restore natural hydrology (i.e., reduce exposure to climate-related shifts in hydrological conditions) by installing water control structures equipped with flashboard risers and tide gates to reduce the impact of saltwater intrusion (a persistence option under "protect key ecosystem features"); and plant salt-tolerant (i.e., less climate sensitive) black gum (Nyssa sylvatica) and bald cypress *(Taxodium distichum)* where land has been cleared to ensure shore stability as the shoreline transitions inland (a change option under "restore structure and function"). In the longer term, as sea-level rise reaches a threshold after which current coastal refuge land becomes permanently inundated, managers are preparing to create migration corridors (i.e., enhance adaptive capacity) through which wildlife can safely reach inland conservation areas (a change option under "ensure connectivity"). As these currently freshwater inland systems transform into brackish bog/swamp systems characteristic of the refuge today, there will be a concomitant transformation of the current refuge area to either salt marsh or open water. Therefore, to fully complete the process of managing for change, refuge managers could also develop strategies to facilitate the trajectory of state change to favor full salt marsh as a "new" component of this refuge.

8.5. Cycling Between Persistence and Change

The case studies above provide examples of adaptation options for managing along the dual pathways of persistence and change. Until recently, the conservation and management communities have mostly focused on managing for persistence, and there will continue to be a place for this focus, especially when thinking at large scales. Indeed, distinguishing between managing for persistence and change can often be scale dependent (e.g., when change is being managed at the local scale to achieve persistence at the regional scale).
At the same time, it is clear that it is becoming increasingly important to plan explicitly for change, that is, to identify and implement techniques to manage during and after unavoidable ecological shifts to facilitate and then manage a new state. Indeed, the changing nature of ecosystems through

Table 8.7. Ecosystem-mosaic example for adaptation options and climate-smart design considerations: Alligator River National Wildlife Refuge.

Target, goal, and key vulnerabilities	General adaptation strategy	Specific management option (example)	Key climate-smart design considerations
Conservation targets: Bogs, fresh/brackish marshes, hardwood and Atlantic white cedar swamps **Conservation goal:** Protect and preserve unique wetland habitat types and associated wildlife species (fish, birds, bears, wolves) **Key climate-related vulnerabilities:** • Sea-level rise - Shoreline erosion - Saltwater intrusion - Periodic inundation - Increased sediment runoff • Altered hydrology - Rising water table	Reduce non-climate stressors	(Persistence) Mitigate runoff of sediments and pollutants from surrounding croplands by preventing further losses (and/or replacing) bottomland hardwood forests	How will climate change related shifts in precipitation patterns and hydrology affect overland runoff of sediments and pollutants? In what locations should priority management of forests be focused to minimize runoff?
	Protect key ecosystem features	(Persistence) Mimic natural hydrology by installing water control structures to reduce the impact of saltwater intrusion	How will sea level rise and changes in the intensity and frequency of large storms affect coastal hydrology? What are the implications for the number, placement and viability of water control structures to mimic natural hydrology?
	Ensure Connectivity	(Change) Work with outside organizations to convert surrounding cropland to nonalluvial hardwoods .to provide corridors and habitat for wildlife	How will climate change affect the viability of nonalluvial hardwoods? What amount of hardwood habitat is needed and where should it be located to ensure sufficient corridors for migration?
	Restore Structure and Function	(Change) Restore structures for coastal soil stabilization by planting flood-tolerant tree species on cleared land	What cleared areas along the coastal edge are most impacted by erosion from sea level rise and storm surge? Which tree species (e.g., black gum, bald cypress) would be most effective as well as least sensitive to climate change?
	Support Evolutionary Potential	(Change) Acquire land to connect the nine coastal Refuges in North Carolina to protect multiple present and future coastal habitats as destinations for species	How will sea level rise shift the locations of appropriate coastal habitats? What land protections/ acquisitions and hydrologic changes will be needed to facilitate unimpeded tidal inundation?
	Protect refugia	(Change) Identify and protect a suite of potential sites within the path of connected Refuges (see above) that provide future refugia for endangered species	How will temperature, precipitation, sea level rise and resulting changes in vegetation and predator-prey relationships shift endangered species habitat along the refuge corridor? What number, location and size of sites is needed for continued provision of habitat?
	Relocate Organisms	(Change) If corridors between refuges do not yet exist/are not possible, manually transport species with limited dispersal capabilities to destination habitats	See climate-smart questions for refugia. Relocate species to appropriate locations identified/ protected.

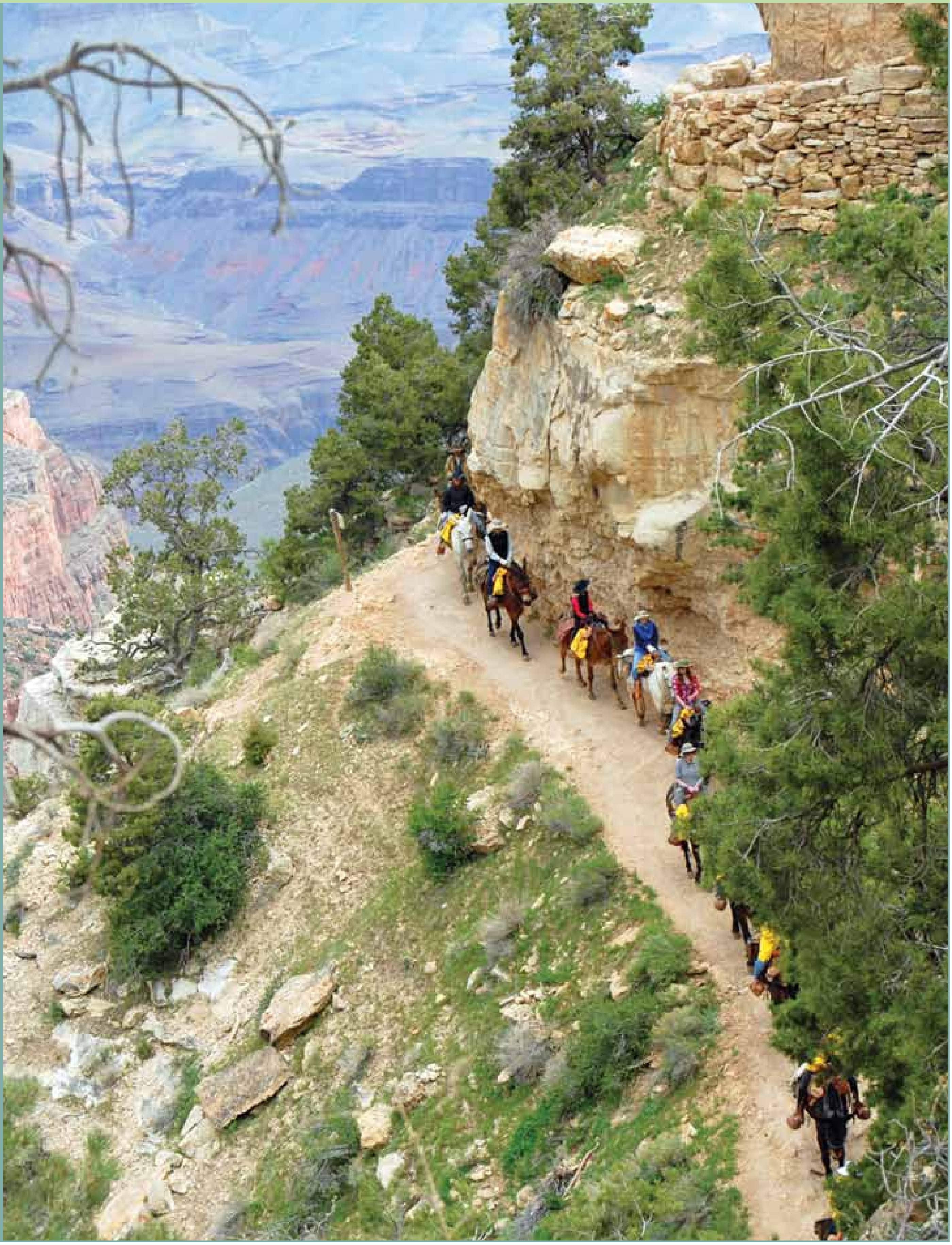
Based on USFWS (2008a), Gregg (2010), and Tucker (2010).

time will require that management be prepared to iteratively cycle between managing for persistence and managing for change.

The shift of a wetland system from salt marsh to mangroves illustrates the concept of cycling between persistence and change (Krauss et al. 2011). The original salt marsh system initially can be managed for persistence using adaptation options that target maintenance of sediment supplies for vertical marsh buildup and implementation of rolling easements to facilitate upslope migration with sea-level rise. At some point, a combination of marsh edge erosion and sea-level rise may surpass the ability of the system to remain as salt marsh, however, with different ecological trajectories possible resulting in multiple new system states: open water, mudflats, or mangroves. In this instance, the ability of the mangroves to become established would depend on such factors as their proximity to the salt marsh, their migration capabilities, suitability of the topography left behind by the salt marsh, and how fast sea level is rising. If decision-makers considered mangroves to be the desired endpoint, compared to open water or mudflat, then managers could employ a variety of adaptation options to facilitate a successful transition to a mangrove system (e.g., planting mangrove seedlings at the onset of the transition from salt marsh). Following establishment of the new system, there would be an opportunity to return to a focus on persistence, this time for the mangrove system. Underlying this process would be a need to define new management targets (species, processes) on which managing for persistence would focus.

While managing for persistence tends to be better understood, actions on the "managing for change" side are largely experimental at this point because so little is known about the magnitude and degree of climate change and how ecosystems will respond in the future (CCSP 2009, Burkett and Davidson 2013). More research is needed on the mechanisms underlying ecosystem responses that determine their trajectories of change, as well as the factors that trigger such changes (Briske et al. 2006, CCSP 2009, Fleishman et al. 2011). Currently, this knowledge is highly variable and in many cases nonexistent. Other gaps affecting the ability to plan include whether an ecosystem transformation will be abrupt and rapid versus gradual and incremental, and whether early warning signals or indicators of an impending transition exist and provide enough advance notice to implement management actions (Groffman et al. 2006, Scheffer et al. 2009, Burkett and Davidson 2013). Finally, there are situations in which no knowledge exists about the kinds of changes that may happen in the future, in which case the only option for managers is to be prepared to react to changes after they occur.

There are some cases where regime shifts have occurred in the past and can inform subsequent management planning (Suding and Hobbs 2009) (such as coral ecosystems flipping to algal-dominated ecosystems [Hoegh-Guldberg et al. 2007]); but in other instances this information is not yet known, and it is difficult to know how to proceed. One way forward is to focus on the planning process itself, making sure that it reflects the climate-smart characteristics described in Chapter 3. Particularly important in the context of managing for change will be: (1) emphasizing management approaches that are robust in the face of uncertainty and provide benefits under a range of possible future climate changes; and (2) maintaining flexible planning processes that continuously incorporate new information and make adjustments to accommodate rapid or unexpected climatic and ecological changes (see Chapter 5). Information continues to be generated through studies of underlying mechanisms, cross-system comparisons, deliberate ecosystem manipulations, and long-term observations (Walker and Meyers 2004). Experimenting with management strategies where possible to help test and generate new information will be important.



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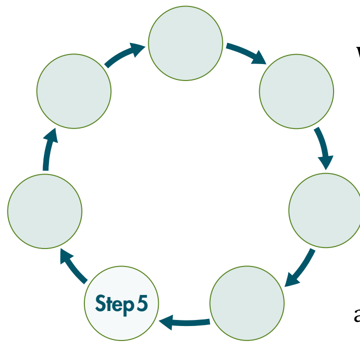
Chapter 9. Choosing Your Path: Evaluating and Selecting Adaptation Options[23]



Which adaptation options are most appropriate to actually put into practice? This chapter, covering step 5 of the climate-smart cycle (Figure 4.1), addresses that central question. While the previous chapter focused on generating a broad array of possible options for reducing climate-related vulnerabilities, this chapter centers on the need to sort through these possibilities to select those actions, or groups of actions, that make the most sense to carry out. The endpoint of this process could be the selection of a clearly defined and practicable set of actions for implementation, a well-supported decision to take no action or continue with the status quo, or even the creation of a prioritization or decision-making process that makes it easier for managers to make climate-smart decisions on opportunities as they present themselves in the future.

In this chapter we lay out some key elements of a logical decision-making process—an approach for *evaluating, comparing,* and ultimately *selecting* among the range of options developed during step 4 of the climate-smart cycle (described in Chapter 8). As with the cycle itself, the degree of formality can vary significantly depending on the complexity of the problem, the number of people involved, legal obligations, and how much is at stake. While many decisions do not require a formal process, more rigorous decision processes can improve the quality, clarity, and defensibility of decisions and decrease the likelihood of unmanaged risk (Keeney 2004).

Whatever the degree of formality, from a climate-smart perspective a major benefit of using a well-defined approach to decision-making is that it exemplifies the concept of "showing your work." Laying out the benefits, costs, and residual risks of alternatives in a clear and transparent way, and then selecting which actions to actually carry out, is the essence of making abstract adaptation concepts concrete. Although this can take time for complex decisions, it pays dividends in improved transparency of decisions; improved engagement and communications with partners, stakeholders, and funders; improved ability to meet any legal or regulatory requirements or challenges; and improved ability to measure success and continue adapting over time. And using a structured process to select specific actions to pursue—rather than simply to prioritize a range of options—vastly increases the likelihood of actual implementation (Gregory et al. 2012, Game et al. 2013).

9.1. Climate Change Implications for Evaluating Alternatives

The process for evaluating and selecting alternative adaptation options relies on many of the best practices that apply to resource management decision-making more generally. However, there are some specific ways in which climate change might affect the way in which some conservation

[23] Lead authors: Jennie Hoffman, Kimberly Hall, and Bruce A. Stein.

decisions are made, as well as the ultimate decisions themselves. In addition to the need to reconsider, and possibly modify, conservation goals or objectives (see Chapter 7) and the possible emergence of novel strategies (see Chapter 8), climate change may affect the evaluation of management alternatives in the following ways:

Performance. Climate change may affect the performance of various alternatives. The effectiveness of an alternative set of actions may improve or worsen as a result of changing climate conditions, which could affect the relative ranking of alternatives. For example, shifts in the intensity of peak flows or extent of low streamflow may affect the performance of different alternatives for construction of fish passages.

New constraints. Climate change may add new constraints, limiting what is technologically, ecologically, or culturally achievable. Changing conditions may make local persistence of some species or habitats impossible (e.g., a combination of topography and rapid sea-level rise may eliminate some habitats locally), or climate-related shifts in land uses may create new obstacles to species movements.

Relative weight. Climate change may affect the relative weight given to different evaluation criteria. For example, if the costs associated with a set of alternatives had all been relatively low, the weight given to differences in cost in selecting among alternatives may similarly have been low. If climate considerations increase costs significantly for one or more alternatives, it may be appropriate to give more weight to variations in this factor.

Perceived value. Climate change may affect the perceived value of various resources. For example, as floods become more frequent and severe in some places, the ability of marshes and wetlands to mitigate flood risk may become increasingly valued.

9.2. Criteria for Screening and Evaluation

Defining explicit criteria for use in evaluation and comparison of alternatives helps clarify what really matters, not just in terms of ecological outcomes, but in terms of other societal values or benefits as well. This can bring conflicting objectives or criteria into the open, help to identify actual or potential constraints (e.g., cost, legal, or social limitations), and make it easier to revisit decisions should new information become available. There is no ideal number of evaluation criteria: while a greater number of criteria can lead to a cumbersome decision process, omitting important criteria can lead to poor decisions.

There are four general classes of criteria relevant to evaluating and comparing alternative adaptation actions, or portfolios of actions:

1) **Conservation goals.** How well do the alternatives help achieve agreed-upon conservation goals and objectives?

2) **Other goals/values.** How well do the alternatives help achieve other (e.g., social, cultural, economic) goals and objectives, or provide co-benefits to other sectors?

3) **Feasibility.** How practicable or realistic is it to implement the various alternatives?

4) **Climate-smart considerations.** How well do the alternatives conform to the principles and characteristics of climate-smart conservation?

These four categories are nonexclusive, and there may be some overlap among categories, but the framework highlights major considerations for evaluation and selection of alternatives. As in the process of identifying “key vulnerabilities” to address with adaptation-focused actions (Chapter 6), it is important to consider what stakeholders value, and connect proposed alternatives with the potential benefit or impairment to those values. We address each criteria class below, going into particular detail on the fourth, which is explicitly climate-centric, and based on the "key characteristics of climate-smart conservation" described in Chapter 3. Here we offer suggestions for how to operationalize those characteristics for use in evaluation and comparison of adaptation alternatives. The criteria discussed below are meant to be illustrative rather than comprehensive; the specific criteria appropriate to use for evaluating a given project will be highly context dependent, and are best determined by the group engaged in making the decision.

9.2.1. Effectiveness at Achieving Conservation Goals and Objectives

Effectiveness is always likely to be an important criterion. If an action is not likely to make a significant difference in achieving desired conservation outcomes, how well it meets other criteria is probably of little consequence. While actions that are relatively easy to put in place (i.e., "low hanging fruit") or that provide a broad suite of benefits (i.e., "no-regrets options") may be attractive, if they don't help achieve the agreed-upon conservation goals, they should be given little priority. Evaluating the effectiveness of proposed actions in meeting relevant goals is a characteristic of good priority setting and conservation planning generally, but takes on added importance in light of efforts to incorporate climate considerations in the reaffirmation or modification of goals and objectives (Chapter 7).

In developing evaluation criteria for effectiveness of actions, it helps to express the ecological outcomes expected from one's agreed-upon conservation goals and objectives. In effect, this process involves describing what "success" looks like, and may focus on various biological levels (e.g., populations, species, habitats, ecosystems) or different attributes at any of these levels (e.g., composition, structure, function/process). These outcomes may focus on persistence-oriented outcomes, change-oriented outcomes, or both possibilities especially in planning based on scenarios and adaptive management. Of course, there is a high level of uncertainty involved in envisioning future conditions, and this uncertainty should be recognized and recorded as decisions are made.

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Even though outcomes are uncertain, articulating desired future conditions can be valuable in "showing your work" and determining how a particular action is intended to help achieve conservation goals and objectives.

9.2.2. Effectiveness at Achieving Broader Societal Goals

The second major criteria class focuses on the broader range of social and cultural goals and objectives that may be brought to the table by those making or affected by the decision. When a certain action promotes benefits to multiple goals, these are sometimes referred to as "win–win" actions, with benefits accruing to other values referred to as "co-benefits."[24] Getting these broader goals and objectives on the table helps to create a space where possible synergies as well as potential conflicts and trade-offs can be openly explored and managed. In some cases, there are clear trade-offs, where actions to benefit one group of stakeholders' values will have costs for another group. Ignoring trade-offs does not make them go away; it simply leaves various stakeholders feeling dissatisfied or not adequately engaged. On the other hand, taking the time to identify the co-benefits of various alternatives can be powerful in achieving broad buy-in and promoting project implementation. For example, a project focused on choosing wetland restoration sites for fish and wildlife habitat can explore where such a project might also provide flood protection to local communities. It is also important to get social or legal constraints on the table, for example, to understand what actions might be impossible to implement for legal,

[24] What constitutes a "co-benefit" depends on one's primary orientation. In projects focused on adaptation for other sectors (e.g., human health, flood risk mitigation), enhancement or protection of natural systems might be considered the co-benefit. Similarly, what is perceived as "maladaptive" can depend on one's primary interest.

political, or social reasons—challenges that may affect the feasibility of the management action, as described below. Social and cultural goals and objectives may target a range of topics, including but not limited to livelihoods, subsistence needs, economics, spirituality, aesthetics, and ethics.

9.2.3. Feasibility

Another major criteria class focuses on the practicability of each adaptation action or portfolio of actions. These considerations are not unique to climate adaptation, but are essential to ensure that the actions under consideration can be implemented in the real world. This is not to imply that only the safest, cheapest, least risky options should be selected, but rather that planners and managers need a sound understanding of feasibility and implementation risks. Such an evaluation can help managers design measures to overcome barriers and obstacles, a subject covered in Chapter 10. Some common criteria for assessing feasibility include direct costs, opportunity costs, technical feasibility, institutional capacity, partnership and cost-share opportunities, community acceptance, and consistency with existing laws and policy. While some of these may be used to compare among options (e.g., the relative cost of each option), others may be absolute constraints that no alternative can violate.

9.2.4. Climate-Smart Considerations

The final class of evaluation criteria focuses on how well the different alternatives conform to the principles and characteristics of climate-smart conservation detailed in Chapter 3. Several of these key characteristics incorporate considerations also reflected in the above categories, while others bring very specific climate concerns into the process. Indeed, climate considerations should be incorporated into the above criteria classes as appropriate, but here we very explicitly identify where and how climate change can be brought into the evaluation process. Again, the specific criteria appropriate to use in any particular evaluation and selection process will vary, but the following offers a set of climate-smart considerations from which planning teams can draw.

- **Link actions to climate impacts.** How effective is the alternative likely to be in reducing identified "key vulnerabilities," or for enhancing the capacity of priority conservation targets to accommodate projected climate impacts? (This characteristic overlaps with the *conservation goals* criteria class described above.)

- **Embrace forward-looking goals.** Does the alternative align with the climate-informed goals that have been adopted? What is the time horizon for the actions in terms of expected benefits (e.g., <20 years, 35 years, >50 years) and to what degree do they address near-term as well as longer-term threats? (This characteristic also overlaps with the *conservation goals* criteria class described above.)

- **Consider broader landscapes.** How well does the action take into account overall landscape context, and recognize prospective shifts in species and other ecological features. Are there landscape factors (e.g., barriers, corridors) or cross-jurisdictional considerations that could limit or enhance the effectiveness of the alternative?

- **Adopt strategies robust to uncertainty.** How sensitive is the alternative to uncertainties in climate trajectories, or ecological and human responses to climatic changes? Are the actions capable of performing well against multiple plausible future scenarios, or are they optimized for a particular projection?

How well do the different alternatives conform to the principles and characteristics of climate-smart conservation?

- **Employ agile and informed management.** Does the alternative commit to an irreversible course of action, or will implementation still allow flexibility to make adjustments or completely change course? Can clear indicators or thresholds be identified that would trigger adjustments, or serve as the basis for "go/no-go" decisions?

- **Minimize carbon footprint.** What direct and indirect greenhouse gas emissions are associated with the alternative? Do the actions contribute to meeting climate mitigation goals through enhancing carbon sequestration and storage, or in other ways?

- **Account for climate influence on project success.** What level of risk do projected climate impacts pose to implementing the alternative? If there is a limited time frame associated with effectiveness of the alternative, is a suitable transition plan possible? (This characteristic overlaps with the *feasibility* criteria class described above.)

- **Safeguard people and nature.** To what extent does the alternative provide benefits to other sectors or help achieve or advance other societal goals? Does the alternative reduce climate vulnerabilities to human communities or assets? (This characteristic overlaps with the *effectiveness at achieving broader societal goals* criteria class discussed above.)

- **Avoid maladaptation.** Would the alternative have the effect of increasing vulnerability to other valued resources? Are there possible unintended consequences or unacceptable trade-offs?

9.3. Evaluate, Compare, and Select Adaptation Actions

To effectively evaluate and compare adaptation options it can be helpful first to organize and screen the actions as a means of reducing the number of alternatives subjected to more detailed evaluation. Appropriate criteria and metrics can then be developed and applied across the evaluations, resulting in the ability to do a meaningful comparison, and make an informed selection.

9.3.1. Organize and Screen Alternatives

Before leaping into an in-depth evaluation and comparison of all of the possible adaptation options generated in step 4 of the climate-smart cycle, it first makes sense to organize them. At the coarsest level, one can identify actions that have sufficient overlap or synergy that they can be combined into a single action or portfolio of actions. If the various actions are very different in scale or degrees of detail, consider ways to group actions to allow consistent comparison. Finally, sort the remaining actions into categories that make them more useful for the planning or decision problem. There is no a priori "best" way to do this, but a good place to start is by considering what decision is being made, how it will get made, and by whom. It is never too early to think about implementation and engagement of key decision-makers in the process. Common categories for organizing actions can include by conservation targets, location, management type, timing, cost, or key vulnerabilities. In many cases multiple management actions will be taken, so it makes more sense to evaluate sets of actions, rather than individual actions. As with other parts of the process, creating portfolios of actions is an iterative process through which one can gain further insight into the decision.

During the process of organization, it may also be possible to screen the broader array of actions from step 4 of the climate-smart cycle to identify those that do not meet minimum thresholds for one or more of the criteria classes described above (conservation goals, other goals/values, feasibility, climate-smart). Screening for those actions, or sets of actions, that would clearly be impossible to implement, or that would have unacceptable trade-offs or consequences, can reduce the total number of alternatives brought forward for more formal evaluation to a more workable number. The result of this organization and screening process should be a defined set of alternatives (single actions or portfolios of actions) that can then be subjected to additional levels of evaluation and comparison.

9.3.2. Moving from Evaluation to Selection

Moving from evaluation to selection is where the rubber hits the road, since it forces those participating in the decision process to make choices about where to invest scarce resources of time, money, and staffing. One of the first steps in moving on to a more formal or deliberate evaluation of alternatives is to determine the specific criteria to use, and how those criteria will be scored. Indeed, to compare the performance of alternatives, one needs some consistent measures to apply across the alternatives. These metrics should link back to a vision of what success looks like, as described above. Clearly defined performance metrics not only help to evaluate and compare options during planning stages, but can also be used to track the effectiveness of actions during implementation (see Chapter 11) and identify errors in thinking or modeling that may underlie any deviations from expected performance. Ideally, performance metrics should be built around what matters for the decision, not simply what is easy to measure. Developing performance metrics will often involve turning fairly general criteria (e.g., "reduces key vulnerabilities") into more clearly defined measures (e.g., number of days over lethal temperature threshold).

Metrics fall into three broad categories. *Natural metrics* are those that measure the stated criteria directly, such as "dollars spent" as a metric for cost, or "number of individuals" as a measure for population size. Whenever possible, natural metrics are the best choice. If what matters is difficult to measure directly, an alternative is *proxy metrics,* which serve as indirect indicators of what matters. An example proxy metric for habitat availability might be acres in "protected" status, with a goal toward increasing that number in areas where it is very low. If there are no natural metrics and no clear proxy metrics, a third option is *constructed metrics.* Constructed metrics typically reflect the consequences of interest, but through a constructed scale that often relies on estimation or expert opinion, for instance, a scale of low–medium–high, or a numeric scale of 1 to 5. Because of the difficulty of directly measuring many conservation-relevant factors and values, the use of such relative scales based on expert opinion is quite common.

Once a suitable set of criteria and performance metrics have been defined, the alternative actions can be scored using those metrics, and then compared. A useful framework for conducting such a comparison is development of a consequences table, which organizes alternative actions along one axis and relevant evaluation criteria along the other axis. Table 9.1. p. 148 illustrates such a table, drawing from the four general criteria categories described in Section 9.2. Depending on the metrics available, such a table may include one or more of the metric types described above (natural, constructed, or proxy), or, as in the case of Table 9.1, a single type of metric. One may also decide to emphasize the importance of certain factors over others by differentially weighting criteria.

Based on such a comparison, a clearly superior alternative may emerge. Conversely, the need for additional information, analysis, or evaluation may become apparent in order to address trade-offs (see below) and make a selection. Indeed, this is a point at which many people find themselves saying they cannot make a decision without more data. While this is sometimes true, it is often the case that what is needed is not better science but better decision processes (Gregory et al. 2006). Science is an indispensable tool for assessing the consequences of particular events or actions as well as identifying risk and uncertainty, but it cannot make decisions for us, or tell us the "best" balance of costs and benefits, risk and certainty.

Table 9.1. Example consequence table. Evaluating the performance of alternative adaptation options can be facilitated through construction of a consequence table. In this hypothetical example, higher scores are better than lower scores.

Possible criteria		Alternative A	Alternative B	Alternative C	Alternative D
Conservation goals	Ecological function	1	3	3	2
	Pollution reduction	1	3	3	2
Broader societal goals	Flood protection	2	2	1	1
	Job security	2	1	1	2
Feasibility	Cost	3	2	1	2
	Technical feasibility	3	2	2	3
	Community support	2	1	2	3
Climate-smart considerations	Reduction in key climate vulnerabilities	1	3	3	2
	Robust to uncertainty	1	1	3	2
	Minimizes carbon footprint	1	2	3	1
Overall score		16	20	22	20

There are a variety of decision tools and approaches to help with the process of comparing options, exploring trade-offs and conflicts, and working with uncertainty, but before getting into any technical or complex analyses or deliberations, it is worth checking for easy ways to simplify the choices. Are there any alternatives equaled or outperformed by another alternative for all stated objectives (conservation and/or other)? If so, they could be removed from consideration. Are there criteria for which there is no difference among alternatives? Although such criteria may be deeply important, if the outcome is the same across all alternatives the criteria will not help distinguish amongst them and does not need to be included in further evaluation. A third option for simplification is to consider merging objectives, where one objective can be expressed in the same terms as another.

9.3.3. Making Trade-offs

If, after simplifying the consequence table, a single alternative outperforms all others, the decision is clear and one can move on to implementation. More typically, decisions will involve making trade-offs among performance on different objectives and criteria. These differences may be challenging to address if they represent conflicting views and risk tolerances among different stakeholders, but there are commonly trade-offs among criteria on which all stakeholders agree.

A good first step is to see whether there are ways to adjust existing alternatives to reduce the degree of conflict. Are there ways to reduce the costs associated with the alternative, or to reduce unintended consequences? This may require a return to step 4 of the climate-smart process, with additional and creative thinking devoted to generating a new or modified adaptation alternative that removes the need for trade-offs. If there is no way around trade-offs, one can explore the relative importance or weight assigned to each criterion. If there is disagreement about the relative importance of criteria, one can explore how changing the weight given to each criterion might change which of the alternatives rank highest. One approach is to sequentially weight each criterion most heavily and look at how the ranking of alternatives changes. It may be that some criteria do not affect the relative ranking of alternatives as strongly, or that there are only a couple of criteria for which weighting really change the decision. This can allow the planning team to focus discussions about the relative importance of criteria on those that have a bigger effect on the actual decision.

This level of formality can seem daunting, and may lead planning teams to suggest starting with so-called *no-regrets* or *low-regrets* options, which can be viewed as options that will provide benefits regardless of what happens with climate change. However, even if an action would provide benefits regardless of what climatic changes or impacts come to pass, it may not be an action that would rank highly given the full suite of criteria, weightings, and negotiated trade-offs. Improving water quality is generally a good idea, for example, but if it has only a small effect on the primary goals and objectives it would be a poor choice given the opportunity costs associated with directing resources away from more effective and targeted alternatives.

As noted above, another popular approach to dealing with trade-offs is to seek alternatives that provide something for everyone, sometimes called *win–win* solutions. Identification and selection of such win–win solutions, when available, can greatly enhance the ability of projects to succeed by ensuring buy-in and engagement from disparate parties. However, unless all important criteria have been laid out and appropriately weighted, such win–win approaches may not always lead to the best decisions, and can at times be a means to avoid fully dealing with difficult trade-offs. In particular, it is important to understand what a "win" means for different stakeholders to ensure that they will recognize it as such.

9.4. Decision Tools

There are a variety of decision tools and approaches available to help with selecting among alternatives based on the results of the criteria evaluation and comparison. Some, such as scenario planning and structured decision-making, are covered in Chapter 12. We present here brief descriptions of select families of decision approaches, but should emphasize that this is just

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a sampling of what is available. There is a variety of texts on decision analytic tools and approaches (e.g., Gregory et al. 2012), so we do not go into detail here. Considerations for choosing a formal decision approach include: necessary levels of rigor, repeatability, and ability to stand up in court; software, computing power, and training needed; levels of resource required (time, money, and data); and what level of transparency is needed and what will be transparent to the target audience. Some tools have been optimized for specific institutional circumstances or to meet existing agency planning requirements or protocols (e.g., the U.S. Forest Service's TACCIMO system). Use of such agency-specific tools and approaches can be a powerful way of incorporating adaptation into existing planning processes. However, one should also remember that the decision or overall adaptation planning process should dictate which, if any, tools to use and not vice versa.

Multi-criteria decision-making. Many decisions involve multiple goals, objectives, criteria, and priorities. Multi-criteria decision-making, or multi-criteria analysis, has arisen as a structured approach to working with this reality (Van Ierland et al. 2013). Our discussion of the use of consequence tables above (Table 9.1) is an example of this approach, but there are a variety of analytical tools of varying degrees of sophistication that can be used to carry out this decision approach.

Cost–benefit analysis. In a cost–benefit analysis, any gain in utility counts as a benefit, and any loss as a cost, regardless of who experiences the costs or benefits. Cost–benefit analysis can be effective when cost–benefit ratio is the main criterion for decision-making and when all costs and benefits can be expressed in a single currency, but falls short if either of these conditions is not met (e.g., if minimizing loss of human life is a criterion, but decision-makers are unwilling to put a dollar value on human life). Since a standard cost–benefit analysis doesn't account for who experiences costs and benefits, equity is a common issue, although some approaches to including equity have been developed. A related tool, cost-effectiveness analysis, can be used to address nonuse benefits.

Decision tree. Decision trees are a way to visualize decision consequences (Clemen and Reilly 2004). They include decision nodes (the outcome is chosen by the decision-maker), chance nodes (where the decision-maker has no control over the outcome, e.g., whether or not it rains), and end nodes, which show the outcome of each possible string of decision and chance nodes. They can be useful ways to organize thinking collectively, and can help to focus on key information. They can also be used to explore consequences of taking action now versus waiting.

Spatial analysis. Many problems or decisions have a spatial component, and many decision approaches, including multi-criteria decision analysis and cost–benefit analysis, can be carried out spatially as well as nonspatially. Spatial decision support tools range from static maps to Geographic Information System (GIS)–based programs with preexisting data sets and manipulation options for broader stakeholder groups (e.g., SeaSketch or MarineMap), to specialized or technical programs for experienced users. A number of these spatial analytical tools and decision-support systems are described in Chapter 13. Marxan is one of the most widely used spatial analysis tools for ecological reserve design, and allows users to identify the most "cost-effective" options for protecting adequate space to meet the needs of specific conservation targets. A handful of tools have been designed specifically for adaptation decisions, including The Nature Conservancy's Coastal Resilience tool[25] or the Coastal Adaptation to Sea Level Rise Tool (COAST),[26] which focuses on the spatial distribution of adaptation costs and benefits (see Chapter 13).

9.5. Case Study: Evaluating Management Alternatives for British Columbia Forests

Climate change introduces a variety of complications into the evaluation and selection of management alternatives, many of which revolve around the considerable uncertainties in how climatic variables will change and the ecological response to those changes. As a result, one of the key characteristics of climate-smart conservation is to adopt strategies robust to uncertainty. Identification and evaluation of management strategies for British Columbia forest practices is an example of putting this approach into practice through the use of a process referred to as "robust decision-making (RDM)."

[25] www.coastalresilience.org.
[26] www.bluemarblegeo.com/products/COAST.php.

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Forests in British Columbia have experienced significant mountain pine beetle infestation, triggered by warmer winters. These infestations affected more than 14.5 million hectares of forest between 1990 and 2008, resulting in profound effects on ecosystems, community economic viability, and the local economy. The degree to which climate change will affect such infestations in the future and what the ecological responses will be is still unclear. To make headway with forest management planning while directly addressing such uncertainties, researchers tested a form of RDM to identify adaptation practices that would be reasonably likely to achieve management objectives over a range of climate and management uncertainties (McDaniels et al. 2012). In this RDM application, the researchers used expert-judgment-based probabilities to assess the performance of different forest management strategies, rather than models, to derive quantitative probabilities.

The first step was to establish management goals and objectives in the short and long term in light of future climate scenarios and the potential for pest infestations and damages. Four alternative strategies, consisting of sets of land management actions, were developed and evaluated. Each alternative was evaluated based on whether they would achieve objectives (short and long term) related to: (1) timber economic value; (2) non-timber values; (3) fire risk; and (4) ecological resilience. They then identified a range of key actions that managers could undertake under three general policy domains: harvest level, silvicultural practices, and fire management. The first two strategies broadly encapsulated the range of current forest management practices in British Columbia, while the second two provided more flexibility to decision-makers in the future. The second two strategy mixes also specifically included increases in landscape-level residual structure and comprehensive restoration along with replanting a variety of tree species.

The researchers then elicited expert opinions, primarily from regional forest management specialists, to create probabilistic distributions for the performance of management alternatives in the short and long term. Using the experts' probability distributions, the strategies and outcomes were evaluated against each of the four objectives to identify the most robust strategies, that is, those that performed best across multiple scenarios. They then analyzed and aggregated the results to develop an overall performance comparison for the four strategy options. Results showed that the latter two strategies were more robust across the various climate scenarios because of their decision-making flexibility and long-term benefits, despite being more costly.

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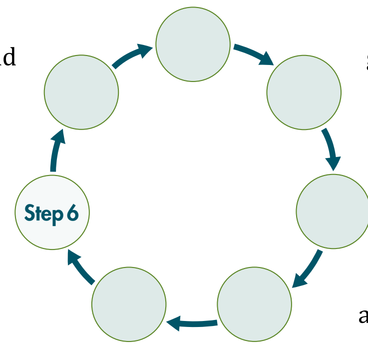
Chapter 10. Putting Plans into Action: Navigating Obstacles and Opportunities for Implementation[27]



Even the most sophisticated and well-designed climate adaptation plan is meaningless if it is not implemented. Moving from planning to action is arguably the most important step of the adaptation process, yet this is a point where many efforts become stymied. In fact, few concrete examples of adaptation plans being moved to full implementation are currently available (Heller and Zavaleta 2009, Wilby et al. 2010, Ford et al. 2011, Bierbaum et al. 2013). In part, this is because climate change adaptation is still in its infancy, but also because managers often encounter a variety of barriers that can make implementation of adaptation actions difficult to achieve. Importantly, many of the obstacles to implementation are social, rather than ecological, in nature.

Climate-smart conservation primarily differs from traditional conservation not so much in how it is carried out, but rather in why, where, or when it is carried out, which is why this guidance focuses on acting with intentionality in adaptation planning. Even though many adaptation actions may be similar to those carried out in traditional conservation, however, there are a number of reasons why implementing climate-smart conservation can be especially challenging to put into action. Accordingly, our purpose in this chapter is not to recapitulate guidance for implementation of conservation and resource management plans generally, a topic for which there already are many good resources available (e.g., Knight et al. 2006, U.S. FWS 2008b, TNC 2009, CMP 2013). Rather, the focus of this chapter is on describing some of the common implementation obstacles that can arise when bringing climate change concerns into the picture, and ways to overcome these hurdles.

This chapter also discusses opportunities for implementing adaptation actions, based on the early experience of groups that have successfully carried out such actions. While most of these considerations and opportunities are not unique to climate-smart conservation, their importance can become elevated due to the social controversies surrounding climate change, the difficulty most people have accepting change in general, and the fact that many people who play vital roles in implementation may have differing views about the seriousness, relevance, and urgency of climate change impacts.

While many of the themes that are discussed in this chapter reflect experiences common among a number of diverse groups working in climate change adaptation, it is important to remember the local nature of impacts, and that there are no "right" and "wrong" ways to carry out adaptation. Successful approaches to implementation will vary depending on a suite of local and individual factors,

[27] **Lead authors: Marni Koopman and Patty Glick.**

John Ragai

several of which are highlighted below. Because each situation is unique, they need to be considered within the relevant local, regional, cultural, historical, and ecological context.

10.1. Overcoming Obstacles

A number of factors have been implicated as obstacles to the implementation of adaptation strategies, from concerns about scientific uncertainty to a void of institutional mandates and leadership (Repetto 2008, Moser 2009, U.S. GAO 2009, Jantarasami et al. 2010, Cote 2011). In this section, we address some of the most commonly identified obstacles and provide options and examples for how to move past them for successful implementation. Interestingly, many obstacles and opportunities relate back to communications and framing of the issue. In addition to the discussion here, information on effectively communicating about climate change adaptation can be found in Chapter 15.

10.1.1. Uncertainty and Model-Based Projections

Uncertainty about climate change, its consequences, and what adaptation measures may be most effective are often cited as significant barriers to moving from planning to action. Although uncertainty is inherent in all natural resource planning, climate change adds an additional layer of uncertainty that many managers are not accustomed to working with. Chapter 12 provides a general discussion of how to deal with uncertainty in the context of decision-making and climate-smart conservation. Here, we address how to move managers and others past the inertia often associated with uncertainty about climate change and its impacts.

Many resource managers report that the uncertainty inherent in model-based projections is a particular obstacle to taking action. Different models use different input variables and analytical processes, and can vary substantially in their outputs and future projections. In addition, many computer-based models are complex and can be difficult for people (especially laypeople) to fully comprehend and understand. Unfortunately, mistrust of models and model-based projections can lead some decision-makers to leave even well-substantiated climate change projections out of their decision-making process and hinder implementation of adaptation actions. There are a number of ways to help overcome implementation issues related to uncertainty and discomfort with model-based projections. One useful approach is to emphasize the direction and rate of already observed and documented changes, and connect those observational records and trends with the model-based projections. It can also be helpful to make the connection between routine use of model projections elsewhere in natural resource management (e.g., wildlife population models, forest growth models) and in other sectors (e.g., urban planning, economics, transportation planning) to help demystify the use of these tools in climate adaptation planning and implementation.

Future conditions are sometimes not as uncertain as they may at first seem. For example, in recent workshops with the California Landscape Conservation Cooperative and U.S. Forest Service, models that differed in their projections for precipitation in the Sierra Nevada range were in general agreement that soil moisture was expected to decline substantially. Indeed, in many instances, there is broad agreement and strong confidence in the direction of changes, even if there may be some uncertainty in the rate and magnitude of those changes. For instance, almost all data and models agree that the average sea level is rising and that the rise will accelerate (Horton et al. 2008, Church and White 2011). Although it is natural to focus on sources of uncertainty, emphasizing areas of agreement and strong confidence can help overcome this barrier to implementation.

Even when there is not agreement among projections, there are mechanisms to help managers move toward implementation. Scenario-based planning (discussed in more detail in Chapter 12) offers a powerful approach to decision-making when future conditions are uncertain. Scenarios can reflect narrative visions of plausible future conditions that can be easy for laypeople to understand. Clearly articulating these possible futures, and selecting strategies that are robust across scenarios (Section 3.4) can help managers overcome their concerns about acting in the face of uncertainty. Similarly, adopting strategies that have benefits in the near term—as well as in the more uncertain longer term—can be helpful for promoting implementation.

10.1.2. Limited Conservation Resources

Another commonly cited obstacle is the lack of adequate resources (time, staff, and funding) to take on the challenge of climate change adaptation, let alone meet other conservation needs (Moser and Tribbia 2007). As highlighted in Chapter 9, climate change adaptation will have both costs and benefits, and in an era of limited conservation funds, there necessarily will be trade-offs in what we can do. Indeed, just how much it will cost to implement adaptation measures for natural resources is difficult to determine in the aggregate, as there are many factors at play. While a thorough discussion of the "economics of adaptation" is beyond the scope of this guide, one thing to recognize is that estimates will vary considerably depending on the methodologies and assumptions used (e.g., how future costs are discounted; whether and how nonmarket values are included; how the costs of inaction are calculated) (ECA 2009). In addition, there are likely to be wide variations in cost among different sectors and within and across different regions.

In many cases, investing in climate change adaptation does not necessarily require new resources. For instance, mainstreaming climate change adaptation into existing conservation and management efforts (Section 10.2.1) offers opportunities to take advantage of existing expenditures, and allocate these investments in more climate-informed ways. Conversely, conservation actions may ultimately be more costly in light of climate change (Shaw et al. 2012), and especially so without consideration of adaptation early on. One way to think about this is to consider the potential value of damages avoided by adaptation (e.g., the value of timber or other natural resources that would have been lost, or the extra costs of restoring habitat for valued species) (Stern 2006).

For actions that do warrant additional expenditures, there is no question that managers face an uphill battle given the current constrained fiscal environment. By addressing cross-sector benefits (Section 10.2.2) and building new and diverse partnerships (Section 10.2.3), funding streams that are not specific to conservation might be available for collaborative projects. Proponents of climate change action also have pursued ways to provide new sources of funding specifically for adaptation. At the international level, adaptation funding has been a central issue among Parties to the United Nations Framework Convention on Climate Change, particularly for support of adaptation actions in developing countries. To that end, the Global Environment Facility, managed by the World Bank, has established a number of funding mechanisms to finance developing country adaptation efforts. In the United States, several legislative proposals in Congress, including the America's Clean Energy and Security Act (HR 2454) that passed the U.S. House of Representatives in 2009, included provisions to generate dedicated funding for climate change adaptation (see Chapter 14). Although these national proposals ultimately did not become law, there are state examples of climate change legislation (e.g., California's AB 32) that already are generating revenue potentially available for adaptation funding. There also have been notable sources of funding and in-kind support for U.S. and international adaptation efforts from nongovernmental entities, including the business community (e.g., Munich Re) and charitable foundations (e.g., the Doris Duke Charitable Foundation, the Rockefeller Foundation, and the Kresge Foundation).

10.1.3. Public Perception and Lack of Political Will

Another key challenge managers face in taking meaningful action on climate adaptation is divergence of social perceptions of climate change and a lack of political will. In some natural resource agencies there can be a difference

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among various levels of staff in the perceptions of climate change and level of commitment to addressing climate impacts. When staff charged with resource management and decision-makers responsible for policy or budget allocations disagree about the reality and/or seriousness of climate change impacts, effective implementation of adaptation plans is unlikely. Differences in political, national, organizational, religious, and intellectual cultures drive disagreements on climate change, and many of these cannot easily be settled by scientific evidence or analysis (Hulme 2011). Even when there is consensus on the science of climate change, there is room for disagreement about the implications of the science and appropriate policy (Vogel et al. 2007, Gifford 2011).

Multiple layers of differing ideas affect peoples' motivations for implementing adaptation strategies.

For some people, there may simply not be a sense of urgency. As we have noted elsewhere, people tend to sharply discount the future, and may not believe that climate change will adversely affect them personally. They may not believe that anything *can* be done. Or, they may believe that the "cure will be worse than the disease." Thus, there are multiple layers of differing values and ideas that can affect peoples' motivations in relation to implementing adaptation strategies (Kunreuther and Weber 2012). Of course, scientific information about the impacts of climate change alone will not necessarily change these perceptions (Vogel et al. 2007). Making climate change adaptation meaningful and relevant will require action on multiple fronts. Again, this is where effective communication will be crucial—but that communication must follow multiple tracks, be sensitive to and respectful of diverse values, and be informed not just by science, but by economics, social norms, and other issues that influence human behavior.

Communicating climate change in a risk management frame is one way to facilitate action on climate change while allowing for different ideologies and viewpoints. Risk management is a common approach to decision-making that resonates with most people. As mentioned in Chapter 6, risk is calculated by weighing both the likelihood (either perceived or actual) of the event and its potential consequences. Even when the likelihood is considered to be low (e.g., someone who doubts climate change science), action may be warranted if the costs of inaction are regarded as unacceptably high. Indeed, promoting precautionary actions against low-probability but high-consequence events is a primary focus of public policy for many natural hazards, supported by regulations such as building codes and insurance requirements. As we discuss further in Chapter 14, ensuring that such policies incorporate the additional risks associated with climate change is an important consideration for adaptation.

10.1.4. Institutional Barriers

Despite some notable progress in acceptance of and attention to climate adaptation among government agencies in the United States, there are a number of institutional factors that have hindered significant adoption of adaptation in the public sector. These include: short-term planning horizons; a tradition of basing management decisions on historical data; jurisdictional limitations; and inflexible policies and management protocols (Repetto 2008; Stern and Wilbanks 2008; Adger et al. 2009; Biesbroek et al. 2009; Moser 2009; Jantarasami et al. 2010; Moser and Eckstrom 2010, 2012; Ellenwood et al. 2012; Bierbaum et al. 2013). As Jantarasami et al. (2010) point out, some agencies are more "institutionalized" than others, in that they have very specific rules and norms that govern decisions. Without specific mandates, managers may not have the authority—let alone the impetus—to embrace some of the more proactive elements of adaptation planning. Furthermore, there are both formal and informal institutional barriers to using relevant climate change information (e.g., resistance to using climate forecasts for water resource management decisions due to perceived "poor reliability") (Rayner et al. 2005, Dilling and Lemos 2011).

One of the most important ways to address institutional barriers is through leadership—not just from the top down, but from all directions (Moser 2009, Moser and Eckstrom 2010, Smith et al. 2010, Bierbaum et al. 2013). As we discuss further in Chapter 14, several new policies have been put in place at the state and federal levels that provide strong impetus for adoption of adaptation strategies, including actions by key natural resource agencies (U.S. GAO 2013). For example, in November 2013, President Obama issued an executive order (EO 13653) intended to accelerate actions to prepare the nation for the impacts of climate change, and which included specific direction to manage lands and waters for climate preparedness and resilience.

Implementation of climate change adaptation strategies is also likely to be bolstered by dedicated efforts to better bridge scientists and managers through partnerships both within and among government agencies, academic institutions, and nongovernmental organizations, such as those being supported by the Landscape Conservation Cooperatives and Department of Interior Climate Science Centers. The U.S. Forest Service, in particular, has emphasized the establishment of science–management partnerships as a means for facilitating planning and implementation of climate adaptation efforts (Peterson et al. 2011). Collaboration between climate change and ecological scientists and resource managers can help ensure that scientific information is targeted in a way that answers key management concerns, and that managers readily have access to the best available science to inform their decisions—both of which can make developing and implementing appropriate adaptation responses more effective (Mastrandrea et al. 2010, Littell et al. 2012, Raymond et al. 2013).

10.2. Creating Opportunities for Climate-Smart Conservation

Despite the difficulties of implementing adaptation efforts, both real and perceived, some plans and projects have tapped existing or new opportunities to carry out climate-smart conservation. Drawing from these experiences, we summarize some key ways to overcome hurdles to adaptation and to move from planning to action.

10.2.1. Mainstreaming Adaptation

One of the overarching themes for this guidance to climate-smart conservation is to integrate adaptation into existing work (Section 2.5). One of the best ways to facilitate successful implementation of adaptation strategies is through "mainstreaming" adaptation into existing processes. Mainstreaming takes advantage of planning and implementation mechanisms that already are in place within an agency, county, watershed council, or other decision-making body. Implementation through mainstreaming generally does not require new decision-making structures, planning efforts, or funding streams. Mainstreaming of adaptation strategies can occur in two ways: (1) ongoing decision-making processes can take climate change into consideration as planning and implementation are carried out; or (2) adaptation strategies can be developed separately and then inserted into ongoing plans that already are slated for implementation. An example of the first is the U.S. Forest Service, which has incorporated a consideration of climate change into the process for required revisions to national forest plans. In contrast, Washington

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State is assessing opportunities for integrating the findings of the Washington Habitat Connectivity Working Group into county, state, and federal land management and conservation policies and plans (Marinello 2010). While mainstreaming adaptation does not guarantee implementation, it greatly increases the likelihood it will occur because climate considerations are incorporated into established and already funded management processes.

10.2.2. Focus on Cross-Sector Benefits and Synergies

Most natural resource management or conservation plans spell out their expected benefits to focal species, populations, or habitats, but historically have not been well integrated with plans to solve pressing problems facing human communities. The concept of "ecosystem services" as an important rationale for conservation is on the rise, however, and there are numerous examples of potential synergies between natural resource conservation and the resilience of human communities (Postel and Thompson 2005). This approach exemplifies the climate-smart characteristic of "safeguarding people and nature" (Section 3.8) and can serve as an important criterion for evaluating among adaptation alternatives (Section 9.2.2). At a time of accelerating climate change and decreasing funding streams, opportunities for cross-sector project implementation and cost sharing should be fully explored. Human communities are already being increasingly impacted and stressed by climate change, and these effects are expected to continue. Stressed communities may have reduced capacity for conservation activities. Thus, preparing both natural and human communities for climate change in a co-beneficial manner will help maintain not only the natural systems that people rely on, but also the local community's capacity to support and restore natural systems over time.

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One approach to identifying synergies between human communities and natural resource conservation is to explore local values and goals. The city of Medford, Oregon, for example, struggles with meeting water quality goals for its intake facility on the Rogue River. Upstream of the intake, an ecological restoration effort on Little Butte Creek recently was implemented, resulting in the return of a historical meander that provides habitat for salmon and increased floodplain connectivity. Water resource managers noticed reductions in water turbidity after the restoration effort, prompting interest in future collaborations that can strategically place restoration areas where co-benefits to natural systems and human communities can be realized. As climate change impacts to water resources and other natural resources continue to worsen, interest in conservation techniques that provide human benefits (i.e., ecosystem services, green infrastructure) is likely to increase as an alternative to more expensive "gray" infrastructure such as dams or levees (Roth 2013).

10.2.3. Engage Diverse Partners Early On

When people with diverse values and goals are involved in the planning process at an early stage, a variety of benefits can be gained, as highlighted in Chapter 5. First, it allows for building trust, which can greatly enhance the implementation of adaptation strategies. Potential conflicts among different sets of values and goals can be resolved early in the process, reducing the likelihood that unexpected conflict will derail implementation. Diverse engagement also increases the likelihood that a variety of partners will support the implementation effort, which can lead to support by decision-makers and funders. In order to facilitate project implementation, some important partners to collaborate with during the planning process might include community leaders, business leaders, federal and state agencies, county planners, local and regional scientists and experts, county commissioners, ranchers and farmers, water managers, and tribes. Effectively engaging such diverse groups requires careful consideration of the ways in which one communicates about the issue, a topic discussed further in Chapter 15. Finding ways to effectively communicate and collaborate with relevant and diverse constituencies, a skill that is not always natural for natural scientists, will often be important to build support for implementation of adaptation actions and plans.

One valuable type of partner is the local conservation "champion." This is someone who is a leader in the region, is able to communicate effectively with other diverse partners and key decision-makers, recognizes the values of different groups, and strongly and passionately understands the importance of the project from many different perspectives. Champions are not necessarily affiliated with conservation organizations—they can come from surprising affiliations that are not historically aligned with conservation.

Involving those with vital roles in implementation, including both project execution and funding decisions, in the planning process can also greatly enhance the likelihood of success. These individuals may even help shape adaptation strategies to better reflect realities in project delivery and cost. Having entities that ultimately will be responsible for implementation involved in planning also will help ensure that they will be vested in seeing plans through.

Partnership and collaboration greatly enhanced the likelihood of effective implementation of conservation efforts in the Klamath Basin in Oregon and California. Beginning in 2005, a diverse group with a long history of conflict and distrust over water in the basin became parties to negotiation over water quality and distribution (Gosnell and Kelly 2010). These parties included two states, numerous state and federal agencies, three tribes, an electric utility, farmers, ranchers, and environmental organizations. Over the next few years, the diverse parties worked diligently to create a plan that addresses different values, including water for irrigation and the restoration of endangered salmon populations for tribes and commercial fisheries. In addition, the plan addresses uncertainty about future water availability, especially due to changes associated with climate change. The products of this collaborative effort include two settlement agreements that, if implemented, represent a historic example of conflict resolution and ecosystem restoration at the watershed scale. While navigating the needs of diverse groups added complexity and duration to the process, and success still rests with congressional action, having diverse partners vested in seeing the agreements implemented greatly increases the potential for success.

10.2.4. Demonstrate Success

The field of climate change adaptation is still young, and with the body of lessons learned still being compiled it will be some time before we have time-tested best management practices. Case studies that demonstrate the efficacy of adaptation plans and measures are greatly in need, especially if they can show co-benefits to people, such as economic savings, mitigation of natural hazards, or continued provision of valued resources. The long-term nature of many climate change impacts means that in many instances we may not see the results of adaptation actions for years into the future. And in some cases, "successful" adaptation may mean that conditions deteriorate less than they may have in the absence of action. However, there are many challenges we already are facing from climate change that may be ripe for demonstrating

Case studies that demonstrate the efficacy of adaptation plans and measures are greatly in need, especially if they can show co-benefits to people.

adaptation and conservation success in the near term—even if at a relatively small scale. In fact, starting small may provide a useful guide for replication at larger scales.

As an example, in an effort to restore the Blackfoot River watershed in Montana for native trout, the Big Blackfoot chapter of Trout Unlimited started working with local landowners to restore individual tributaries by planting riparian vegetation, improving upland management, and improving in-stream flow. One tributary, Wasson Creek, became a showcase for future work due to increasing cutthroat trout *(Oncorhynchus clarkii)* populations and stabilized water temperatures. In a test of system resilience, a drought in 2000 caused fish populations to decline, but they quickly rebounded when streamflow and temperature conditions recovered. What began as a group of sportsmen has grown into a larger community forum called the Blackfoot Challenge, which is working to implement a collaborative Blackfoot Drought Response Plan (Blackfoot Challenge 2010). The proven success of Wasson Creek and the increased level of partnership among agencies, tribes, nongovernmental organizations, private landowners, and local citizens have created momentum in the efforts to restore the Blackfoot River watershed in an era of climate change and associated drought.

10.2.5. Take Immediate Action, But Keep Sight on Transformative Change

Climate adaptation will often require new ways of thinking, communicating, partnering, planning, and monitoring. Because the assumption of a relatively stationary climate (at least within the range of historic variation) is ingrained within our decision-making structures at all levels, there are many potential areas of disconnect between sound adaptation strategies and current processes and policies. New decision-making processes are likely to require greater flexibility and agility so they can respond quickly to new information and changing conditions. Some have suggested moving from a top-down hierarchical style of decision-making to a more collaborative and proactive style in the form of adaptive governance (Brunner et al. 2005, Folke et al. 2005).

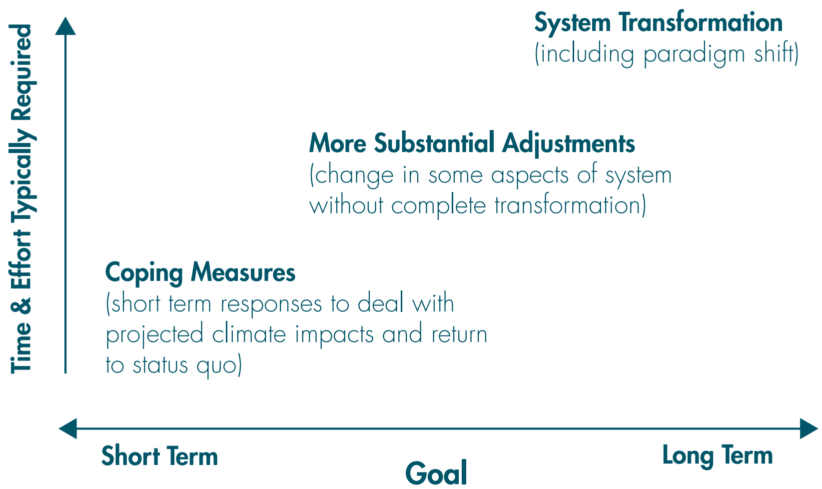

Figure 10.1. Scope and scale of adaptation, indicating the transition from short-term coping measures to more fundamental transformation and paradigm shifts. (From Moser and Ekstrom 2010, © National Academy of Sciences.)

Because expedient action is needed on climate change, to the extent possible, it is useful to implement adaptation strategies within current decision-making paradigms. But equally important is identification of where current decision-making structures, policies, and funding hinder adaptation, to understand where systems-level transformations will be necessary (Moser and Ekstrom 2010). As Dave Cleaves, Climate Change Advisor to the U.S. Forest Service, has said, "You can't steer a bicycle until you get it moving" (U.S. Forest Service 2011). Action within current paradigms gets us moving, but we need to steer in the direction of positive and transformative change on multiple levels (see Figure 10.1).

For example, the threat of climate change has contributed to a significant shift in the approach to and focus of water management in Lake Okeechobee, Florida (Vedwan et al. 2008). Water management in South Florida has long been a concern as a growing human population and associated water use for agriculture and urban uses has contributed to significant environmental degradation across the region, from the lake itself to the Everglades and Florida Bay. Historically, efforts to manage trade-offs between human and ecological uses were largely driven by centralized "command and control" type management and an emphasis on reactive and mechanistic approaches rather than participatory, proactive decision-making focused on a functioning system. Ultimately, this led to considerable mistrust among stakeholders and a lack of meaningful progress in solving the multiple water management challenges facing the region. Continued environmental degradation, together with growing concerns about the additional challenges posed by climate change, eventually led to an evolution in management, and the development of the Comprehensive Everglades Restoration Plan (CERP). The CERP adopted an "ecosystem approach" for lake management that links decisions for water levels, flows, and nutrient pollution at a system-wide level, and involves a more transparent and inclusive decision-making process and greater flexibility to manage in the face of the uncertainties and risks posed by climate change.

The examples provided throughout this chapter provide examples of progress on overcoming key obstacles and taking advantage of opportunities implementing climate adaptation efforts. As Bierbaum et al. (2013) succinctly put it, there is "more than before, but less than needed." As such case studies and examples of climate-smart conservation become more numerous and robust, a body of evidence will become available on which to model best practices for adaptation implementation. At this early stage in the development of the field of climate adaptation, it is imperative that scientists, managers, and decision-makers continue employing best practices for putting conservation and natural resource management plans into action, even as they continue developing ways of overcoming the unique hurdles facing implementation of adaptation efforts.

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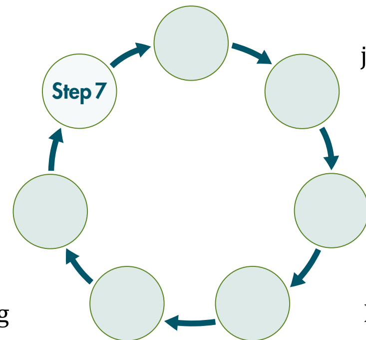
Chapter 11. Tracking Action Effectiveness and Ecological Response[28]



Monitoring and evaluation are well established in natural resource management and conservation, and given the ongoing shifts associated with climate change, will only increase in importance for ensuring the success of adaptation efforts. Sound monitoring protocols and efforts underlie several of the key characteristics of climate-smart conservation (Chapter 3), especially those focused on: linking actions to climate impacts; employing agile and informed management; considering broader spatial and temporal scales; and minimizing emissions of carbon and other greenhouse gases. Much of climate adaptation will depend on planning for an uncertain future, and well-conceived and executed monitoring and evaluation efforts are a means for determining how well plans align with conditions as they actually develop.

Although tracking action effectiveness is portrayed in the climate-smart conservation cycle (Figure 4.1) as the final step (step 7), designing appropriate monitoring efforts is usually concurrent with earlier steps in the cycle (especially steps 5 and 6). Indeed, the results of monitoring and evaluation efforts (both ongoing and project specific) directly inform many of the previous steps. Reflecting the iterative nature of the climate-smart cycle knowledge gained through relevant monitoring efforts is integral to the cyclic process of review, refinement, and adjustment.

In the context of climate adaptation, monitoring refers to a broader range of activities than just biophysical measurements. Monitoring, evaluating, and reporting organizational and implementation milestones can be critical to keeping projects focused on a moving target, sometimes long before on-the-ground results are apparent. Most climate-smart conservation projects will require regular review and appropriate revisions to goals, objectives, strategies, and actions based on observations and an evolving understanding of the conservation resources, and the context in which projects are taking place. Results from monitoring and evaluation are often the basis for climate change adaptation efforts as we contend with climate-driven changes to ecological systems, increased climatic variability, and the need to evaluate effectiveness of our management interventions under changing climate, social, and political conditions. Evaluating and reporting project results is important to advancing conservation science and improving practices, but it is also essential to appropriately scale monitoring and not overdesign given project needs and capabilities.

11.1. Monitoring to Support Climate-Smart Conservation

Looking to the future, monitoring and evaluation strategies will need to be designed to better anticipate climate-driven changes and identify new challenges and opportunities. Managers will

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need to be more strategic, and increasingly employ multi-scale monitoring efforts that track shifts in landscape-scale ecological conditions as well as the effectiveness of adaptation actions at specific sites.

Two broad types of monitoring address the needs of climate-smart conservation efforts:

- Monitoring focused on documenting the status and long-term trends in ecological conditions and climate change variables
- Monitoring designed to evaluate the effectiveness of specific conservation projects or actions

The design and implementation of long-term (>20 years) monitoring programs is an involved process generally undertaken by agencies with secure funding. Those interested in long-term status and trends monitoring (e.g., National Park Service Inventory and Monitoring, U.S. Forest Service Forest Inventory and Analysis, and many U.S. Geological Survey (USGS) and NOAA programs) will want to undertake extensive consultation and employ a more comprehensive process to design, implement, and evaluate monitoring (Busch and Trexler 2003, Fancy et al. 2009, Dilling and Lemos 2011, Gitzen et al. 2012). Long-term monitoring, as well as resampling of historical research sites, has allowed researchers to clearly establish links between climate change and ecological attributes, such as changes in the timing of flowering and migration, distribution of species, snowpack, and the size and frequency of wildfires (Root et al. 2003, Westerling et al. 2006, Moritz et al. 2008, Pierce et al. 2008, Rosenzweig et al. 2008, Jiguet et al. 2010). These sorts of observations are essential input to vulnerability assessments (step 2 of the climate-smart cycle) and may inform changes in conservation goals and objectives (step 3). The second type of monitoring—effectiveness monitoring—focuses on tracking and evaluating management actions that are being implemented for climate adaptation purposes (step 6). This chapter is directed primarily to managers who are designing adaptation projects with outputs that are typically realized within 2–10 years, and at local to landscape scales.

On a project-relevant scale, the role of monitoring and evaluation in adaptive management approaches is well recognized and described (e.g., Salafsky et al. 2002, Williams and Brown 2012). These well-articulated roles for monitoring remain relevant, but we focus on considerations particularly important to climate adaptation projects. For example, a factor that frequently makes evaluation especially challenging for climate-smart conservation is that the desired (ultimate) results of management efforts may not be known for years, if not decades, as climate change continues to unfold (Pringle 2011, Spearman and McGray 2011). Uncertainty around future climate conditions and ecological responses to those changes challenge one's ability to identify and define conditions that represent a desired conservation outcome and to pinpoint appropriate indicators to help gauge whether those conditions are being approached (Janetos et al. 2012). These complications highlight the need to carefully consider conservation goals (step 3) and adaptation options (steps 4 and 5) in the monitoring and evaluation process.

Table 11.1 describes a general process for designing and implementing monitoring and evaluation for climate change adaptation projects. These steps include: developing an explicit purpose(s) for the evaluation; compiling existing information; developing conceptual models; identifying and selecting relevant indicators; defining sampling design and methods; and conducting data management and analysis. Although the six steps are presented as a linear process, oftentimes these steps will occur concurrently or iteratively. While these steps are important to any successful monitoring effort, climate-smart monitoring will need to systematically consider issues associated with an adaptation-planning context (e.g., Bours et al. 2013). In the following sections we highlight ways in which climate change might influence monitoring approaches.

Table 11.1. Steps for designing and implementing climate change adaptation monitoring. Most projects will be concurrently engaged in several steps during the design and implementation phases.

Steps in Monitoring Design	Outcome or Information Gained
1. Articulate goals and objectives	Focus; define what's in or out of scope; identify "why" and "for whom"
2. Compile and assess existing information	Opportunities to use existing data and partnerships; identify gaps in existing programs; identify known trends or issues
3. Conceptual models and interactions	Identify known relationships and uncertainties in understanding and/or data gaps; identify key drivers, stressors, and responses; develop communication aids
4. Identify, prioritize, and select indicators (targets)	Identify high-ranked indicators; needs for research or monitoring; select list of indicators for further development
5. Sampling design and methods	Establish efficient, defensible, and repeatable monitoring design and protocols
6. Data management, analysis, and reporting	Create process to ensure efficient data quality, availability, and relevance; create outputs designed to increase likelihood that data will be used to inform the right decisions at the right time

11.2. What Climate Change Adaptation Means for Monitoring

Almost by definition, adaptation projects are likely to focus on conservation targets vulnerable to loss or transformation. Monitoring programs may thus need to accommodate shifting priorities and indicators as project goals and adaptation strategies evolve. In some cases, climate adaptation projects will specifically target areas or systems likely to be subject to threshold events, where abrupt and dramatic changes (sometimes referred to as "pulse" events) will require an adaptive monitoring design. At other times, the changes may be more gradual (i.e., "press" events). Even where goals and strategies remain the same, changes in monitoring may be required to address shifts in species ranges, phenology, and community structure or composition. An increased emphasis on managing for change may translate into selecting ecological processes, communities, or services as monitoring targets rather than particular species (Jump et al. 2010).

Monitoring for climate-smart conservation will entail new thinking to accommodate evolving goals, objectives, and strategies as well as shifting environmental conditions. Successfully implementing climate change adaptation projects may require a shift in *what* to monitor (i.e., priorities and indicators) as well as *how* to monitor (i.e., the *where, when,* and, possibly, even *who* participates in the monitoring). Explicitly identifying the purpose for the evaluation of the monitoring data—*why* we are monitoring—is an essential first step and careful consideration up front will help guide many subsequent decisions regarding program design.

11.2.1. Why Monitor?

As with climate change adaptation planning in general, designing an effective monitoring and evaluation strategy requires a clear definition of purpose. Why is monitoring needed? Who will use the results? How will the results be used? Monitoring and evaluation programs can serve multiple purposes, most of which are not unique to climate-smart conservation. Monitoring and evaluation programs can:

- Provide accountability and assess compliance with contractual requirements
- Measure the effectiveness of management actions toward achieving outcomes
- Assess why actions were or were not successful
- Inform/improve future management strategies (adaptive management)
- Assess efficiency (investment cost–benefit)
- Compare outcomes across similar projects
- Build institutional capacity and learning
- Track climate systems and ecological response

Few projects will have the resources (or need) to monitor and evaluate for all the purposes listed above, and the selection of monitoring indicators should be based on the explicit goals of the adaptation project. Defining the purpose(s) for a monitoring and evaluation program depends largely on four factors: (1) the objectives of the climate-smart conservation project; (2) uncertainties; (3) audience; and (4) the climate change adaptation focus of the project (Pringle 2011, Spearman and McGray 2011, Villanueva 2011). Because evaluations are commonly aimed at gauging the effectiveness of actions toward achieving particular outcomes, monitoring program design is chiefly informed by agreed-upon project goals and objectives (see Chapter 7). Monitoring purpose may also be influenced by the uncertainties and assumptions about the conservation target and its response to the actions being implemented (steps 2 and 4 of the climate-smart cycle). While reducing some uncertainty may be required to assess outcomes and adjust management actions when a system reaches a predetermined state, linking monitoring to decision-relevant information is important.


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Considering the key audiences and end users for the monitoring and evaluation results can help clarify purpose. There are often contractual requirements to demonstrate the short- and long-term achievements and challenges of a project to funders and supervisors (Pringle 2011), in addition to the learning benefits of sharing information with colleagues. Finally, the climate change adaptation focus of the project may be of relevance in determining evaluation purpose and monitoring program design. Most adaptation projects are clearly focused on tangible management actions and their outcomes for the conservation target. However, in some cases the process of implementing adaptation planning, sharing learning, and building institutional adaptive capacity are important achievements (Villanueva 2011, Ellenwood et al. 2012). In other cases, sustaining ecological services and human livelihoods may be the targets of adaptation (Spearman and McGray 2011).

11.2.2. What to Monitor

Even though clearly articulating the why for evaluation in a climate-smart conservation project goes a long way toward identifying what to monitor, the climate adaptation context raises additional challenges to identifying appropriate monitoring indicators. Adaptation options vary in scope, from relatively simple site-based actions to complex projects that include goals to build capacity for adaptation and promote institutional learning (Figure 11.1). In many cases projects offer a mix. Research to develop indicators specifically to measure the effectiveness of climate change adaptation efforts is still in the early stages (USGCRP 2011a, 2011b, 2012). Some initial thinking has tended to focus on process indicators—to track such things as progress toward developing and implementing adaptation policies, plans, or strategies—and on various measures of societal or institutional adaptive capacity (DEFRA 2010, Pringle 2011, Stadelmann et al. 2011), rather than on outcome indicators focused on biophysical response.

Spearman and McGray (2011) suggest developing sets of indicators relevant to "different adaptation dimensions," or the multiple adaptation foci of the project: (1) adaptation actions and outcomes; (2) elements of adaptive capacity and enhanced learning; and (3) long-term sustainability of ecosystem services and livelihoods. This is a more comprehensive approach to monitoring and evaluation and serves to enhance the effectiveness of the entire adaptation process. Process and capacity indicators may entail using more qualitative information, such as measures of people's perceptions, values, and experiences, in addition to the more traditional quantitative biological measures. For example, an effort to develop adaptation-relevant indicators for New York City identified mainly social and institutional metrics (Jacob et al. 2010).

Ultimately, indicators for climate-smart conservation efforts will need to address the biophysical resources (e.g., species, habitats, ecosystems) that are the target of adaptation attention. For many projects, the long timescale of climate-driven changes poses a challenge for gauging the effectiveness of adaptation. If evaluations are aimed at demonstrating the effectiveness of adaptation actions toward achieving specific conservation outcomes, monitoring approaches should be closely aligned with performance metrics based on project objectives (step 5). For projects designed to achieve long-term goals, appropriate intermediate milestones can be particularly important for demonstrating progress toward results that will manifest over longer time frames. Whether developing biological indicators to track

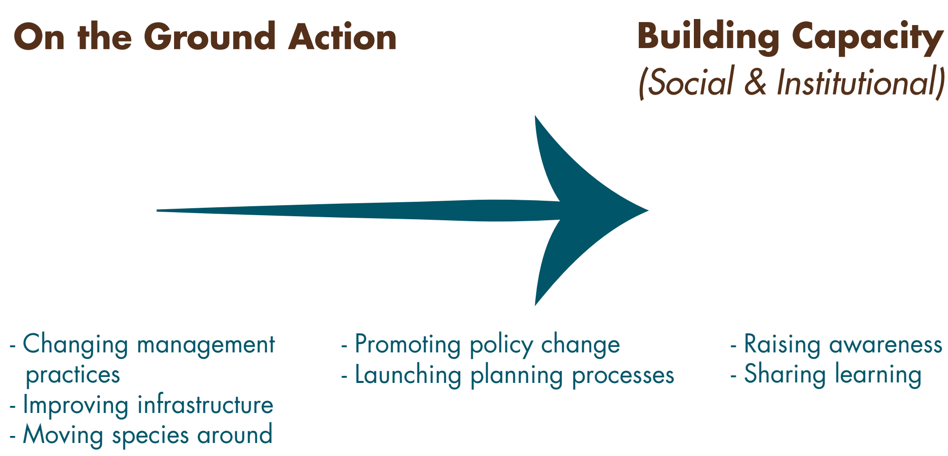

Figure 11.1. The range of climate change adaptation options potentially relevant for monitoring and evaluation, from on-the-ground conservation delivery to policy and process interventions.

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outcomes or process-relevant indicators, climate-smart conservation projects may require the identification of new indicators and incorporation of new types of information. For example, measuring and monitoring carbon capture, storage, and/or release in natural systems are becoming increasingly important for projects designed to not only provide conservation value but carbon mitigation benefit.

Conceptual models of various types, which are often developed to assess vulnerabilities (step 2) and generate adaptation actions (step 4), can also be helpful in identifying potential indicators and crafting monitoring approaches. In particular, they can help identify the parts of a system one is attempting to influence, the mechanism(s) through which the interventions are expected to achieve desired outcomes, and any underlying assumptions in one's logic or rationale (Margoluis et al. 2009, CMP 2013). Conceptual models, including theory of change graphics and logic models, can also provide a temporal framework to link the actions selected for implementation to immediate outputs and short-term outcomes to adaptation impacts (Pringle 2011, Spearman and McGray 2011). Conceptual models linking actions to outcomes can also be used to identify potentially negative results on other conservation resources, and possible indicators of those maladaptive effects (Pringle 2011).

Lastly, as climate-driven changes become more pronounced there may be cases where indicators currently providing information on the efficacy of management strategies may no longer be meaningful indicators of project success. For example, analyses by Lohmann et al. (2012) project that climate-driven changes in shrub–grass dynamics will make shrub encroachment considerably less likely, regardless of grazing intensity. With future climates, shifts in the species composition of perennial grasses will likely be more useful indicators of grazing impacts than the shrubs that are currently favored monitoring targets. Thus, it may be necessary to include multiple monitoring indicators (e.g., both shrubs and perennial grasses in this example) to account for and accommodate uncertainty in projections of future climate impacts.

11.2.3. How to Monitor

Issues that influence *how* one might monitor given a climate adaptation context include: the long timescale of climate change; shifting baseline conditions; the challenges of attribution; and coordination of monitoring across landscapes, jurisdictions, and programs. These are primarily relevant to finalizing the selection of indicators and designing sampling protocols for a climate-smart monitoring and evaluation program. Decisions on many of these issues will depend on how one intends to measure the performance of the project because there are multiple ways to gauge adaptation effectiveness.

Climate-smart monitoring and evaluation generally will be implemented in the context of existing data, studies, and monitoring programs. Data that may be relevant to adaptation monitoring are available for most regions, and identifying, reviewing, and evaluating existing information can save considerable time and expense, as well as enable new monitoring efforts to build on existing time series. With limited capacity, it may become necessary to look for opportunities to exploit existing monitoring networks and develop partnerships that work toward meeting shared monitoring needs. Existing networks that collect and use standardized indicators and protocols at regional to national scales (e.g., the U.S. Forest Service Forest Inventory and Analysis Program; the USGS National Water-Quality Assessment Program; the National Park Service Inventory and Monitoring Program; and the USGS National Phenology Network) can provide important context at scales much broader than the operational scale of most projects.

Establishing baseline conditions or reference sites to use in comparative studies is standard practice in conservation and natural resource management. Unfortunately, we can no longer assume that current baselines or reference conditions, against which to measure project effectiveness, will remain constant (Milly et al. 2008). Directional climate change will almost certainly lead to novel environments that are beyond current baseline conditions, or the historical range of variation (Williams and Jackson 2007). These emerging no-analog communities will challenge us to track adaptation in different ways. For instance, rather than using current baselines for comparison, it may be possible to compare expected changes (based on model-based projections) with observed changes (Ferraro 2009). There are pitfalls in using model projections as a metric against which to measure progress, however. These include model uncertainty, and a need to be mindful of potential circularities in using data for model calibration/validation and evaluating progress.

Similarly, scenario planning approaches to adaptation (see Chapter 12) can inform monitoring by identifying indicators useful for distinguishing which, if any, of the "plausible futures" identified during scenario development are actually playing out (Peterson et al. 2003, Kass et al. 2011). In this case, monitoring is an integral component of implementing actions identified by scenario planning, and monitoring data feed the decisions on which options are appropriate to deploy over time. For example, Conroy et al. (2011) developed several potential scenarios for bird communities in the Appalachians under changing climate conditions. The high degree of uncertainty in the responses of the target species over time complicated identification of appropriate monitoring indicators. Accordingly, the authors suggested ways to optimize selection of monitoring variables, such as basing decisions on known relationships among species and systems, experimentation, and expert judgment.

The ability to attribute ecological outcomes to implemented adaptation actions will often be important to judging project success. Many factors influence the outcomes of projects, however, and ascribing attribution can be difficult even in the absence of shifting climate conditions. Additional monitoring targets may be required to provide enough information to attribute observed outcomes to a reduction in climate-related versus other stressors or management interventions given the long-term nature of climate change and complexity of systems. Pringle (2011) suggests that, rather, it may be more appropriate to document the contribution of adaptation to overall project outcomes.

Beyond gauging adaptation effectiveness, there are other factors associated with *when* and *where* to monitor that affect sampling design. Changes in environmental conditions will likely affect the timing of detection and sampling protocols used in monitoring efforts. Shifts in seasonality, rainfall patterns, maximum spring flows, migration patterns, bud burst, and other phenological phenomena can affect the optimal time (seasonal and diurnal) for recording observations. In other cases, we may be trying to answer new climate-related questions that will require adjustments to the timing of monitoring. An example is tracking phenology associated with climate shifts during a particular season. Greater climatic variability may require more frequent sampling, sampling over longer periods, or evaluation of data at a finer temporal resolutions.

Projected climate-driven changes in ecological processes, species ranges, or other ecological functions may also influence the selection of suitable monitoring sites. Sampling designs may need to account for likely shifts in species distributions or capture important environmental or management gradients that may shift over time. Model projections of shifting species ranges and associated phenologies may guide the location of monitoring sites or the timing of sampling regimes. Indeed, the idea of using models to identify suitable monitoring locations is well established, both for climate-related changes and changes due to other factors (e.g., Urban 2005). For example, if climate change models project a northward shift in the geographic range of a tree species into your forest management unit, it might be appropriate to monitor areas within your unit at the edges of its current range to determine whether the shift occurs, and if it does the rate of establishment and expansion. In other cases, it may be desirable to identify places with similar geomorphology, hydrology, slope, or aspect that could serve as a network of replicates for monitoring the effects of different adaptation strategies.

Finally, *who* participates in monitoring may require some adjustment as monitoring encompasses broad areas and requires coordination across larger spatial scales and multiple jurisdictions. As a more diverse suite of systems is incorporated into monitoring regimes, there likely will be need for more monitoring capacity and, given limited capacity, to confront trade-offs among multiple monitoring goals. In many cases, this may require rethinking monitoring priorities, looking for new partnerships, and addressing monitoring needs across a patchwork of public and privately owned lands. These partnerships would need to include a range of expertise—scientists, landowners, resource managers, and interested citizens, to

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name a few—and monitoring strategies will need to accommodate new institutional relationships. New partnerships can create opportunities to share the burden, make it feasible to do the monitoring, and facilitate comparisons among related adaptation efforts in similar systems. Citizen science–based monitoring efforts represent an emerging opportunity (Dickinson et al. 2010), and can be particularly useful at extending observational capacity across broader landscapes.

11.3. Case Study: Tracking Adaptation Effectiveness in the Gunnison Basin

The Nature Conservancy in partnership with the Gunnison Climate Working Group (a broad consortium of partners) is in the process of implementing on-the-ground climate change adaptation in southwestern Colorado. The primary goals of the project are to restore and enhance the resilience of wetland and riparian areas within sagebrush shrublands and enhance the adaptive capacity of the Gunnison sage-grouse *(Centrocercus minimus)* and other wildlife species dependent on these wetland habitats (TNC and GCWG 2013). Many of the wetland/riparian sites in the project area were degraded by historical land uses. Under current conditions, projected increases in temperatures (as much as 7°F by 2050) and increasing drought frequency are expected to exacerbate the decline in wetland habitat in the region (Neely et al. 2011).

The project exemplifies an intentional approach to climate adaptation, with efforts to improve and restore wetland habitats building on a growing body of vulnerability assessment and adaptation planning work conducted for the Gunnison Basin (e.g., Neely et al. 2010). Project participants will, in turn, share tools, methods, and findings with other groups working to implement climate adaptation. To date, structural improvements have been installed in two priority locations, Wolf and Redden creeks. These sites were selected because they are expected to provide high-quality wetland/riparian habitats for sage-grouse and associated wildlife species under a wide range of future climate scenarios. Rock dams have been placed at intervals along the reaches of both creeks to slow water flow, raise the groundwater table, and promote the reestablishment of wetlands and riparian vegetation in areas that upland vegetation colonized in the past.

Monitoring was acknowledged as a key component of this overall climate adaptation effort. The wetland restoration project specifically adopted an adaptive management approach supported by monitoring key indicators (e.g., vegetation attributes, water table, and soil moisture) to document how the sites are responding to treatments. The monitoring program was aligned with realistic project expectations. Although some project objectives will likely be realized within the first 2 years of the project (e.g., structure installation on 500–800 acres of riparian habitat, initial shifts in vegetation composition and soil moisture content), other goals will take longer to accomplish (e.g., significant shifts in riparian vegetation, improvement and maintenance of brood-rearing sage-grouse habitat).

The monitoring program is intended to determine the effectiveness of the management treatments in modifying vegetation. Accordingly, the group measured baseline conditions, installed dams, and monitored vegetation responses through 2013. The monitoring protocol and indicators are vegetation based and include evaluating the goal to reduce upland species cover and increase wetland species cover by 20%, respectively. Although the project was designed specifically with climate adaptation in mind, the protocols and sampling objectives are not, by themselves, notably different than one might conduct for any other restoration project.

Benefits other than vegetation change are also being monitored. For example, increased understanding of what it means to prepare for change, increased support and engagement, identification of the most cost-effective and repeatable methods to meet monitoring needs (e.g., photo-points vs. plots). The vegetation monitoring protocol was designed to be straightforward so other groups could sustain monitoring after the initial funding ended. Building from the permanent plots established for vegetation monitoring, several partners (Bureau of Land Management, Natural Resources Conservation Service, U.S. Forest Service, and the local university) are expanding the monitoring to include vegetation productivity, transects that extend to the side slopes/upland vegetation, groundwater wells, and a commitment to sustain the original monitoring protocol in the future. The extended period of data collection and the monitoring elements being added by project partners will facilitate evaluation of the longer-term adaptation goals and the effectiveness of specific adaptation actions.

Betsy Neely/TNC

Part 3 | Making Adaptation Count

Part 3 of this document offers guidance on a number of topics that are critical for achieving effective adaptation outcomes. These include techniques to deal with uncertainty, find and use best available scientific information, understand and employ supportive policies, and improve how we communicate about climate change and adaptation.

Uncertainty in its various permutations figures prominently in how many practitioners think about climate change, sometimes creating a sense of confusion and paralysis. Chapter 12 addresses the central topic of decision-making in the face of uncertainty, and deconstructs the various types of uncertainty users are likely to encounter in carrying out adaptation initiatives. The intent of this chapter is to provide tips and tools that will enable readers to overcome their fear of uncertainty and embrace it instead.

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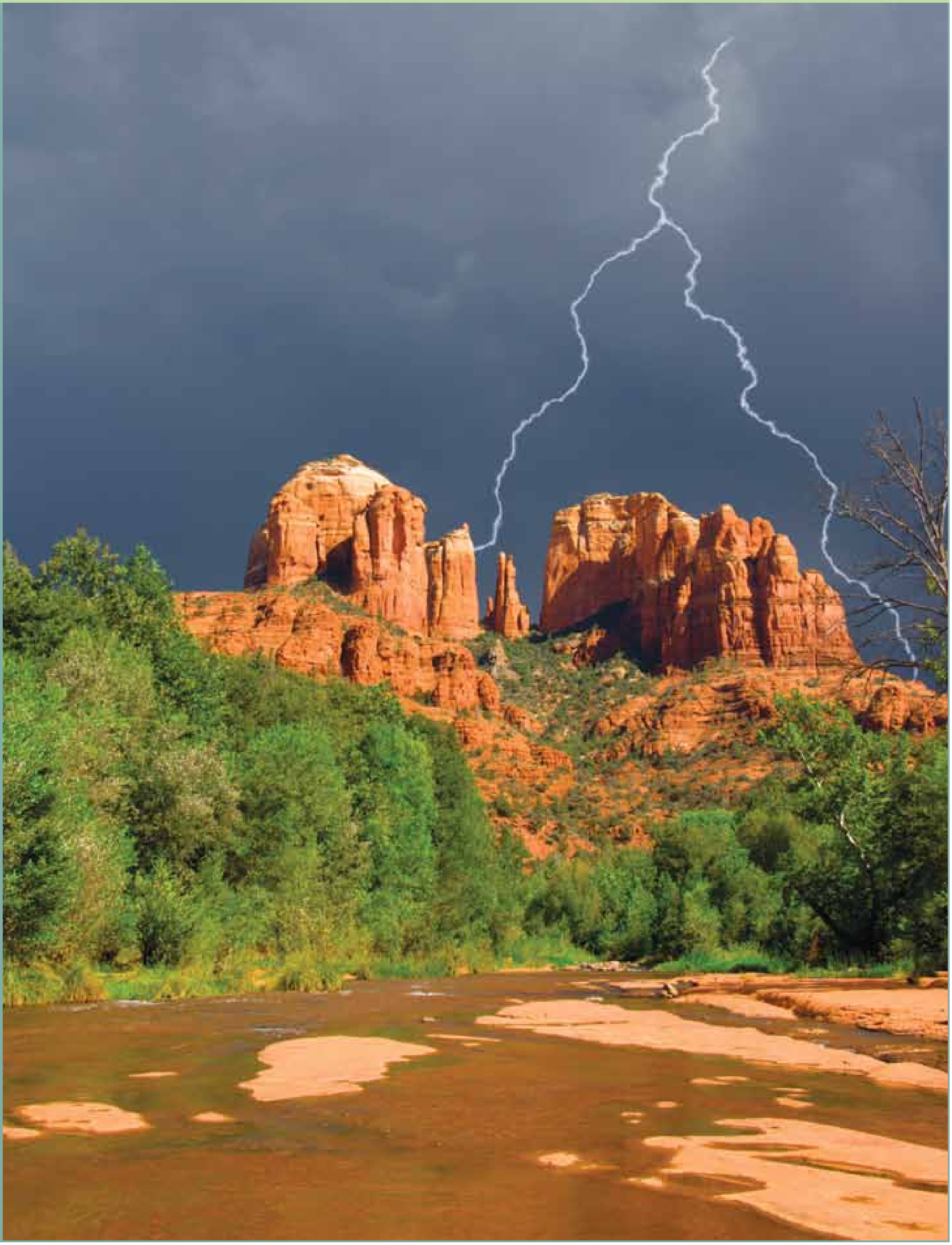
A sound scientific understanding of likely impacts and ecological responses is at the heart of successful adaptation efforts. Chapter 13 delves into the subject of finding and using the best available and most relevant scientific information for particular adaptation efforts. The ability to accurately assess impacts and vulnerabilities, and develop suitable adaptation strategies depends on accessing the most relevant science. This chapter provides an overview of some of the most important sources for scientific data, expertise, and tools.

The policy and legal framework within which we work has a strong influence on the ability to successfully carry out climate-smart conservation activities. Chapter 14 therefore looks at how existing policies can be employed to help promote climate-smart conservation efforts, or conversely may constrain the ability to carry out effective adaptation. In particular, it highlights ways that the underlying policy environment can promote the type of broad collaboration and forward-looking thinking that will be required to carry out climate-smart conservation.

Finally, designing and carrying out adaptation efforts will be highly dependent on how one communicates about the work to various stakeholders and audiences. Chapter 15 offers advice for communicating about climate change generally, and climate adaptation in particular. Drawing on emerging work in the field of strategic communications, this chapter provides specific examples for how to reach different audiences that may have shared values and interests, even if they have differing views or levels of understanding about climate change.



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Chapter 12. Managing Under Uncertainty[29]

Managers commonly cite uncertainty as a major obstacle to planning and decision-making in the face of climate change, and some claim that the deep uncertainty around climate change makes it different from other issues faced by the conservation and resource management community (e.g., Ranger 2011). The reality is that our world is rife with uncertainty, and the uncertainty surrounding climate change is not the only or necessarily the largest source of uncertainty for many aspects of management decisions. Whether explicit or in the background, uncertainty is a daily presence for conservation practitioners.

That said, uncertainty related to climate change is a very real issue, and asking the "climate question" means dealing with uncertainty. Most of the key characteristics of climate-smart conservation directly or indirectly incorporate uncertainty, and uncertainty comes in at virtually every stage of the climate-smart cycle (Figure 4.1). Although approaches for addressing uncertainty are referenced at many points in this document, because it is such an overarching concern this chapter addresses the issue and discusses approaches in a single, coherent chapter that applies to the entire climate-smart process.

In light of the pervasive nature of uncertainty, it is no surprise that theory, guidance, and tools for assessing, understanding, and incorporating uncertainty into decision-making occur in a wide range of fields (e.g., Polasky et al. 2011). A growing literature explores this issue specifically as regards climate change adaptation (e.g., Lempert et al. 2003, Dessai and van der Sluijs 2007, Reeder and Ranger 2011), with some authors arguing that existing approaches to managing in the face of uncertainty (e.g., adaptive management) are sufficient for working with climate-related uncertainty (e.g., Nichols et al. 2011). The goal of this chapter is to provide a broad-brush introduction to the field, a conceptual framework to help managers and policy-makers get their minds around it, and an introduction to several tools that can help make decisions in the face of uncertainty.

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12.1. Common Responses to Uncertainty

Before getting more deeply into uncertainty and tools for dealing with it, it is worth examining the value of effectively incorporating uncertainty into climate-smart conservation and management. There are several common responses to uncertainty and its implications for adaptation planning (loosely based on Moser and Ekstrom 2010):

Proceed as though there is no uncertainty. Managers may be caught off guard when the single conceptual model or anticipated future on which they based their decisions fails to materialize, and may make poor decisions based on a false sense of certainty. Here managers jump too quickly into the planning phase before having adequately understood the problem.

[29] Lead authors: Jennie Hoffman, Erika Rowland, Cat Hawkins Hoffman, Jordan West, Susan Herrod-Julius, and Michelle Hayes.

Wait for more certainty before taking action. Managers may miss opportunities to minimize risk or harm, or to take advantage of opportunities. Here managers fail to even begin the adaptation planning process.

Frame the problem as one of uncertainty or lack of information rather than as one of making a good decision in the face of uncertainty. This can lead to "analysis paralysis" where the adaptation process remains stuck in the understanding phase.

Focus on better-understood problems or parts of the problem where uncertainly seems more manageable. While this gives a good feeling of actually tackling both climate change and uncertainty, it may shift the focus away from the impacts or problems that matter most to the stakeholders or decision in question.

Understand and work with uncertainty within the problem or decision context. This does not guarantee that we will always achieve the outcome we want, but it does give the best chance of it. It also builds capacity for the type of flexible thinking an uncertain future demands. This is the approach we advocate as part of climate-smart conservation.

The bottom line is that being uncertain is not the same as knowing nothing: there are ways to use uncertainty as information in decision-making. Indeed, if the state of the science is that uncertainty is high, the principle of using the best available science requires that we build uncertainty into our decisions rather than choose a single future scenario or model of how we believe a system works on which to focus. The following section highlights ways of dealing with different sources and categories of uncertainty, as well as approaches for deciding whether or not to consider particular uncertainties in decision-making.

12.2. Characterizing Uncertainty

Much of the discussion around climate change centers on uncertainty about future climate projections—how much warmer will it get? How quickly? Will storms increase? Yet this is just one source of uncertainty around climate change that has implications for resource management and conservation. Key sources of uncertainty relevant to adaptation planning include:

- Uncertainty about how the *climate system functions*
- Uncertainty about trajectory of *greenhouse gas emissions*
- Uncertainty about *how species or ecosystem will respond* to climatic changes
- Uncertainty about *how humans will respond* to climatic or ecosystem changes and whether they will reduce greenhouse gas emissions
- Uncertainty about the *effectiveness or implementation* of policy, regulatory, or management actions
- Randomness: some processes or systems are heavily influenced by pure chance

Understanding sources of uncertainty can help identify what sort of information we need and what might or might not be possible in terms of understanding or reducing uncertainty. When selecting the most appropriate tools to use in any given context, it is useful to group uncertainties into sets of categories (van der Sluijs et al. 2003, Walker et al. 2003, Janssen et al. 2005). We focus here on three key axes for categorizing uncertainty: reducible and irreducible uncertainty; controllable and uncontrollable uncertainty; and uncertainty in magnitude versus direction of change.

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12.2.1. Reducible and Irreducible Uncertainty

Some uncertainties are virtually impossible to reduce, such as what future anthropogenic greenhouse gas (GHG) emissions will be. In these cases, decision-makers simply have to recognize the uncertainty and incorporate it into their planning as they move forward. Other uncertainties have been significantly reduced, such as projections of how global greenhouse emissions will affect future climate at regional scales. In many cases, further reductions in uncertainty may be fairly modest, or take a lot of effort relative to the gain in certainty. Still other uncertainties can still be significantly reduced, such as improved understanding of how changing temperature and precipitation may affect vegetation dynamics. In these cases, further measurement, modeling, or experimentation may greatly improve the level of certainty. Planners and decision-makers will need to weigh the cost of further reducing uncertainty against the decision-relevant benefits of doing so.

12.2.2. Controllable and Uncontrollable Uncertainty

How the future unfolds, be it bird population numbers or atmospheric greenhouse gas concentrations, depends on a number of system drivers. Some of these can be influenced by management or other actions; others are beyond our control, at least within the context of the problem being addressed. For example, the condition of a stretch of coastline in the future may depend in part on the effects of global sea-level rise, which is uncontrollable (at least at the local scale), and in part on land-use decisions made by local authorities, which are (at least theoretically) controllable. The degree of controllability influences how best to work with the applicable uncertainty. Scenario analysis, for example, is typically built around uncontrollable uncertainties, while adaptive management focuses more on the controllable (Peterson et al. 2003).

12.2.3. Uncertainty in Magnitude versus Direction of Change

In some cases, we are fairly certain about the direction of change—the average global temperature will continue to rise for the foreseeable future—even if we are not as certain about how much change will happen, both in terms of rate and magnitude. In other cases, we may not even be certain about the direction of change. For example, climate models for the Great Lakes region suggest an increase or decrease in lake levels is plausible, depending on the balance of increased precipitation and evapotranspiration (Angel and Kunkel 2010). The degree of flexibility or adaptive capacity needed to achieve a particular likelihood of success may be greater if the direction of change is uncertain. Consider the problem of designing a dock for cargo ships if water level may increase or decrease by several feet! That said, thresholds in management decisions or consequences can make uncertainty around magnitude more problematic as well. For example, paleontological evidence suggests that mangrove forests can keep pace with climate change up to a particular rate of sea-level rise (Ellison 1993), but will drown if the rate goes higher. This could influence whether restoration plans focus on maintaining mangroves or on supporting the transition to a new habitat type.

12.2.4. Importance to the Decision

Not all uncertainties will be relevant to the system or decision at hand. For example, uncertainty around peak springtime flow rates in streams or the size of the 100-year flood may be essential for decisions about road design; relevant, but less essential for decisions about what plants to use for riparian restoration projects; and irrelevant for decisions about deer management strategies. Assessing the sensitivity of a decision to various uncertainties (be they scientific or sociological) can help focus scarce resources on those knowledge gaps that matter most (Means et al. 2010, Byer et al. 2011, IOM 2013). These sensitivity analyses can take a probabilistic approach if we know the range within which the true value is found, but can also work even when we have little idea of where reality might lie (Feick and Hall 2004). A set of techniques, known as value of information analyses, assess not just the likelihood of a decision change, but the potential change in expected payoff as a result of that change (Raiffa and Schlaifer 1961, Felli and Hazen 1998, Runge et al. 2011). This helps decision-makers further assess not just whether but potentially how much it is worth investing in gathering more information. Runting et al. (2013) applied this approach to decisions regarding where to locate coastal reserve systems and found that in some cases it was worth spending more than 90% of the project budget on high-resolution topographic information and process models.

12.3. Decision-making Approaches

Good decision processes involve a mix of deliberation and analysis (NRC 2009). Thus climate-smart conservation requires both analytic tools for addressing uncertainty and approaches or frameworks that increase conservation practitioners' capacity for skilled deliberation that incorporates uncertainty. We present a few such tools and approaches here, but emphasize that decision-making under uncertainty is a robust field (Toth 2000, van der Sluijs et al. 2003, Dessai and van der Sluijs 2007, Refsgaard et al. 2007).

The first two approaches, expert elicitation and scenario-based planning, can help users delve into the realm of uncertainty. Although these can be used to inform decisions, their strength is in their ability to promote exploration and enhanced understanding of the system in question and the nature and range of uncertainties relevant to the situation at hand. The next three approaches—structured decision-making, adaptive management, and robust decision-making—specifically focus on making decisions and moving from understanding to action. There is a host of decision analytic frameworks (e.g., Toth 2000), but we focus here on those most commonly suggested for climate-related decisions. It is worth noting that these various approaches and tools can be used in concert or in combination with other decision-focused approaches, to deepen and enrich the process. Brown (2011), for example, combines sensitivity analysis with a decision analytic framework to link climate model outputs with more bottom-up, context-driven adaptation approaches.

12.3.1. Expert Elicitation[30]

Expert elicitation is a multidisciplinary process for obtaining the judgments of experts to identify and characterize uncertainty and fill data gaps where traditional scientific research is not feasible or adequate data are not yet available. The goal of expert elicitation is to characterize each expert's knowledge about relationships, quantities, events, or parameters of interest. The expert elicitation process uses expert knowledge to produce conclusions about the nature of, and confidence in, that knowledge. It takes advantage of the vast amount of local knowledge available from experts who are familiar with the state of the science for the system of interest. It can also help in taking advantage of integrated and contextual knowledge and understanding, generating buy-in or ownership by the experts engaged in the process, and being rapid or low-cost relative to intensive data gathering or modeling. Expert elicitation is not, however, an appropriate tool for addressing political or value-dependent questions.

Recent efforts to understand ecosystem vulnerabilities to climate change have explored how to adapt expert elicitation theory for use in qualitative assessments of climate sensitivities in complex ecological processes (U.S. EPA 2012a, 2012b). In tailoring expert elicitation for ecological assessments, the first step involves breaking down the problem (e.g., what are the climate change sensitivities of salt-marsh sediment retention processes?) into a set of distinct questions (e.g., how does increased wave action affect sediment fluxes?) that clearly and explicitly define parameters and relationships of interest. To structure the questions, conceptual or influence diagrams can be used to define the causal relationships among physical (e.g., freshwater inflows) and biological (e.g., net organic accumulation) variables. This includes their connections to the climate change drivers that experts believe are of greatest importance for determining ecosystem process functions. A systematized coding scheme can then be provided to the experts to record their judgments about the degrees of sensitivity of individual components of the system, in order to better understand the system as a whole. This can be further structured to identify which relationships among variables have a disproportionate influence on the process over all, and where threshold system responses are likely to occur. As sensitivities and thresholds associated with certain variables emerge, it is possible to cross-reference the type of variable (e.g., nutrient inputs) with appropriate management responses (e.g., adjusting pollution control actions to improve their effectiveness under climate change) (U.S. EPA 2012a, 2012b).

There are a variety of options for how to elicit expert opinion. The degree of formality and process appropriate to use depends on such factors as resources (e.g., funding, staffing, technology), the importance of engaging a broad range of stakeholders, desired efficiency, and likelihood of contention or lawsuits. In cases where legal action is likely, a formal approach following published and ideally court-tested methodologies and using recognized, published, and credentialed experts may be best. If the goal is to build broad

[30] This material is based on information from EPA's Expert Elicitation Task Force White Paper (http://www.epa.gov/spc/expertelicitation/index.htm) and EPA's Climate Ready Estuaries Vulnerability Assessments (U.S. EPA 2012a, 2012b).

engagement and support for the process, a larger group that includes individuals recognized for the scientific knowledge as well as those recognized for site-based knowledge may be good (e.g., fish and wildlife managers).

12.3.2. Scenario-Based Planning

Initially developed for military use and adapted for business applications beginning in the 1970s, the use of scenarios is a relatively recent addition to the suite of tools for conservation planning and management. While *strategic planning* methods usually anticipate a single future based on past conditions and behaviors (i.e., "forecast" planning), *scenario-based planning* considers several alternative versions of the future, the relative likelihood of which are unknown (i.e., probabilities cannot be assigned). Scenarios are not predictions or forecasts, but provide several divergent, plausible accounts of how the future might unfold that serve to describe, and "bound" the decision space for managers. Climate change scenario planning is a structured, "what if" exercise that uses qualitative and quantitative information to envision possible future ecosystem changes associated with climate variables and effects, as well as policies and societal directions (Snover et al. 2013).

We commonly use an informal version of scenario planning to inform personal decisions from the mundane ("what if … it rains? … the traffic is heavy? … the train is delayed?") to the weighty ("what if … technology changes suddenly? … the stock market drops? … housing prices rise? … my job doesn't work out?"). The perceived difficulty of our decisions increases with the number of unpredictable factors that are beyond our direct control, and have the potential to significantly affect our lives.

Similarly, the uncertainty, uncontrollability, and potentially large consequences that are prevalent in management decisions associated with climate change can stymie decision-makers. In view of the complexity of climate futures, narrowly focused, predictive studies often are inadequate to fill the information gap for planners and decision-makers (Peterson et al. 2003), and even downscaled climate models cannot provide the level of certainty most managers desire. Scenarios, however, can help to overcome management paralysis by organizing and integrating information about relatively predictable/certain, and unpredictable/uncertain decision factors or "drivers" to support analysis of plausible future conditions, thus guiding decisions required today.

There are numerous methods for developing scenarios—all involve creating storylines that capture critical uncertainties using a systematic approach via several key steps. Scenario planning ideally involves participants with subject matter expertise (e.g., ecologists, climate scientists, etc.), as well as managers and stakeholders. Additionally, creative thinkers who are not particularly associated with the issue may be included to provide unconventional ideas that others may not consider (Schwartz 1992).

The first step in creating scenarios is to define the issue, question, or decision facing the manager or organization. The question or decision phase generally parallels the first step in the climate-smart cycle, identifying conservation targets. An example of a planning issue or question in the context of climate change might be, "what are the best actions to meet our goals given influences from climate change over the next 50 years?" Scenario planning participants then consider how climate change or other system drivers may influence the relevant actors, processes, and ecosystems, and use this information to describe plausible scenarios that combine the factors of high uncertainty and high importance to the issue at hand. The scenarios may be built around uncertainties in the climate system, responses to climatic changes by people, species, or ecosystems, or some combination of both. The key is to create

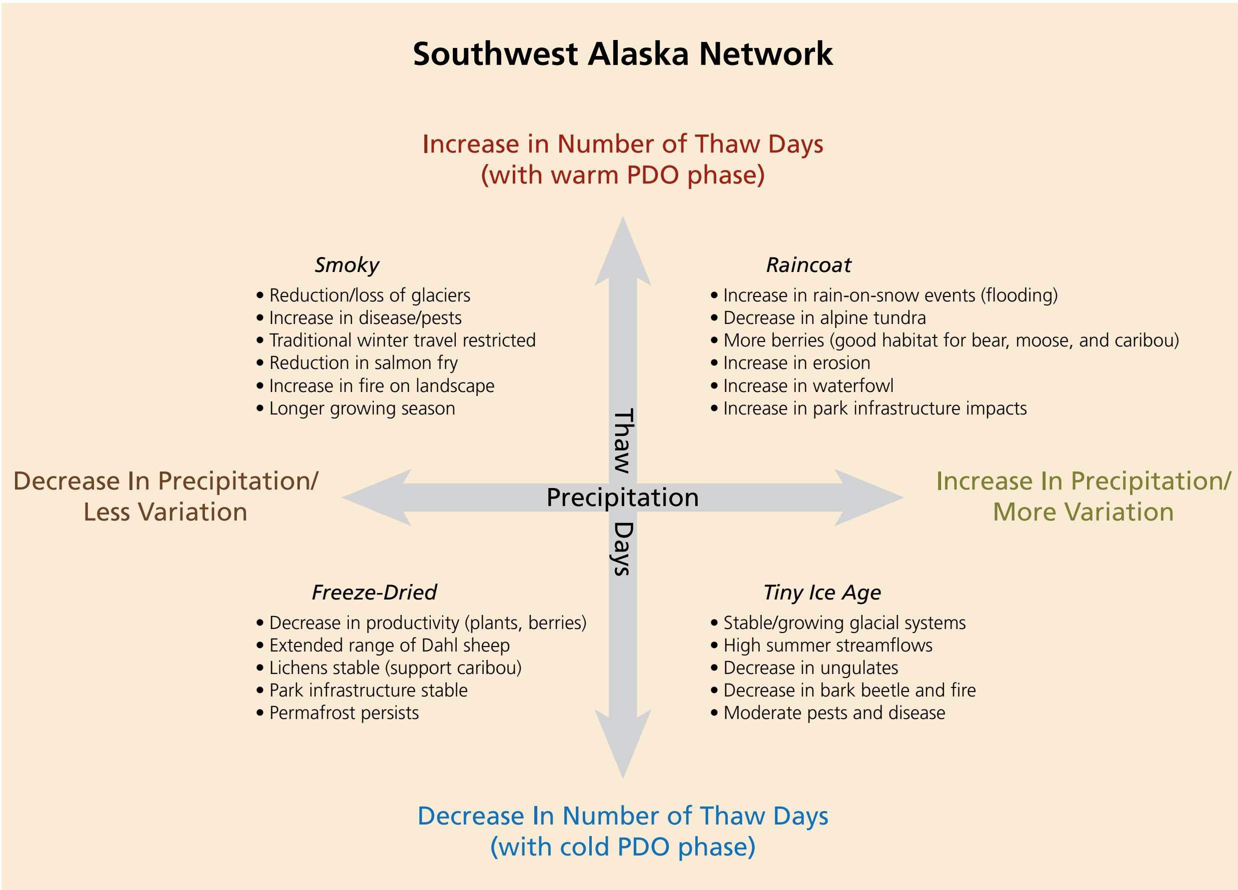

Figure 12.1. Example of a four-quadrant matrix displaying plausible future scenarios for southwest Alaska's Arctic and coastal region. In this matrix the x-axis depicts changes in precipitation and the y-axis changes in the number of days above freezing per year, taking into consideration the Pacific Decadal Oscillation (PDO). (Source: National Park Service [Weeks et al. 2011].)

scenarios that, while plausible, stretch participants' thinking. For example, managers of a site for which climate projections include an increased temperature and the potential for precipitation to increase or decrease may explore the implications of, and potential management actions relevant to, a warmer and wetter future as well as a warmer and dryer future, within a context of increasing population and demands for ecosystem services such as water supply.

One of the most common, and straightforward, approaches for developing and displaying such scenarios is to use a matrix approach in which four quadrants identify a range of plausible futures (Rose and Star 2013). The matrix consists of two critical uncertainties (e.g., "precipitation" and "thaw days" in Figure 12.1) forming an x- and y-axis, with the intersection of those uncertainties forming the quadrants. Using an iterative process, planning teams may apply this approach with a number of important uncertainties in order to determine which combination reveals a set of future scenarios that are most relevant for use in further analysis. Oftentimes a narrative "story" and shorthand title is developed to go along with each quadrant/scenario as a means to effectively communicate these disparate futures (e.g., "tiny ice age" and "freeze-dried" in Figure 12.1).

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Developing of a set of plausible scenarios, whether using a matrix or other approach, provides a platform to explore implications of the various futures ("what problems or opportunities would this future present?"), actions ("what actions would be relevant under the circumstances of each future?", "what actions should we implement immediately under the circumstances of each future?"), and parameters to monitor ("what indicators will tell us if a particular scenario is emerging?") so that management actions may be adjusted over time. Within this "decision space," conservation practitioners can test ideas and seek actions that are robust (i.e., make sense across all scenarios). Scenarios can also illuminate current activities that may not make sense in any of the plausible futures.

Perhaps one of the greatest utilities of scenario work is initiating dialogue about what seems an intractable situation. For example, in its application in the National Park Service, scenario planning has proven successful in fostering rich interactions between climate scientists and decision-makers; in broadening decision-makers' perceptions of potential climate impacts; and in inspiring the creation of robust management strategies and actions, as well as identifying where actions or policies may actually be counterproductive (Rose and Star 2013).

12.3.3. Structured Decision-Making

Although we make decisions daily, we do not always make them in a structured way. For many decisions this is fine, but having a structured process becomes immensely useful for more difficult and complex decisions. Here we give a brief background on the field of structured decision-making (SDM) and refer interested readers to key texts such as Gregory et al. (2012). This approach is similar to the "Deliberation with Analysis" approach put forward by the National Research Council (NRC 2009).

At its core, structured decision-making is simply "a formalization of common sense for decision problems which are too complex for informal use of common sense" (Keeney 1982). The practice of structured decision-making ranges from quantitative and model driven to qualitative and deliberative, but in all cases it follows set of steps that provide a transparent, explicit, and replicable process, which are in many ways similar to key steps in the climate-smart conservation cycle. In particular, it emphasizes the importance of beginning with a solid understanding and framing of the problem to be solved (Hammond et al. 1999). This involves identifying those with actual decision-making authority, not simply people with a stake in the decision, and assessing the triggers for the decision. What problem are decision-makers seeking to solve? Why now? Other elements of problem framing include determining the constraints, scope, frequency, and timing of the decision(s). After framing the problem, participants clarify objectives, develop a creative set of alternatives, evaluate the consequences of each alternative relative to the objectives, and make any necessary trade-offs.

For every step of the process, there are tools that help to clarify and structure various components of the decision, including several well-developed approaches for addressing uncertainty at various stages of the process. These include tools for evaluating the relative importance of various objectives or how well each alternative action meets the full suite of objectives. While not developed specifically for climate change, most decision analytic tools and approaches can be applied to climate-smart decision-making.

In the context of SDM, evaluation and prioritization typically are more formal and quantitative than in many adaptation planning processes. Because of the clear problem–objectives–alternatives path, evaluation is specifically linked to how well each alternative meets the objectives. This in turn can help to clarify objectives, the relative importance of different objectives, and even the problem statement itself. Indeed, achieving clearer thinking is one intention of a structured decision process. See Section 4.10 for a case study using SDM.

12.3.4. Adaptive Management

Adaptive management is perhaps the most widely invoked approach for decision-making and management in the face of uncertainty. The term adaptive management, however, is used to cover an enormous diversity of practices (Williams et al. 2009, Allen et al. 2011, McFadden et al. 2011, Williams and Brown 2012). These range from formal applications built around specific decisions that rely on ongoing management and monitoring to test hypotheses, reduce uncertainties, and adjust management practices, to informal applications of "learning by doing." Regardless of the formality of approach, adaptive management recognizes that it is sometimes best to simultaneously pursue knowledge to better manage the resource while still moving forward to make and implement decisions (Nichols et al. 2011).

Although adaptive management can be a useful tool for managing in the face of climate change, it is not a panacea, and is most appropriate and effective when the following conditions are met:

1) **There is a clear, recurrent decision.** Objectives of the decision-making can be explicitly stated, and the decision will be revisited periodically.

2) **There is a need for learning.** There is uncertainty that matters in terms of management decisions.

3) **Learning is possible.** It is possible to design monitoring to discriminate among alternative hypotheses or models of system function or management effect.

4) **Change is possible.** Management strategies and actions can be changed in response to what is learned.

Adaptive management follows many of the same initial steps as structured decision-making, but adds another, embedded iterative phase in which monitoring results are used to update the models (conceptual or mathematical) used in the decision process, and management decisions are subsequently reevaluated using the updated models. The climate-smart conservation cycle explicitly draws on and incorporates many of the attributes of adaptive management, particularly from the perspective of using a structured process for developing management actions and an iterative process for reviewing, reconsidering, and adjusting actions. A primary motivation for adaptive management is the acknowledgement of critical uncertainties that impedes decision-making; thus, identifying critical uncertainties is essential to developing an effective adaptive management plan. Such articulation ideally consists of explicit descriptions of alternative hypotheses in the form of multiple predictive models. For these to represent critical uncertainty, the competing models must lead to different recommended actions (Runge et al. 2011). If the uncertainty is so great that alternative hypotheses cannot be articulated, scenario planning and robust decision-making may be more appropriate. Monitoring supports tests of the multiple working hypotheses by enabling comparison of the outcomes of management action with responses predicted by the models associated with each hypothesis. Model updating and accumulated information about system response serves to reduce key uncertainties.

Since its appearance as an explicit, formal strategy for natural resource management (Holling 1978, Walters and Hilborn 1978), the concept of adaptive management has received strong support, but also criticism due to its often imperfect application, and from misunderstanding due to divergent definitions. Walters and Holling (1990) describe three approaches to structuring adaptive management:

- **Evolutionary, or "trial and error."** Initial choices are haphazard, and later choices focus on the subset of actions that give better responses.

- **Passive adaptive.** Based on historical data, a "best guess" model for system function forms the basis for decision-making, with adjustments to the model as new information becomes available.

- **Active adaptive.** Available data (historical and projected) support alternative models of system function, and management and monitoring results serve to test and refine these models.

More recently, the National Research Council (NRC 2004) and the Department of the Interior (Williams et al. 2009, Williams and Brown 2012) have explicitly rejected "trial and error" as falling within the definition of adaptive management. Regardless of how one defines it, the effectiveness of adaptive management as a learning and management tool diminishes when there is no experimental framework or research design that allows for learning, no ability to proactively track management effectiveness or lack thereof, and no clear feedback loops indicating how information will be used (Nie and Schultz 2012). Without these key elements, the process is more like "ad hoc contingency planning" than directed "learning while doing" (Ruhl and Fischman 2010).

12.3.5. Robust Decision-making

Robust decision-making (RDM) is an approach that explicitly incorporates consideration of multiple futures into a decision analytic approach and uses "robustness" rather than "optimality" as the primary criterion for evaluation (Lempert et al. 2006, Lempert and Collins 2007). In other words, the goal of this approach is to identify decisions that maximize the likelihood of some acceptable outcome across a range of scenarios rather than seeking the best possible outcome for one scenario. This can be achieved with approaches ranging from quantitative models to open, deliberative processes.

The first step in applying RDM to climate change management decisions is to structure the elements of the analysis, including articulating the goals, the full array of management options, and the assumptions and uncertainties associated with attaining those goals and implementing the options. Subsequently, results of simulation models run many hundreds of times using an array of climate scenarios and an initial set of management strategies reveal which strategies are most robust across the greatest variety of climate scenarios. Of most interest are climate scenarios under which even the most robust strategies perform poorly. Statistical algorithms identify those strategies and characterize the future climatic conditions under which they perform poorly to reveal the trade-offs among them with respect to the key vulnerabilities. Strategies can then be revised to address key vulnerabilities, and simulations are run again with revised strategies. For situations in which analyses reveal that no strategies are robust, existing conservation goals may not be attainable and may need to be revised. These last few steps help illuminate the combinations of uncertainties that are most influential in a decision, and the set of beliefs about the uncertain state of the world that are consistent with choosing one option over another. Results of these analyses provide important information for ranking the selection of adaptation options.

Robust decision-making has been applied to a variety of issues relevant to climate change, such as strategies to reduce greenhouse gas emissions (Lempert et al. 1996), manage water supply (Hulme 2007, Groves et al. 2008), address infrastructure vulnerability to sea-level rise and flooding (Lempert et al. 2012), address flood risk from hurricanes (Fischbach 2010), and evaluate conservation management options for endangered and threatened species (Regan et al. 2005). More applications of this approach are currently underway to analyze water quality and aquatic ecosystem management decisions under climate change. RDM can also apply in ways that parallel adaptive management to improve robustness as experimentation and learning occur. For example, a strategy may be designed with corresponding indicators that signal when one of several critical paths of change is occurring, which then triggers some kind of modification to that strategy, including initiating additional actions (Dewar 2001).

Limitations of RDM include the computing and analytic capabilities required to conduct analyses, the related issue of communicating the fairly complex, data-rich results to decision-makers, and the subjective judgments required to define "vulnerability" and "robustness" for any given decision context (although this last limitation is not uncommon to any approach that explicitly addresses uncertainty) (Means et al. 2010).

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Chapter 13. Tapping into the Wealth of Data, Models, and Tools[31]

Assembling high-quality and relevant scientific information is a critical step in undertaking climate-smart conservation. Science-based information—including results from studies and experiments, status and trends monitoring data, simulations and scenarios, and results from modeling and analytical tools—informs virtually every step in the climate-smart cycle. Over the past few years an incredible amount of environmental data have become available through Web sites and online portals, and advances in computer technology now make it possible to conduct climate assessments at multiple scales for almost anywhere in the country. When undertaking their own adaptation planning processes practitioners can draw upon an increasing number of Web-based tools, completed assessments related to climate and natural resources, and related climate action plans (West et al. 2009, Peterson et al. 2011, Adelsman and Ekrem 2012).

The challenge for natural resource managers is to efficiently tap into the wealth of available scientific information and extract the most relevant and highest quality science for their needs. A number of factors can make finding and using such data by natural resource managers and decision-makers challenging, however. First, existing tools, data, and models may not be well suited to the management questions at hand (West et al. 2009). Second, model-based projections of future climatic conditions are often at a spatial and temporal resolution too coarse for making site-specific decisions, and a lack of agreement among projections can complicate interpretation and use of the results. And finally, many natural resource managers have little experience using climate data and therefore may have difficulty understanding and incorporating it into planning efforts, or conversely not understand its limitations and use it in ways that are not scientifically well supported.

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In this chapter, we discuss considerations for finding the best available and most relevant science for planning and implementing climate adaptation. The chapter is intended to serve as a resource that supports all steps of the climate-smart conservation cycle (Figure 4.1). We start by discussing ways to define information needs, and narrow the search for relevant data. We then summarize some key sources of ecologically relevant climate information, and conclude by discussing how to identify suitable data, models, and tools from among the range of options available. Because available data, models, and tools are ever-expanding and evolving, we do not attempt to provide comprehensive lists of suitable data sources in this document. Instead, we refer readers to some of the growing number of data, information, and knowledge-sharing portals being developed and managed by federal agencies, academic institutions, and nongovernmental organizations (Box 13.1, p. 190).

[31] Lead author: K. Bruce Jones.

Box 13.1. Key sources for data and information relevant to climate-smart conservation.

National Climate Change and Wildlife Science Center is a USGS program established to assist natural resource managers identify scientific information and tools for assessing and responding to climate change (https://nccwsc.usgs.gov).

Department of the Interior (DOI) Climate Science Centers (CSC) are a network of joint federal–university partnerships that focus on fundamental climate-related scientific research needs of Landscape Conservation Cooperatives and other federal, state, tribal, and private resource managers (http://www.doi.gov/csc/index.cfm).

Landscape Conservation Cooperatives (LCC) are a network of DOI-led public–private partnerships to support the interface between scientific information and natural and cultural resource management (http://lccnetwork.org/)

NOAA Regional Integrated Science and Assessment Programs are a NOAA-led network of regional climate-science research and support centers that provide products and tools to enhance the use of science in decision-making (http://cpo.noaa.gov/ClimatePrograms/ClimateandSocietalInteractions/RISAProgram.aspx).

NOAA Climate.gov is a source of authoritative scientific data and information about climate, and offers a variety of useful data and map products (www.climate.gov).

ClimateWizard is a Web-based tool supported by The Nature Conservancy, University of Washington, and University of Southern Mississippi that enables technical and nontechnical audiences to access climate change information and visualize impacts (www.climatewizard.org).

Climate Adaptation Knowledge Exchange (CAKE) is an information and knowledge-sharing Web site hosted by EcoAdapt that provides access to adaptation-relevant case studies, literature, tools, and practitioners (www.cakex.org).

Data Basin is an online portal hosted by the Conservation Biology Institute that provides open access to numerous biological, physical, and socioeconomic data sets that can support climate change adaptation and related research needs (http://databasin.org/).

13.1. Defining Data Needs

Before delving into the vast array of data sources available, it is worthwhile to carefully define the data needs for one's planning effort. Carefully considering data requirements at the outset of a project can reduce the time spent learning about or acquiring data, models, and tools that may not be directly relevant to the management issue at hand. A useful first step is to develop a chart of the full cycle of activities involved in the planning process, from initial identification of goals and objectives to monitoring for outcomes and adaptive management. The various steps of the climate-smart cycle provide a good starting place for developing this list of activities. In charting the activities for a specific project, it is helpful to consider the specific management situation, develop more detailed lists of activities for each step in the cycle, and then consider the data that may be required to support each activity.

Many of the same considerations involved in planning the overall adaptation planning process (step 1) apply to defining data needs, such as choosing specific assessment targets, and determining the appropriate geographic and temporal scope and scales for consideration. Data requirements will almost certainly evolve and need to be refined during the course of the adaptation planning process. In particular, new data needs may be identified during the vulnerability assessment process (step 2) or during the development of adaptation options (step 4). Data needs also may need to be revisited when considering how best to monitor for the effectiveness of adaptation actions (step 7). An important objective in defining data needs is to determine what information resources are already available that might meet project needs, and where new investments may be necessary to obtain necessary information. Developing, analyzing, and interpreting data can be time-consuming and expensive. Accordingly, it is important to distinguish, to the degree possible, between information that is truly necessary to address the problem at hand, and information that may be interesting, but is not essential.

As discussed elsewhere (e.g., Chapters 5 and 11), the development of conceptual ecological models is a useful step that allows scientists, managers, and stakeholders to develop a common understanding of important elements and processes affecting one's ability to meet conservation goals and objectives. In turn, well-defined conceptual models help identify the types of data, measurements, and indicators needed to conduct the program, as well as the spatial and temporal scales of interactions and drivers of change. This information is essential for determining which types of existing data may be necessary or desirable to acquire (for example, data from field samples vs. from remote sensing) and for evaluating the utility of existing information resources.

13.2. Sources of Climate Change Information

There are many sources of climate-related information, from published reports and literature to Web sites and portals providing access to historical observations or future model projections, and Box 13.1 has already listed a few key resources. Numerous federal and state agencies and nongovernmental organizations have initiated or published climate vulnerability assessments, as well as climate adaptation strategies and frameworks that draw upon existing science and knowledge. These reports and publications, many of which are available through Web-based compilations such as the Climate Adaptation Knowledge Exchange (CAKE), are a good place to review existing approaches, studies, strategies, and available data resources. Many of the dedicated adaptation strategies developed for specific states or regions also deal with multiple targets or environmental endpoints such as water, the built environment, human health, ecosystems, species, habitats, agriculture, and ocean and marine environments.

Facilitation of science–management interactions has been a consistent message coming out of climate assessments and adaptation strategies (Scheraga and Furlow 2001, Griffith et al. 2009, West et al. 2009, Peterson et al. 2011). Numerous science–stakeholder-based programs seek to address this need and offer significant potential for finding existing studies and data to address specific questions related to climate change. Some of these science providers have a long track record of engaging a range of users, such as the Regional Integrated Science and Assessment Centers supported by NOAA and typically housed in academic institutions, and several regional- and basin-scale centers or program offices. Others are newer to the scene, including the Department of Interior LCCs and CSCs referenced in Box 13.1. A key activity of both LCCs and the regional CSCs is to develop Web sites and portals that provide a wide range of climate science and ecological information relevant to conservation and climate adaptation needs. Similarly, science–management partnerships are being employed by the U.S. Forest Service to help ensure that data and research are tailored to meet adaptation planning needs (Millar et al. 2007, Littell et al. 2012).

There is an ever-expanding universe of databases, Web sites, and portals providing data relevant to climate adaptation activities. This includes data on air, biota, climate and weather, ecosystems and landscapes, and multiple environmental stresses such as pollutants, air toxics, land use, and population growth. Some Web sites, like the National Atlas,[32] provide data on multiple environmental variables. Many provide visualization and online query applications to help users explore and download specific databases. Several national-scale monitoring programs provide data portals that permit download of environmental data that are consistent across geographic areas. Data archives such as BISON, VertNet, and NatureServe maintain increasing amounts of locational data on species occurrences. When combined with biophysical data, this type of locational data can be used for species and habitat distributional models (see Section 13.3). Observational systems, such as the Breeding Bird Survey, provide opportunities to address questions at multiple scales across diverse landscapes, and are the basis for development of statistical models (Sagarin and Pauchard 2010). Well-documented methods and data that use consistent protocols and sampling and classification designs and schemes permit analyses at multiple spatial scales and have led to nationally consistent environmental assessments of aquatic (Carlisle et al. 2010) and riparian ecosystems (Jones et al. 2010), U.S. drinking water supplies (Wickham et al. 2011), forests (Wickham et al. 2008), U.S. green infrastructure (Wickham et al. 2010), and rangelands (Herrick et al. 2010).

Some Web sites provide historical data related to biota (e.g., the Breeding Bird Survey) and climate change (e.g., University of Arizona Laboratory of Tree Ring Research) whereas others provide modeled scenarios of potential future change (e.g., climate change and impervious surface scenarios [Bierwagen et al. 2010]). Modeled future scenarios are one way to evaluate how environmental resources and the processes that sustain them might be affected in the future (Wiens et al. 2011, Snover et al. 2013). They also are a good way to test habitat, species, and ecosystem model sensitivities to specific types of environmental change (e.g., climate, land use, pollution). Many of these data sets come in spatial data formats that can be used in a geographic information system (GIS). Finally, some Web sites provide information on "best management practices" to improve environmental quality at local to watershed scales (e.g., U.S. EPA's Web site on storm-water management best practices).

Data on the responses of environmental targets and endpoints to different management interventions and approaches are not as readily available (Bernhardt et al. 2005, West et al. 2009, Fleishman et al. 2011). These data are fundamentally important to managers who want to reduce uncertainty and adjust their management strategies to reduce the vulnerability of key environmental targets to changes in climate and other stressors. There are a few publications highlighting case studies and the values of adaptive management (Trulio and Clark 2005, Butterfield and Malmstrom 2006, Nichols et al. 2007, Nassauer and Opdam 2008, Vernier et al. 2009, Williams and Brown 2012), but most address management actions related to issues other than climate change. However, these examples provide good background on how to implement the adaptive management framework.

[32] http://www.nationalatlas.gov.

13.3. Availability of Models and Tools

A wide array of models are available that can be used to project future climatic conditions, as well as the effect of these changes on ecological resources. Similarly, many tools have been developed to assist in the application of these models, and in the analysis and interpretation of their outputs. Table 13.1 describes a number of analytical tools and models of relevance for use in climate-smart conservation planning.

The development of analytical tools is often seen as a critical step in enabling scientists and managers alike to integrate and use the diverse sets of data and models needed to address climate change issues (NRC 2009, Fleishman et al. 2011). As important and useful as these tools and models are, it is important to understand the underlying design criteria, limitations, and data requirements to ensure that the selected model is robust for the intended use, as well as to properly interpret results. In the best case, models and tools can provide valuable insights into current and future conditions, can help guide the

Table 13.1. Analytical tools relevant for adaptation planning. The following are examples of analytical tools that may be useful in the development of climate-smart conservation plans. A few additional analytical tools are included in Table 5.1 (adaptation planning approaches) and Tables 6.4 and 6.5 (vulnerability assessment approaches).

Type	Name	Description	Web Address
Conservation planning	Marxan	Software supporting reserve system design, evaluation of existing reserve networks, and multiple-use zoning plans for natural resource management	http://www.uq.edu.au/marxan/
Conservation planning	NatureServe Vista	A GIS-based decision-support system designed to help integrate conservation with land use and resource planning	http://www.natureserve.org/conservation-tools/data-maps-tools/natureserve-vista
Ecosystem management	Ecosystem-Based Management Tools Network	A Web portal cataloging and linking to a wide array of analytical and modeling tools for ecosystem analysis and management	http://ebmtoolsdatabase.org/tools/
Ecosystem services	ARIES	A Web-based tool designed to assist in rapid ecosystem service assessment and valuation	http://www.ariesonline.org/
Ecosystem services	InVEST	Software containing a suite of models designed to map and value ecosystem services and goods	http://naturalcapitalproject.org/InVEST.html
Distribution modeling	GAP Analysis Program Species Viewer	An online tool offering vertebrate species ranges and distribution models based on habitat associations	http://gapanalysis.usgs.gov/species/viewer/

(continued on p. 194)

Table 13.1. Continued.

Distribution modeling	Maxent	Software employing a "maximum entropy" approach to species distribution modeling based on environmental variables and georeferenced occurrence locations	http://www.cs.princeton.edu/~schapire/maxent/
Distribution modeling	Random Forests	An algorithm for modeling species distributions making use of an ensemble learning method for classification and regression trees	http://www.stat.berkeley.edu/~breiman/RandomForests/
Effects analysis	Climate Change Atlas	An online atlas providing U.S. Forest Service (USFS) model-based projections of tree (134 species) and bird (150 species) distributions based on future climate scenarios	http://www.nrs.fs.fed.us/atlas/
Effects analysis	Climate Change Sensitivity Database	A tool for assessing the climate sensitivity of species based on life-history attributes and other ecological factors	http://climatechangesensitivity.org
Effects analysis	Climate Change Vulnerability Index	A tool for applying the NatureServe CCVI, designed to identify the relative climate change vulnerabilities of a wide range of plant and animal species	https://connect.natureserve.org/science/climate-change/ccvi
Effects analysis	ClimateWizard	A Web-based tool to provide technical and nontechnical audiences with access to historical and modeled climate information and visualizations	http://www.climatewizard.org/
Effects analysis	Sea Level Rise and Coastal Flooding Impacts Viewer	An online tool to visualize the impacts of sea-level rise scenarios on coastal zones	http://www.csc.noaa.gov/digitalcoast/tools/slrviewer/
Effects analysis	SimCLIM	Software to facilitate climate risk and adaptation assessments across various sectors	http://www.climsystems.com/simclim/
Effects analysis	SLAMM—View	A tool designed to visualize and analyze the impacts of sea-level rise on coastal areas based on the Sea Level Affecting Marshes Model (SLAMM)	http://www.slammview.org/
Effects analysis	System for Assessing the Vulnerability of Species	A tool to apply the USFS SAVS approach to assess climate change vulnerability of vertebrate species	http://www.fs.fed.us/ccrc/tools/savs.shtml

Table 13.1. Continued.

Effects analysis	USFS Climate Change Resource Center	A Web portal featuring several tools to help incorporate climate change and carbon stewardship into management decisions	http://www.fs.fed.us/ccrc/
Landscape analysis	ATtILA	A GIS-based tool to calculate and map many landscape composition and pattern metrics	http://www.epa.gov/esd/land-sci/attila/intro.htm
Landscape analysis	FRAGSTATS	Software designed to compute a wide variety of landscape metrics for categorical map patterns and landscape pattern assessments	http://www.umass.edu/landeco/research/fragstats/fragstats.html
Landscape modeling	Circuitscape	A tool borrowing from electronic circuit theory to predict patterns of movement, gene flow, and genetic differentiation in heterogeneous landscapes	http://www.circuitscape.org/Circuitscape/
Landscape modeling	Conefor	Software that quantifies the importance of habitat areas and links for improvement of landscape connectivity	http://www.conefor.org/
Landscape modeling	Connect	A GIS-based tool that packages three connectivity modeling and conservation planning tools (Circuitscape, NetworkX, and Zonation)	http://www.unc.edu/depts/geog/lbe/Connect/index.html
Landscape modeling	Corridor Designer	A GIS-based tool for designing and evaluating corridors in a heterogeneous landscape at regional scales	http://corridordesign.org/downloads
Landscape modeling	FunConn	A GIS-based connectivity modeling toolbox that includes habitat models and landscape networks	http://www.nrel.colostate.edu/projects/starmap/funconn_index.htm
Landscape modeling	LANDIS	Software designed to model forest succession, disturbance, and seed dispersal across large landscapes	http://www.nrs.fs.fed.us/tools/landis/
Landscape modeling	Linkage Mapper	A GIS tool designed to support regional wildlife habitat connectivity analyses based on core habitat areas and resistances among them	http://code.google.com/p/linkage-mapper/

development of suitable adaptation actions, and can help track the effectiveness of those actions over time. Conversely, improper application of models, or inappropriate interpretation (e.g., according a false level of accuracy or precision to results), can seriously compromise the resulting conservation and adaptation decisions, and actually be counterproductive. Accordingly, it is essential to have a sound understanding of the suitability of any particular models or tools for the use at hand, and to seek expert assistance in application and interpretation where necessary.

Wilsey et al. (2013) provides a useful summary of the types of analytical models most relevant for application for climate-smart conservation. These include climate models, along with four classes of models important for projecting climate change effects on ecological resources: hydrology, fire, vegetation, and individual species responses. Chapter 6 provides a brief introduction to some of these model types (e.g., climate models and species distributional models), but it is beyond the scope of this guidance to discuss the details of and strengths and weaknesses for particular modeling approaches (i.e., use of process-based vs. empirical species distribution models). For additional detail on selection of suitable models and scenarios, we would refer interested readers to recent reviews on the topic such as by Wilsey et al. (2013) and Snover et al. (2013).

The tools listed in Table 13.1 range in complexity from those that are fairly simple to use (e.g., Web-based visualization tools) to highly technical software (e.g., several landscape-connectivity models) that require fairly extensive training. Some tools (e.g., NatureServe Vista) are GIS based, while others operate directly over the Web (e.g., ClimateWizard). A number of relatively new landscape analysis and modeling tools are now available (e.g., Circuitscape, Corridor Designer) that permit analyses useful in identifying landscape connectivity and critical nodes for the movement of species and habitats (Rayfield et al. 2011). Finally, a few Web sites provide linkages to multiple models and tools. The Ecosystem-based Management Tools Network, for instance, catalogs and links to a very wide array of tools related to ecosystem and natural resource management, many of which are relevant to climate adaptation.

In many cases it is preferable to use more than one model or tool. For example, the use of an ensemble of models is often recommended for development of species and habitat models (Stohlgren et al. 2010), including those related to climate change (Iverson et al. 2011). Doing so helps users understand variability and uncertainty associated with different models and tools, and the different assumptions associated with each. It also can facilitate a “convergence” or “weight of evidence” analysis from which decisions can be made. Another important consideration is whether or not the model or tool will be used for coarse-level geographic targeting (for more detailed studies and analyses), sensitivity analysis, or prioritization, or whether it will be used for prediction. Many Web-based tools permit coarse-level analyses and assessments but are not well suited for delivering predictive results.

Meta-analysis is another analytical approach that can be useful for comparing results from multiple related studies and filtering through large amounts of Web-based studies and data. Such an analysis can also lead to discoveries not revealed in individual studies or databases. Meta-analysis of specific issues related to environmental targets has been facilitated by enhanced Web search engines and digital publication of reports and data (Egger and Smith 1997), including issues related to climate change and ecosystem services (Egoh et al. 2007, Rosenzweig et al. 2008, Benayas et al. 2009, Cooper et al. 2009, Allen et al. 2010). For example, Mantyka-pringle (2012) conducted a meta-analysis of more than 1,300 published papers to determine potential synergistic effects of climate change and habitat loss on biodiversity. The key to successful meta-analyses are well-defined search criteria

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(Egger and Smith 1997, Cooper et al. 2009), and code for statistical software has been developed to facilitate such analyses (Kuss and Koch 1996).

Most conservation practitioners do not need to know about all available tools, only that many tools now exist and where and how to find them. In many cases, it will be helpful to seek assistance from modeling and tool experts before searching for and selecting from among the wide range of tools available (acknowledging that various tools developers have institutional or personal preferences, often based on their involvement with particular applications or approaches). Objective expertise can, however, help determine which tools are right for specific applications and problems, along with estimates of the level of data, time, expertise, and costs associated with applying any particular tools. Explicitly considering these factors up front can save considerable time, money, and frustration, and help ensure that tools are used as effectively and appropriately as possible.

13.4. Identifying High-Quality and Relevant Information

The next step involves evaluating existing studies, assessments, data, models, and tools to determine how well they meet the planning team's defined information needs and standards for quality, tolerance of uncertainty, and relevance. Agencies, climate centers, and organizations focused on specific landscape settings (e.g., Box

13.1), as well as local- and regional-scale experts from state and county agencies, universities, and institutes, can be particularly helpful at this juncture. These organizations should be aware of broader-scale studies and monitoring that relate to a specific region.

Many data services offered by agencies and organizations provide metadata on how the data were measured (e.g., sampling design and indicators) and collected (sampling method), as well as information on the spatial and temporal scale of the data. For example, federal agencies follow the Federal Geographic Data Committee metadata standards for spatial data (Office of Management and Budget Circular A-16),[33] and these metadata can be used to assess the relevance of a particular data for specific geographies and applications. Some agencies have model and tool certification processes and maintain Web sites with details on specific models and tools. For example, U.S. EPA maintains a model validation Web site.[34] Certain National Aeronautics and Space Administration (NASA) research grants programs (e.g., NASA ROSES) require that these decision support systems be used in its funded projects as these systems increase the probability of NASA data and tools being used to make environmental decisions.

It is important to evaluate how well the existing information applies to your specific biophysical setting. Some models and Web-based tools were developed for particular biophysical settings (e.g., humid, warm-temperate areas) and when applied to other biophysical settings (e.g., arid ecosystems) may provide spurious results. Sometimes, it may be possible to get the tool creator to reengineer the model or tool to fit your needs.

[33] www.whitehouse.gov/omb/circulars_a016_rev/.
[34] http://cfpub.epa.gov/crem/crem_report.cfm?deid=75821.

Although existing studies on responses of species and ecosystems to climate-related management interventions are limited, there may be a set of existing studies on the effectiveness of certain types of management actions on species and ecosystems that apply to your situation. Williams and Brown (2012) provide a good review of these types of studies. Moreover, these types of studies may be a useful source of monitoring protocols to use as part of an adaptive management plan coming out of the adaptation planning process. Finally, several training courses have been implemented for resource managers and decision-makers that cover data sources, assessment methodologies, and environmental decision-making using the best available data and tools, and adaptive management principles (e.g., see the course curriculum of the National Conservation Training Center).[35]

13.5. Informing Climate-Smart Conservation

Finding, acquiring, and using the best available and most relevant science are important but difficult tasks given the number of information sources that currently exist. In some cases, the challenge is sorting through huge amounts of data to find information that is best suited for the question at hand. In other instances, the challenge is dealing with a lack of directly relevant data. Carefully and clearly defining the conservation goals and objectives, as well as developing conceptual models of how the system functions, will make it easier to identify data needs for specific climate-smart activities. Moreover, development of a full-cycle chart and list of activities consistent with the climate-smart conservation cycle can help identify data requirements from the outset.

A wide array of tools and resources are increasingly available to help managers take better advantage of climate-related data. Science–management organizations, government agencies, universities, and nongovernmental organizations have expertise and resources that can assist managers in finding and using the best available science for their specific geographic areas. Finally, we are seeing an increasing number of tools that can be operated through a Web browser where the user can independently conduct climate-related analyses. Many of these tools take advantage of the increasing number of Web serviceable data, and programs that enhance data and model interoperability. These Web-based tools have the potential to be game changers with regard to climate change assessments and providing the science to underpin climate-smart plans.

With enhanced data accessibility and growing computational power, however, it is crucial that users exercise caution and be informed about their choices. Such a caveat emptor attitude is essential to ensure that the application of any particular data set, model, or tool is appropriate and scientifically well supported. That said, we now live in an age in which abundant and available information and knowledge resources can dramatically enhance the quality of conservation decision-making and serve to inform the effective deployment of climate-smart conservation approaches.

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[35] http://nctc.fws.gov.

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Chapter 14. Using Policy to Enable Adaptation Action[36]

This guidance document largely focuses on how conservation practitioners and natural resource managers can better incorporate climate considerations into on-the-ground conservation efforts. Such efforts, however, are strongly influenced by the policy environment in which they are carried out, and laws, regulations, and policies can either help enable climate-smart conservation, or hinder adaptation efforts. Accordingly, this chapter looks at some of the ways that existing legal and policy frameworks can be used by practitioners to advance adaptation objectives, as well as highlight where changes may be needed. It is not our intent to provide a comprehensive review of policy and climate adaptation, an important topic that is beginning to receive increased attention, and is the subject of several recent reviews (e.g., Craig 2010, Ruhl 2010, Kostyack et al. 2011, Gerard and Kuh 2012).

As with conservation more generally, the reigning paradigm for conservation and environmental law and policy assumes ecological stationarity, often focusing on the goals of preservation of status quo conditions or restoration to some previous unperturbed or pristine state (Craig 2010, Ruhl 2010). Modifying existing laws and policies, or creating new ones better capable of addressing changing climatic and ecological conditions, will be important to advancing the practice of climate adaptation. In particular, climate change will require that laws and policies increasingly accommodate shifting ecological baselines, provide mechanisms that truly support adaptive approaches to management, facilitate broader jurisdictional coordination, and provide increased flexibility to respond to unanticipated situations.

A wide range of laws, policies, and regulations may need to be revisited, either in the way they are interpreted and implemented, or in the actual language of the statutes. At the federal level, examples include the Endangered Species Act (ESA), Clean Water Act, North American Wetland Conservation Act, the Migratory Bird Treaty Act, and conservation provisions of the Farm Bill; similar lists could be generated for state and local laws and policies (e.g., see Table 14.1). In some instances, the current legal and policy framework is flexible enough to accommodate the new challenges posed by climate change, while in other cases adjustments will be needed to remove hurdles or create new mechanisms altogether. Modifying existing laws and policies can be quite difficult. And even among those supportive of advancing climate adaptation, many people have concerns about unintended consequences of modifying environmental legislation or regulations, due to the possibility of weakening hard-won protections, or introducing ambiguity that open them to legal challenges.


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Recognizing the importance of tackling this issue, the recent presidential executive order on climate adaptation (EO 13653) calls on the federal government to "reform policies and Federal funding programs that may, perhaps unintentionally, increase the vulnerability of natural or built systems, economic sectors, natural resources, or communities to climate change related risks" (EOP 2013). As part of the order's direction on managing

[36] Lead authors: Amanda Staudt, Naomi Edelson, and Ryan Kingston.

lands and waters, agencies are specifically required to: "complete an inventory and assessment of proposed and completed changes to their land- and water-related policies, programs, and regulations necessary to make the Nation's watersheds, natural resources, and ecosystems, and the communities and economies that depend on them, more resilient in the face of a changing climate."

In this chapter we consider the implications of climate adaptation on laws, policies, and regulations at the local, state, and federal levels. We largely focus on those things that managers have the ability to influence, from changes in the way existing laws are implemented to development of new policies that can be promulgated at the agency level. We start from the assumption that significant progress in climate adaptation can be accomplished by incorporating adaptation into work already being carried out. Climate-informed analysis of laws and policies will be necessary at all levels of government (local, state, and federal), and will involve consideration of the interplay among these different levels of government. Although the specific policies may differ, the basic considerations are similar across these multiple scales of government.

14.1. Incorporating Climate into Existing Policy

The current legal and policy framework provides numerous opportunities to take climate change into consideration, particularly in the way lands, waters, fish, and wildlife are managed. Indeed,

Table 14.1. Examples of existing state policies and plans relevant for adaptation.

Subject	Policy or plan
Zoning/ Environmental review	• State Comprehensive Plan (FL) • Growth Management Act (WA) • Environmental Quality Acts (CA) • Conservation and Development Policies Plan (CT)
Wildlife and habitat	• State Wildlife Action Plans (many states) • Natural Community Conservation Program (CA) • Ecological Reserve Monitoring Programs (ME) • Fisheries Management Plans (MD) • Forest Reserve Management Guidelines (MA)
Coastal	• Coastal and Estuarine Land Conservation Plan (MD) • Strategic Beach Management Plan (FL) • Wetland Delineation Handbooks (MA) • Shoreline Management Act (WA)
Water	• Watershed Management Act (WA) • 401 Water Quality Certification Regulations (MA) • Water Allocation Policy Planning: Critical Path (CT) • Clean Water Revolving Fund (MD)
Restoration/Hazard mitigation	• Mitigation Banking (CA) • Waterfront Revitalization Programs (New York) • Natural Hazards Mitigation Plan (CT)
Private landowner	• Landowner Incentive Program (MD) • Conservation Reserve Enhancement Program (MD) • Woodlands Incentives Fund (MD)
Recreation	• Comprehensive Outdoor Recreation Plan (CT) • State Recreational Trails Program (CT)

Based on state climate adaptation plans, from Chmura et al. (2014).

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this is central to the concept of *mainstreaming* climate adaptation into existing natural resource management. Various state climate adaptation plans have identified specific opportunities for incorporating climate change considerations into existing policies, a number of which are detailed in Table 14.1. Incorporating climate change adaptation into other state and community planning processes—such as those that address drought, erosion control, transportation, or storm-water management—can also provide important benefits for wildlife and ecosystem conservation (Arroyo and Cruce 2012). Here we discuss four general categories that are promising for integrating climate adaptation into policies and their implementation: (1) modifying analysis requirements; (2) adjusting standards, zoning, and other regulatory requirements; (3) adding climate adaptation as an objective of existing programs; and (4) increasing coordination across jurisdictions and sectors.

14.1.1. Modify Analysis Requirements

The implementation of many conservation and environmental laws includes various analysis requirements intended to evaluate potential environmental impacts of relevant activities (e.g., development, water discharge, or recreational usage), and possible alternatives or response options. Environmental impact statements are required under the National Environmental Policy Act (NEPA) for many development projects and other federal actions, and many states have similar statutes. Similarly, scientific assessments are required under the ESA to justify federal listing of threatened and endangered species, and in the designation of critical habitats for listed species. Many of the nation's landmark environmental laws were passed, and procedures for their implementation instituted, before the threat of climate change became apparent. And although a

Box 14.1 Integrating climate considerations into Clean Water Act permitting.

Climate change can influence water quality in multiple ways. Increasingly heavy precipitation events can wash more pollutants and nutrients into waterways, while increasing air temperatures can result in warmer runoff and higher water temperatures, both of which have potentially serious implications for aquatic organisms.

The permitting processes designated under the federal Clean Water Act (CWA) can be applied in ways that account for the increasing risks from climate change, and the National Water Program 2012 Strategy: Response to Climate Change (U.S. EPA 2012c) identified a number of ways in which climate considerations should be incorporated into regulatory programs. These include the following strategic actions related to wetlands and pollution discharge permitting, respectively:

- Consider the effects of climate change, as appropriate, when making significant degradation determinations in the CWA Section 404 wetlands permitting and enforcement program.
- Promote consideration of climate change impacts by National Pollutant Discharge Elimination System (NPDES) permitting authorities" and "encourage water quality authorities to consider climate change impacts when developing wasteload and load allocations in Total Maximum Daily Loads where appropriate.

One way that these strategic actions can be met is by requiring that the best available science, which includes consideration of the impacts of climate change, must be used to model water flows, flood risks, water temperatures, and water pollution. Integrating climate science into water quality and water resource management decisions, instead of relying only on historical data, can help reduce water pollution, protect drinking water supplies, safeguard fish and wildlife, and better prepare communities for flooding now and into the future.

strong case has been made that climate change should be included in these analyses (Kostyack and Rolf 2008), it usually is not explicitly identified as one of the environmental stressors to be considered. Introducing climate considerations into such analyses can be an important step toward mainstreaming climate adaptation, and is an administrative action that can result in significant improvements to project performance, public safety, environmental protection, and fiscal responsibility.

Incorporation of climate considerations into some analysis requirements already are being developed and implemented at the federal level. Under NEPA, environmental reviews are required for all "major federal actions," including federally funded projects and federally issued permits. Guidance for incorporating climate adaptation into NEPA analyses is being drafted by the Council on Environmental Quality (the federal entity with oversight for NEPA) and should result in more NEPA documents including adaptation considerations, as many already do for climate mitigation (i.e., greenhouse gas emissions) concerns. Agencies will then need to focus on how to address these requirements via associated formal and informal guidance mechanisms. Climate is also now routinely considered in species listing and other decisions conducted under ESA, although not yet in the revision of existing species recovery plans.

In another example, the Federal Emergency Management Agency has begun taking climate into account in its flood mapping efforts, and recently released an analysis indicating that climate change could increase the size of Special Flood Hazard Areas by 40 to 45% in the United States by 2100 (FEMA 2013). Indeed, the Biggert-Waters Flood Insurance Reform Act of 2012 created a Technical Mapping Advisory Council, tasked to, among other things, take sea-level rise, increased storm frequency and intensity, and increased storm surge into account when mapping flood zones and establishing flood insurance rates. And the U.S. EPA has identified ways that climate change should be considered under the Clean Water Act (see Box 14.1).

14.1.2. Adjust Standards, Zoning, and Other Regulatory Requirements

As climate change presents new environmental conditions, it will also be necessary to revisit regulatory requirements, ranging from pollution standards set by federal and state agencies to zoning ordinances established by local jurisdictions. In some cases, more stringent standards will be necessary to promote the resiliency of natural systems by reducing the impacts from other environmental stressors. For example, more stringent regulatory limits on phosphorus (i.e., total maximum daily load [TMDL]) are being considered for Lake Champlain because heavier rainfall events are washing more nutrients into the lake (Zamudio 2011). Similarly, TMDL limits on thermal pollution recently were updated for the Klamath River in California, and include adoption of a Thermal Refugia Protection Policy that limit discharges near plumes and pools of cold water important for the survival of salmon (California Water Resources Control Board 2010).

In other cases, requirements will need to address a directional trend in climate conditions. For example, many coastal areas are facing the need to modify coastal setbacks in anticipation of accelerating sea-level rise. Located on the coast of San Diego Bay, Chula Vista has recognized its vulnerability to sea-level rise and higher storm surges. In its 2011 Climate Adaptation Plan, the city committed to revise its grading ordinance to consider a project's vulnerability to sea-level rise to ensure that future projects are not at risk of flooding (City of Chula Vista 2011). Other localities are considering requiring larger culverts to handle more extreme rainfall events. Hurricane Irene, for instance, ravaged the Northeast in 2011, blowing out culverts and bridges in many places, and endangering lives and property. A comprehensive study by the University of Massachusetts Amherst in partnership with The Nature Conservancy found that thousands of culverts in Massachusetts not only pose a risk to humans where heavy rainfall increases the possibility of flooding, but severely limit aquatic connectivity and migratory pathways for fish (Jackson et al. 2012).

In other cases, it may be necessary to adjust jurisdictional boundaries of regulatory programs. For example, in 2008, Maryland passed changes to its Chesapeake and Atlantic Coastal Bays Critical Area Act to update the jurisdictional boundaries of the program, which originally were based on 1972 aerial photography. These changes are intended to better reflect current conditions, and establish a process and continuing standard for decadal updates to accommodate future changes in shoreline conditions and sea-level rise. Under the new statute, the jurisdictional boundaries of the critical area are based on the location of state and private wetlands, extending 1,000 feet beyond the landward boundaries of designated wetlands (Wetlands and Riparian Rights Act).

Finally, some natural resource agencies already are adjusting harvest limits or fishing and hunting seasons in response to climate impacts, for example, from warming streams or changes in migration patterns. One notable example is the effort to protect the pollock (*Pollachius* spp.) fishery in the Bering Sea. In the mid-2000s, several environmental indicators, such as warm years with

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low sea ice, a decline in prey, and an increase in predation, suggested that the fishery was headed for a steep decline. In response, the NOAA Fisheries Service lowered the Bering Sea pollock quota from about 1.5 million tons to 0.8 million tons for 2006 through 2010 (NOAA 2012). Subsequent years brought colder weather and more sea ice, allowing the population to grow, resulting in an increase in the quota to 1.27 million tons (NOAA 2012). The 2012 Fishery Management Plan developed by the North Pacific Fishery Management Council explicitly recognizes climate change as an important factor to be considered in setting future fishing quotas (NPFMC 2012).

14.1.3. Add Adaptation as an Objective of Existing Programs

While in some cases it will be sufficient to modify scientific assessment requirements or adjust regulatory levels, in others it will be necessary to explicitly add climate adaptation as an objective of these existing programs. This is particularly true when trying to use existing policy tools to meet new challenges posed by climate change, such as rapid sea-level rise or shifts in the ranges of species. In these cases, it will be important to explicitly state that addressing climate change is a priority, along with the other stressors that programs originally were intended to address.

Some states already are looking to use existing programs geared at land acquisition and protection to help improve habitat connectivity as a means of facilitating climate-related species range shifts. Massachusetts specifically conducted a habitat vulnerability assessment to ensure the latest climate science was taken into account as the state plans acquisitions now and in the future. Maryland has developed new conservation targeting and scoring criteria, and developed "climate resilience" easement provisions aimed at protecting and managing wetland adaptation corridors. Land acquisition strategies have also been modified to focus on parcels that would allow for the landward migration of wetlands, and away from areas likely be submerged within the next 50 years.

In some cases it will be sufficient to modify requirements or adjust regulatory levels, while in others it will be necessary to explicitly add adaptation as an objective of existing programs.

In addition, all states and territories currently are working to include climate change in updates to their State Wildlife Action Plans, which are required by 2015. These plans are used to guide their agency's conservation efforts as well as those of many partners in the state. The Association of Fish and Wildlife Agencies prepared voluntary guidance on how states can incorporate climate change into these plans (AFWA 2009). By explicitly considering climate impacts, states will likely adjust lists of priority species, habitats, and threats, resulting in modified priorities for action and monitoring, and in some cases, needed modifications in policies.

14.1.4. Increase Coordination across Jurisdictions and Sectors

As noted in Chapter 3, climate adaptation should take the broader landscape context into consideration, which will necessitate working across political jurisdictions and multiple levels of governance, as well as engaging more with private sector partners. Several efforts already have been initiated with the intent of improving coordination, such as the Department of Interior (DOI) Landscape Conservation Cooperatives and DOI Climate Science Centers. Even so, various agencies and levels of government still usually work independently, and oftentimes have an incentive to act without collaborating because they are under pressure to make decisions on permit applications and other time-sensitive questions. Much greater collaboration will be essential to ensure interested parties are identifying, agreeing upon, and tackling the most important conservation needs with already limited conservation funding, staff, and other resources. Incentives to collaborate, especially through regional funding opportunities and information sharing initiatives, can help improve such cross-state collaborations.

Taking a more comprehensive approach to managing natural resources often runs counter to existing approaches to conservation and environmental regulation. American laws are very compartmentalized, generally targeting water, air, land, and wildlife separately. This separation of environmental domains can make it difficult to resolve situations where actions relevant to one domain have impacts on another (Craig 2010). Federal and state agencies are increasingly recognizing the importance of collaboration in achieving mutual goals. The National Fish, Wildlife and Plants Climate Adaptation Strategy (NFWPCAP 2012) brought together experts from diverse organizations, including U.S. FWS, NOAA, U.S. EPA, NPS, Farm Service Agency, tribal governments, and state fish and wildlife agencies to outline a strategy for natural resource adaptation to climate change. "Enhancing capacity for effective management in a changing climate" is one of seven broad goals of the plan, and specifically acknowledges that increased collaboration across jurisdictions is necessary for effective implementation of the strategy.

Recent extreme events have also been instrumental in advancing coordination among diverse entities. The devastation wrought by Hurricane Sandy heightened awareness of the need to make smarter development and infrastructure investments that reduce risks from future extreme weather impacts in part by increasing the natural defenses provided by healthy ecosystems. At times, however, agencies charged with building and maintaining coastal infrastructure and those charged with maintaining and restoring coastal habitats have worked at cross purposes. The U.S. Army Corps of Engineers' Institute for Water Resources is leading an effort to identify the appropriate mix of green and gray infrastructure to build coastal resilience in the region battered by Hurricane Sandy. By bringing together agencies and organizations with diverse interests, this approach is intended to reduce conflicts and advance the dual goals of reducing the risk of vulnerable human populations and of promoting resilient coastal communities. Similarly, the State of Maryland has issued new siting and design guidelines for state construction in response to a 2012 Climate Change and "Coast Smart" Construction Executive Order issued by the governor. Coast Smart practices include the identification, protection, and maintenance of ecological features that may serve to buffer a project from the impacts of future sea-level rise, coastal flooding, or storm surge, or that support general climate adaptation practices.

14.2. New Policies to Enable Adaptation

Adaptation planning efforts at the federal and state levels have led to several new policy mechanisms and recommendations intended to advance adaptation practice. A strong signal from government leadership is often an important first step for initiating these efforts. For example, shortly after being elected, President Obama established the Interagency Climate Change Adaptation Task Force. In Presidential Executive Order 13514, President Obama directed the task force to develop recommendations for strengthening government policies and programs to be better prepared for adapting to climate change (CEQ 2010, 2011a). More than 20 federal agencies participate in this task force, which presented initial recommendations to the president in March 2010 and a progress report in October 2011. The executive order also directed federal agencies to evaluate their operations and services, with an eye to reducing their climate footprint and to preparing for climate adaptation. As a result, federal departments were required to adopt formal climate change adaptation policies by 2011 and then to develop and publish adaptation plans by 2012 (CEQ 2011b). In June 2013, the president issued his Climate Action Plan which lays out a climate agenda for federal agencies, and as referenced previously, in November 2013 he issued an executive order (EO 13653) that formalized the adaptation portion of that climate plan.

Numerous planning efforts and changes in government practices have resulted from the original executive order and task force recommendations (Pew 2010, C2ES 2012). In December 2012, Department of Interior finalized its Climate Change Adaptation Policy, which is now officially part of the Departmental Manual (U.S. DOI 2013). The U.S. Forest Service, in the Department of Agriculture, has also been integrating climate change into its planning and operations. For example, the Forest Service has introduced a climate change scorecard for measuring progress by each of its national forests and grasslands. In addition, three cross-cutting interagency national strategies have been developed to address the task force recommendation for increased coordination across agencies: (1) the National Fish, Wildlife and Plants Climate Adaptation Strategy (NFWPCAP 2012); (2) the National Action Plan: Priorities for

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Managing Freshwater Resources in a Changing Climate (CEQ 2011c); and (3) the National Ocean Policy Implementation Plan (CEQ 2011d).

Several states and cities have also developed new policy approaches using a similar mandate from top-level leaders, leading to development and implementation of new policies or programs at the department or agency level. In April 2007, Governor Martin O'Malley of Maryland signed an executive order establishing the Maryland Commission on Climate Change. The principal purpose of this commission was to develop a Climate Action Plan for the state to address the drivers of climate change and develop strategies for adaptation. This plan, released in 2008, emphasized the impacts of sea-level rise on coastal communities and ecosystems, as well as climate impacts on water resources, farms and forests, and human health (Maryland Commission on Climate Change 2008). In 2011, the commission released a second report to specifically address adaptation needs in the state, and offered recommendations focused on human health, agriculture, terrestrial ecosystems, bay and aquatic ecosystems, water resources, and population growth and infrastructure (Maryland Commission on Climate Change 2011).

New York City has been a leader in developing policies designed to address the impacts of climate change, and in 2008 then Mayor Michael Bloomberg convened the New York City Panel on Climate Change (NPCC). The NPCC released several reports, including one in 2010 specifically addressing adaptation in the city and building a risk management response (NPCC 2010). These recommendations informed changes in flood zones and building requirements, and stressed the importance of green spaces and wetlands in flood management. Although these efforts helped mitigate some of the impacts of Hurricane Sandy in 2012, the storm showed that much work is left to be done. In response, the city of New York released *A Stronger, More Resilient New York* (Bloomberg 2012). Of particular interest is an emphasis on incorporating natural and nature-based approaches to protect the city's 520-mile coastline.

14.3. Moving Toward Climate-Aligned Policies

As noted above, significant progress can be made by modifying or augmenting the implementation of existing environmental laws and policies to incorporate climate change adaptation considerations. Nonetheless, many of the assumptions that provide the basis for these laws and regulations may need to be reconsidered. In particular, the emphasis on preservation and restoration that underlies many ecological protections is based on an assumption that human-caused environmental degradation is inherently reversible. However, climate change may well push ecosystems past key thresholds, making it very difficult if not impossible to return to previous conditions.

In some cases, current regulations may complicate efforts to adapt to future climate impacts. One example is the Stafford Act of 1988, which provides the basis for federal natural disaster assistance to state and local governments. The Stafford Act requires that impacted areas being rebuilt with these funds are reconstructed to the standards in place before the disaster (Moss and Shelhamer 2007). As a result, bridges, roads, flood control measures, and other public infrastructure are funded to be rebuilt based on historical climatic conditions, rather than designed to be resilient to future impacts. Modification of this law could allow federal funds to be used for disaster preparedness, mitigation, and recovery based on current and projected, rather than historical climatic conditions.

As human responses to climate change intensify, so too will the risk of maladaptation because interventions that address vulnerability for one sector may exacerbate vulnerabilities to another. Adaptation efforts in other societal sectors will have both direct and indirect environmental effects. People may respond to increasing climate impacts in many ways that will affect wildlife and habitats, from extracting more water from some rivers or aquifers, relocating inland as sea levels rise, abandoning some drought-stricken areas, and changing agricultural, grazing, and forestry practices. Current laws largely address water, land use, air pollution, wildlife, and other natural resources separately. But climate change interacts with—and causes interactions among—all the components of the natural environment (Staudt et al. 2013). Hence the great need for a more coordinated and *climate-aligned* approach to environmental management.

14.4. Funding as Policy

Funding decisions ultimately are policy decisions. Deciding what to fund and how much to provide is perhaps the clearest expression of priorities for a particular administration, legislature, private foundation, business, or nongovernmental organization. As such, influencing funding decisions can be an important mechanism for advancing climate-smart policy and programs. Although Chapter 10 provides some guidance for carrying out adaptation work with limited funds, it is likely that significantly more funding will be needed to address future conservation and natural resource management challenges caused by current and future climate change impacts.

Many opportunities exist for agencies and foundations to use existing grant opportunities to advance climate adaptation. For example, land conservation grant and cost-share programs—such as the North American Wetlands Conservation Act and the Land and Water Conservation Fund—can add climate change adaptation as a decisional factor and draw on the key characteristics outlined in this guide (Chapter 3) to evaluate proposals. The National Fish and Wildlife Foundation, which administers federal grant funding for a number of important conservation programs, could also explicitly incorporate climate considerations into the grant processes they manage. Among the important considerations are whether proposed projects consider the influence of climate change on project success, reflect forward-looking goals, and employ strategies likely to be robust in an uncertain future.

Some grant programs already are applying these sorts of criteria. The NOAA Great Lakes Habitat Restoration Program values (although does not require) proposals that "yield significant ecological benefits that will be robust to potential climate impacts to the region." Foundations have also begun to take climate change into account in targeting their investments. The Doris Duke Charitable Foundation is focusing much of its land protection funding in the eastern United States on landscapes specifically identified for their resilience to climate change (see Section 3.7.1), and is supporting adaptation projects through its support to the Wildlife Conservation Society's Climate Adaptation Fund. That grants program focuses exclusively on applied on-the-ground projects designed to implement priority adaptation activities, and many of the case studies profiled in Part I and II of this document are based on projects supported by that program.

Another policy mechanism involves use of financial incentives to change behaviors that directly affect land and water conservation. This includes voluntarily buy-out programs that allow homeowners to move out of floodplains and other areas increasingly at risk from natural hazards. In addition to reducing risks to people from natural hazards, such programs can restore environmentally sensitive areas and make them available for conservation and recreational use.

Ultimately, larger-scale funding mechanisms will be necessary to address the conservation and adaptation challenges posed by climate change. A handful of bills have been introduced in the U.S. Congress that would have the potential to generate significant new revenue. For example, the American Clean Energy and Security Act (HR 2454), passed by the U.S. House of Representatives in June 2009, included a title specifically directing funds derived from carbon pollution permits to natural resources adaptation. A Senate version of the bill that also included natural resource adaptation provisions was passed out of the Environment and Public Works Committee, but not taken up by the full Senate. As the impacts of climate change become more apparent, and with them the rising need for and cost of adaptation, national legislation will likely reemerge on the political scene. When that happens, it will be important to ensure that the large-scale funding required for adaptation not only addresses the needs of human systems and the built environment, but also the natural systems that benefit both people and wildlife.

Steve Hillebrand/USFWS

USACE

Chapter 15. Communicating About Climate Adaptation[37]

Conservation professionals are increasingly called upon to communicate about climate change, how it is affecting the resources they manage, and efforts underway to address it. Indeed, conservation professionals have an important role and responsibility to convey what they are seeing and doing for wildlife, cultural heritage, and broad landscapes. Adaptation offers a tremendous opportunity to convey the impacts of climate change coupled with hope and the need for actions to address them.

While proactive communication about climate change adaptation is essential for making sure that key decision-makers and constituencies understand the value of climate-smart conservation, several barriers exist for effectively communicating about the topic. The subject matter is complicated and highly interdisciplinary, and thus requires repeated efforts to connect the dots for people in terms of what climate change may mean for their lives and livelihoods and what actions they can take to prepare for or cope with potential changes. The implications of climate change can seem overwhelming, leaving many people unsure how to respond. Furthermore, the issue of climate change is politically charged. Fortunately, climate adaptation can overcome some of these challenges by providing hope for the future and engaging a wide range of audiences in action. In short, climate-smart conservation is about doing something to prepare for and reduce the impacts of climate change on nature and our communities.

This chapter provides guidance about how to navigate these communication challenges, and points to other resources for developing effective strategies to engage people in understanding climate change and identifying and implementing appropriate and effective solutions. This guidance is intended to help with communication needs for the wide range of audiences that conservation professionals encounter, including:

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- Decision-makers and other influential individuals from one's agency and other relevant agencies, as well as elected officials from any level of government

- Others directly involved in conservation, such as natural resource managers, leaders in the restoration community, and private landowners such as ranchers and farmers

- Local and state conservation groups from "friends" groups to land trusts to state-based organizations

- Professionals from other related sectors, such as transportation, water management, or urban development

- Communication professionals, interpreters, and educators

[37] Lead authors: Amanda Staudt, Naomi Edelson, Ellie Cohen, and Helen Chmura.

Box 15.1. Top tips for effective communication about climate adaptation.

- **Balance urgency with hope.** Address head-on the urgency and scientific basis for addressing climate change impacts on wildlife, habitat, and ecosystems, coupled with the hope provided by climate-smart conservation actions for nature and people.

- **Tailor communications to your audience.** Convey the facts while also emphasizing shared cultural values to each unique audience.

- **Emphasize preparedness, risk reduction, and a healthy future.** Emphasize being prepared as a means of reducing future risks and costs and the potential for securing a healthier future based on the climate-smart actions we take today.

- **Build on conservation expertise.** Empower conservation professionals to make a difference by building on their past experience in managing natural resources while trying new climate-smart approaches.

- **Make it personal, local, and timely.** Use local examples and storytelling to help your audience connect the dots between their own experiences, climate change, and response strategies.

- **Junk the jargon.** Translate confusing and technical scientific jargon to easily communicated and remembered words and phrases.

- Members of academia and the research community

- The multifaceted "general public"

Within each of these audiences, there is a range of climate change understanding and concern, making it necessary to tailor communications to address multiple levels of understanding.

Engaging constituents is particularly important when it comes to climate adaptation because some climate-smart strategies will not show immediate results or may incur higher short-term costs for longer-term benefits than other alternative strategies. Furthermore, some climate adaptation efforts will be intended to prevent impacts that have not yet happened, which can make it more difficult to justify investments up front. Thus, it is imperative to develop some shared knowledge about what climate change means for our natural resources, cultural heritage, and communities, as well as the implications for considering climate change in conservation planning. This goes hand-in-hand with the urgent need to raise awareness of the value of nature to humans—both the economic and the ecological benefits.

While this chapter provides some guidance specific to communicating about climate adaptation, many additional resources are available about how to design a communication strategy more generally (e.g., Ward 2007, CRED 2009, Maibach et al. 2011b). An effective communication strategy, ideally developed in close collaboration with communication professionals, will form the blueprint of any activity to raise awareness, gather support, and get others to take action on climate change adaptation. Good strategies set forth clear communication goals, provide a structure for identifying issues and actions that need to be addressed, identify and prioritize potential audiences, develop appropriate messages, and help identify channels to deliver information. Box 15.1 summarizes several tips for effective communication about climate adaptation, which are further elaborated on in the rest of this chapter.

15.1. Balancing Urgency and Hope

Climate change is already affecting species and habitats, and projected future impacts are even more significant (Staudinger et al. 2013). It is important to honestly convey the scientific understanding and the urgency for action while also conveying hope through the promise of implementing climate-smart conservation strategies (Stern 2012).

Projected climate impacts provide the rationale and imperative for taking action, including modifying existing conservation projects; thus, it is critical that conservation stakeholders understand the true extent to which nature is at risk. This knowledge can create a psychological "tension" or dissonance between one's previous worldview and the threats to it. While this tension makes us uncomfortable, psychologists find that it is an important precursor to meaningful action (Pike et al. 2010). Yet the reality and expected consequences of climate change can understandably overwhelm many people. Overstating or overemphasizing possible dire outcomes can backfire, causing your audience to reject the scientific information or conclude that any actions to avert climate change or prepare for impacts are futile (CRED 2009).

Several psychological factors are at play when people are learning about climate change and considering possible actions to address it. For example, studies have examined the idea that people have a *finite pool of worry,* essentially a limited capacity for worrying about issues (Linville and Fischer 1991). Also, immediate threats tend to take precedence over future threats (Weber 2006). So, when the U.S. economy took a downturn in 2008 and 2009, polls showed that environmental (including climate) issues fell in prominence of public concerns. Another factor is the potential for emotional numbing, when overexposure to a threat causes people to resist or neglect taking action (Rolfe-Redding 2012).

To limit the dispiriting impacts of climate change communications, one should balance the specific scientific information on current impacts and future projections with descriptions of actions being taken now and potential efforts that could be taken (CRED 2009). In other words, building a sense of *efficacy*—the belief that individuals and society at large have the know-how and capacity to tackle climate change (Pike et al. 2010)—can go a long way toward moving from inaction to action. Describing climate-smart response strategies that are achievable and matched to the scale of the problem can counteract a tendency to feel helpless in the face of climate change.

Climate communication efforts can be further enhanced by painting a picture of the positive benefits associated with taking proactive measures (Pike et al. 2010). Often our tendency is to describe response options as necessary to reduce some negative impact. However, this approach still leaves the audience with the impression that the future will be dreary, though perhaps less dreary if certain actions are taken. In contrast, we should describe climate change response strategies in ways that highlight how they could provide conservation benefits that we do not enjoy today. For example, protecting and restoring floodplains, a long-time conservation goal, takes on new urgency under climate change because they can make our communities more resilient to extreme rainfall and flooding, while also creating crucial wildlife habitat and great recreational areas, and even sequestering carbon. Indeed, talking about climate adaptation is an excellent opportunity to provide specific examples of how nature can help us prepare for climate impacts, reduce costs to society, and reduce carbon pollution in the atmosphere. An important goal for communication efforts is to make

Box 15.2. Connecting mitigation and adaptation.

Responses to climate change are grouped into two general categories: (1) *climate mitigation* efforts intended to limit the amount of greenhouse gases in the atmosphere; and (2) *climate adaptation* efforts intended to prepare for and respond to the impacts of climate change.

Historically, some have likened adaptation to "giving up" on the possibility of averting significant climate change impacts altogether and have encouraged limited communications on the topic. More recently, however, there has been recognition that adaptation must be undertaken because the climate has already changed. Indeed, additional future warming is already locked in due to past emissions "in the pipeline" and future emissions that will occur before we can put appropriate policies, management, and infrastructure in place. We can no longer avoid this discussion.

Moreover, many people are finding it to be easier to constructively engage audiences around the idea of adaptation because these options provide hope that there are practical ways to respond to climate change. Adaptation actions are common-sense options for dealing with increasing climate extremes and the actions are most often locally implemented, giving people something they can do right in their own community or region. Some studies even suggest that engaging communities around climate adaptation can help build support for climate mitigation efforts (TRIG 2011).

From a climate-smart conservation perspective, the treatment of adaptation and mitigation should be synergistic—they should work together to achieve even more. This is why one of the key climate-smart characteristics is to *minimize the carbon footprint* of practices by minimizing the energy use and emissions of the project. We can also sustain and increase the natural ability of ecosystems to sequester and store carbon with climate-aware management practices. Natural resource managers have an opportunity to communicate about how conservation of natural systems can address multiple climate response objectives, from helping wildlife adapt to changing conditions, to increasing the resilience of human communities, to limiting the magnitude of climate change by storing carbon.

the direct connection that taking adaptation action is safeguarding people *and* nature together (see Box 15.2).

It is worthwhile to consider including a broad range of possible benefits of climate adaptation in communication efforts. In particular, the benefits of climate adaptation also may include the possible economic stimulation associated with new investments. For example, new industries for coastal engineering, salt-marsh and mangrove restoration, or enhanced science education may inject new resources into local communities, business markets, or school systems.

15.2. Tailor Communication for Your Audience

Conservation practitioners engage with many different audiences including: decision-makers and other influential stakeholders; peers including a broad range of natural resource managers, urban planners, and conservation groups (friends groups, Audubon chapters, etc.); and the media and the general public (e.g., refuge and park visitors). There is a range of values, baseline knowledge, expectations, and needs within and among audiences. Thus, it pays to tailor your message in ways that are meaningful to the target audience's experience, values, and sphere of influence. As such, listening to the audience is an essential, though often overlooked, part of effective communication.

The idea of segmenting an audience and framing arguments in a way that resonates with target groups is a strategy frequently recommended by communication guides (e.g., CRED 2009, Pike et al. 2010, Balbus 2012). Several efforts have been made to segment the American public, most notably *Global Warming's Six Americas* (Maibach et al. 2011b) (see Box 15.3) and *The Ecological Roadmap* (Pike et al. 2008). These audience segmentation studies provide insights for a range of climate-communication and behavior change efforts.

Tailoring your message does not mean modifying the facts of climate change in any way. Rather, it means taking into account the kind of knowledge the audience has and the actions they are likely to take. For example:

Box 15.3. *Global Warming's Six Americas:* An example of audience segmentation.

Effective communication starts with knowing one's audience. But how does one do that when communicating to the media or general public? Especially difficult is that Americans have different psychological, cultural, or political perspectives about climate change. In other words, there is no single "general public."

To better understand the motivations of different segments of the American public, researchers at the Yale Project on Climate Change Communication and the George Mason University Center for Climate Change Communication have repeatedly conducted extensive surveys since 2008 (Maibach et al. 2011b, Leiserowitz et al. 2014).[38] They have identified distinct audiences—global warming's six America's—that respond to climate change in different ways. The distribution of the American public across these six audiences is shown in figure below. This sort of segmentation can be used to effectively tailor communication efforts, particularly if an audience is known to fall into particular categories.

Global warming's six America's audience segments. Proportion is represented by area of circles. Source: Yale/George Mason University, from Leiserowitz et al. (2014).

[38] http://environment.yale.edu/climate-communication/article/global-warmings-six-americas-screener-manual.

- Providing more or less background about climate science as appropriate for talking to decision-makers, versus a professional gathering of colleagues, versus a public lecture

- Choosing a messenger who is best able to connect with a specific audience or who provides particular credibility regarding the specific issues

- Taking a step back to listen to what the audience has been experiencing and what they already think about the subject, and then adjusting communications accordingly while still working to achieve your communication goals

Another way to think about tailoring is that it means *framing* the issue in a manner that grabs the audience's attention and makes the scientific and technical information accessible and relevant. Effective frames provide useful shortcuts for people to fit new information into their existing mental models by tapping into their deeply held and widely shared cultural values (Schwartz 1992, Crompton 2010). These values—which span from loyalty to prudence to love of nature—can carry much more weight in an individual's decision-making than new knowledge. Researchers have found that simply telling people more information, the so-called *deficit model* for science communication, is not a reliable way to change people's understanding much less their behavior (Rolfe-Redding 2012). This is particularly important for biologists and natural resource professionals to guard against.

Making the connection between climate change adaptation and cultural values can be straightforward, in large part because many of the key characteristics of climate-smart conservation are based in common-sense management strategies. The characteristics focused on *forward-looking goals* and being *robust in an uncertain future* are grounded in climate-smart values such as prudence, frugality, and a desire for security. With an objective to protect wildlife and nature, climate-smart strategies also are grounded in shared values of altruism, self-transcendence, and preserving a world of beauty.

The following sections offer three suggested ways to frame discussions of climate-smart conservation:

- Emphasize preparedness, risk reduction, and a healthy future, as a way to tap into values related to prudence and security (Section 15.3)

- Build on conservation expertise, as a way to draw upon the desire to protect our conservation legacy and preserve a world of beauty (Section 15.4)

- Make it personal and local, as a way to connect the dots between individual experiences, climate change, and response strategies (Section 15.5)

Certainly other frames can be useful as well. For example, climate communicators have had success focusing on health impacts, national security, urban concerns (Moser 2006, Myers et al. 2012), and the moral and ethical responsibility to future generations. The choice of framing for any specific engagement opportunity will depend on understanding where the audience stands; in some cases, it may make sense to combine more than one frame or be prepared to switch frames based on audience feedback.

The right messenger can be one way to help establish a desired framing, while also lending instant credibility to the discussion, especially for an audience that might be more skeptical. Ideally, the messenger would be someone who the audience might recognize as one of their own (e.g., a hunter to speak to a hunting club, a local church or civic leader) or as having relevant credentials (e.g., a wildlife biologist to talk about big game or migratory birds, a fisheries expert to talk about impacts of climate change on riverine habitats). It can also be quite effective to use more than one messenger, particularly when their backgrounds and expertise may be different (e.g., a climate scientist, a wildlife biologist, and a local hunter) but they are conveying the same message.

15.2.1. Responding to Climate Change Myths

Many myths about climate change science have been widely circulated, despite scientific evidence to the contrary. When communicating about climate change, it is helpful to be aware of some of the most persistent myths and be prepared to respond appropriately. Fortunately, several excellent resources are available that explain the origins of these myths and provide suggestions for responding to them. For example, the Skeptical Science Web page[39] provides responses at a range of technical detail, while the Real Climate Web page,[40] which is authored by climate scientists, delves into more of the active scientific debate.

It is also important to be mindful about how climate change myths are presented because the process of debunking myths can sometimes backfire and reinforce the myth in people's minds (Cook and Lewandowsky 2011). Simply explaining the myth may increase awareness of it and a lengthy, complicated refutation may be harder for people to accept than a straightforward myth. The likelihood of a debunking backfire can be reduced by sandwiching the myth between facts, clearly cautioning the audience before introducing a myth, and keeping explanations simple and succinct.

15.3. Emphasize Preparedness, Risk Reduction, and a Healthy Future

A fundamental premise of climate adaptation is the need to prepare for new climate conditions, especially weather extremes. This idea of managing risk is familiar to almost everyone, from homeowners protecting their own property or finances to city officials planning for the safety and viability of a community to natural resource managers designing strategies that promote the health of ecosystems. Putting the new risks of climate change in the context of the risks with which the audience already grapples can be a useful engagement strategy.

Focusing on what we can do to minimize risks associated with climate change is rooted in values around being prudent and ensuring long-term security. Security—defined as "safety, harmony, and stability of society, of relationships, and of self"—is one of the 10 groups of values that have been found to be held universally (Holmes et al. 2011). Studies have shown that interest in security-oriented values increases in the wake of events that threaten one's safety, such as terrorist attacks (Frink et al. 2004, Verkasalo et al. 2006, Goodwin and Gaines 2009). It is partly for this reason that many climate communicators are focusing on extreme weather events as an important way to connect with people about the local threats of climate change (e.g., Leiserowitz et al. 2012).

15.4. Build on Conservation Heritage and Expertise

The conservation community has a rich history, from the establishment of parks, refuges, and wildlife management areas to major investments in restoring game, endangered species, and important migratory bird and other wildlife habitats. Climate change puts this heritage and these achievements at risk. Furthermore, continuing historical practices without reflecting upon the viability of efforts under future conditions could render current conservation investments futile. Honoring and respecting conservation accomplishments to date and the strong desire to sustain and further improve ecological conditions can be a powerful frame for discussing climate change adaptation

[39] www.skepticalscience.com.
[40] www.realclimate.org.

strategies to these audiences. It is important to also recognize that what conservationists have already done or tried to do has not been without effect. It has led us to where we are; now we must add the climate lens.

For communicating with other natural resource managers, focusing on our conservation legacy also provides an opportunity to recognize and reinforce the experience and expertise that they have to offer in developing and implementing climate responses. Connecting the climate challenge with the sorts of decisions and actions these managers already make can nurture a strong sense of efficacy, that we can tackle these new challenges. In addition, recognizing climate-smart actions that resource managers and others are already taking—in their professional capacities, communities, and households—can encourage more behaviors and actions that address the issue. People have a strong inclination to behave in a way that is self-consistent: the more that we begin defining ourselves and our institutions as climate smart, the more likely we are to make choices that match that designation.

15.5. Make It Personal, Local, and Timely

Climate change is often perceived as a problem affecting faraway places (e.g., polar bear in the Arctic) or future generations. Yet local ecosystems and communities worldwide are already experiencing impacts. Framing climate change as a local problem with immediate impacts can promote the audience's sense of connection to the issue and urgency to take action (e.g., Maibach et al. 2011a). In practice, this means highlighting examples of impacts on natural, cultural, or community resources the audience knows first-hand, and relating these to response strategies that provide more time to adapt and reduce risks.

Climate impact reports, vulnerability assessments, and climate action plans are an excellent source of localized information. Specific examples of climate-smart conservation strategies that could be or already are being implemented in the community can help make the idea of climate adaptation more accessible to people. Another useful strategy is to connect climate change with personal experiences. Sharing these personal experiences leaves little room for argument, makes you more relatable to the audience, and brings out our personal passion. Likewise, it can be quite effective to ask people to reflect about their own experiences with climate change, which can elicit powerful observations about the local natural environment. This strategy allows the audience to define the local frame that they find most apparent and important. Indeed, expert climate communicators recommend building in time for this sort of reflection in public lectures and engagement.

15.6. Junk the Jargon

Some communication hurdles are caused simply by confusing terminology. Scientists and other expert practitioners tend to develop their own lexicon to talk about their discipline, often using acronyms and other shorthand to refer to complicated ideas quickly. While useful for communicating with others working in the same field, this sort of jargon impedes effective dialogue with other expert communities, decision-makers, and key constituencies. An additional challenge for an emerging field, such as climate-smart conservation, is that many terms are still being defined and may not yet have a standard usage.

Sometimes confusion derives from the way that different scientific disciples and communities of practice use the same words to mean different things. The use of the word "adaptation" is a prime example (Glick et al. 2009). In an ecological context, the term refers to changes in an organism's behavior, physiology, or other characteristics that enhance its survival in a new environment. Evolutionary biologists use the term to mean development of novel traits and genetic changes that may result from natural selection. Climate scientists use "adaptation" to mean human interventions in natural or human systems intended to reduce vulnerability to the expected impacts of climate change. This confusion over the word is a large reason why we have adopted the term "climate-smart conservation" for this guidance.

Some use of jargon should be easy to identify, especially very technical terms that could be replaced with common language substitutes. However, in some case, the jargon problem is deceptively hard to address because we are not even aware that the words we are using might be misunderstood (Somerville and Hassol 2011). Table 15.1 gives some examples of scientific terms that are often used in climate and other natural sciences, and that can be easily misinterpreted by nonexpert audiences. Similar confusion about definitions can also occur as we rework conservation efforts to be climate smart. Take, for example the word "restoration," which has traditionally referred to efforts designed to return an ecosystem to some former condition. Climate-smart restoration, however, can mean making the ecosystem more resilient and adaptable to future climate conditions, often with a focus on ecological processes, rather than historical species composition. In this case, a "restored" ecosystem may or may not resemble the conditions that existed in that place in the past.

One strategy for overcoming language barriers among diverse stakeholders is to include an opportunity at the outset to agree upon common terminology. For example, the increasingly popular term "resilience" has multiple meanings, and is interpreted and used in varying ways both within the ecological and scientific communities, and by more general audiences. Investing some time to ensure that all participants in the dialogue have a shared vocabulary and understanding of foundational concepts from their respective fields can help avoid misunderstandings and frustration later in the process. Another option is to make use of social science research or targeted focus groups about words that are effective at conveying information and intended messages. For instance, Water Words that Work LLC has used social science research to develop lists of phrases that are particularly effective in promoting water pollution control campaigns.[41] While such existing lists can help in communicating about climate-smart conservation, depending on one's needs it may be worthwhile to invest in focus group research or targeted polling to pinpoint the expressions that best meet specific adaptation communications needs.

Table 15.1. Terms that have different meanings for scientists and the public.

Scientific term	Public meaning	Better choice
Enhance	Improve	Intensify, increase
Positive feedback	Good response, praise	Vicious cycle, self-reinforcing cycle
Uncertainty	Ignorance	Range
Bias	Distortion, political motive	Offset from an observation

Excerpted from Somerville and Hassol (2011).

[41] http://www.waterwordsthatwork.com/our-methods/message-method/words.

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Chapter 16. Taking the Next Step[42]

As the 21st century unfolds, we face climatic changes unprecedented in the human experience, which are ushering in a new era for conservation. Over the past century, we have made considerable progress in protecting our natural world. We have set aside ecologically significant lands and waters as wilderness, parks, and refuges; worked to reduce air and water pollution; restored and revitalized degraded forests, wetlands, and other habitats; and rebuilt wildlife populations and recovered endangered species. Without these important efforts, many of our special places, and the plant and animal species they sustain, would have been lost. Continuing to safeguard these vital natural systems and life-forms, however, will require that conservationists and resource managers begin consciously incorporating climate considerations into virtually every aspect of their work.

This guide is designed to help managers put adaptation principles into practice, and more specifically to understand which current conservation actions will continue to be appropriate in an era of climate change, and when and where new or different approaches will be needed. Given the rapid climatic and ecological changes already underway, it is not sufficient to simply do more of the same, only "better." Accordingly, this guide emphasizes the importance of applying four overarching themes in the practice of climate-smart conservation: (1) acting with intentionality, by linking conservation actions to climate impacts; (2) managing for change, not just persistence; (3) reconsidering conservation goals, not just management strategies; and (4) integrating adaptation into existing work. To support the application of these themes, we offer a general framework for adaptation planning and implementation—the climate-smart conservation cycle—around which much of this guide is structured.

Although planning for and carrying out adaptation will have costs, the cost of inaction—through continuing with business as usual—is likely to be far higher. Furthermore, the sooner we begin the task of planning for a climate-altered future and taking meaningful adaptation action, the more successful these efforts ultimately will be. There are, of course, impediments to taking action. Apart from the perennial issue of limited financial resources, unease about making decisions in the face of the uncertainties surrounding climate change has emerged as one of the primary barriers to taking action. Given that uncertainty pervades virtually all natural resource management, not to mention other forms of planning—from urban development and transportation planning to personal finances—there are well-established ways to overcome real or perceived uncertainties, and avoid being paralyzed into inaction. Indeed, despite the tendency to focus on uncertainties, there is often considerable confidence in our

Whether one is already actively focused on adaptation, or just beginning to think about climate change, it's time to take the next step for making conservation efforts climate smart.

[42] Lead authors: Bruce A. Stein, Patty Glick, Naomi Edelson, and Amanda Staudt.

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understanding of the direction, if not the actual rate and magnitude, of likely future conditions that can form a solid basis for planning and action.

Seemingly every week, new research reveals additional details of how rapid climate change is affecting our natural ecosystems and human communities, along with the accelerating pace of many of these changes. It is, therefore, imperative that natural resource managers begin to act now to prepare for and manage these changes, in order to provide the best chance for cherished conservation values to endure. While our knowledge of coming changes is imperfect, by being deliberate and intentional in planning for adaptation, conservation practitioners can identify immediate steps to carry out that also keep options open for the future. Putting adaptation principles into practice will be essential for successful conservation in an era of climate change, and it is our hope that the techniques presented in these pages will inspire and motivate managers to move forward with this urgent and vital work. Whether one is already actively focused on adaptation, or just beginning to think about climate change, it's time to take the next step for making our conservation efforts climate smart.

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