Chapter 11

Responding to Climate Change: A Toolbox of Management Strategies

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The road to success is always under construction.

—*Lily Tomlin*

Climate change and its effects are writ large across the landscape and in the natural and cultural heritage of parks and wilderness. They always have been and always will be. The sculpted walls of Yosemite National Park and the jagged scenery of the Sierra Nevada wilderness would not be as spectacular if periods of glaciation had not been followed by periods of deglaciation. High biodiversity in forests of the Great Smoky Mountains reflects a legacy of climate change, migrating species, and isolated climatic refugia. Fossils unearthed at Dinosaur National Monument reflect a time when the climate was very different than it is today, as do ruins left by peoples who practiced agriculture in places in the American Southwest where food production is not possible today. Over eons, climate change has molded the diversity of life and landscape in areas now protected as parks and wilderness.

Contemporary climate change is quite different, however. For the first time, the pace and direction of climate change appear to be driven significantly by human activities (Intergovernmental Panel on Climate Change 2007). Contemporary climate change is playing out across landscapes already affected by other anthropogenic stressors—pollution, invasive species, altered disturbance regimes, and land fragmentation. Compared to landscapes with continuous habitat, fragmented landscapes severely diminish the ability of species to respond adaptively to rapid climate change.

Contemporary climate change therefore places much that humans value at risk. Biodiversity is threatened, as are precious park landscapes. The glaciers in Glacier National Park are projected to disappear by 2030 (Hall and Fagre 2003). Models suggest that climate change may make it impossible for Joshua trees (*Yucca brevifolia*) to persist in Joshua Tree National Park (Cole et al. 2005). Rising sea level threatens the freshwater wetlands of Everglades National Park. Increasingly severe drought, earlier snowmelt, reduced stream flows, larger and more intense fires, and widespread insect and disease infestations portend a future of diminished park and wilderness values, both social and ecological (Saunders et al. 2007).

The first step in responding to climate change is to clarify protected area goals and purposes. A prominent theme in this book has been the need to move beyond the singular traditional goal of sustaining naturalness and articulate diverse forward-looking goals more helpful in guiding when and how to intervene in ecosystems. Beyond this, there is an immediate need to begin planning for and responding to climate change. Some actions can be taken in the near term; others will bear fruit only in the future. Some actions can be implemented locally; others will be successful only when played out over large landscapes. In this chapter, we describe a toolbox of potential management responses to climate change. We begin with a general management framework, move to more specific near-term, local management actions, and conclude with longer-term, larger-scale approaches. Dealing with uncertainty—acknowledging it, taking action despite it, learning, and responding appropriately when surprises occur—is a central theme of the chapter.

Management Approaches in the Context of Climate Change

One of the actions protected area managers can take immediately is to incorporate climate change into existing management plans (Heller and Zavaleta 2009). Several frameworks for doing this have been proposed. Most involve articulating goals, identifying key ecosystem elements and processes, identifying indicators, setting baselines or limits of acceptable variation, assessing vulnerabilities and sensitivities, establishing monitoring programs, and identifying appropriate adaptive responses to climate change (Spittlehouse and Stewart 2003; Baron et al. 2008; Kareiva et al. 2008; Heller and Zavaleta 2009). For example, the National Park Service prepares a foundation plan as part of their general management plan. The Forest Service prepares a comprehensive evaluation report as part of their land management planning process. These documents focus on patterns and trends in environmental conditions, emerging stresses, and anticipated changes. Scenario planning exercises relevant to climate change (described in detail in Chapter 13) can be incorporated into strategic visions and frameworks that contribute to final plans.

The four management emphases explored in the second part of this book, autonomous nature, historical fidelity, ecological integrity, and resilience, represent a range of protected area goals with different management strategies. Where autonomous nature is the goal, the response to climate change is to not manipulate ecosystems. In contrast, to maintain a high degree of historical fidelity, intensive and frequent manipulation of ecosystems, much of it at localized and small scales, is often necessary. For example, Tuolumne Meadows in Yosemite National Park might be sustained as the largest subalpine meadow in the Sierra Nevada, offering the same stunning views in upcoming centuries as it has in the past. But this will probably require continual removal of lodgepole pine (*Pinus contorta*) seedlings and saplings that invade the meadow with increased frequency as climate changes, and possibly even irrigation to maintain species intolerant of drier conditions.

Ecological integrity and resilience are management goals that are in several ways intermediate between autonomous nature and historical fidelity. They imply active intervention to conserve elements of biodiversity, as managing for historical fidelity does, but are generally implemented at lower intensities and larger spatial scales than efforts to sustain historical fidelity. For example, with ecological integrity or resilience as a goal, lodgepole pine might be allowed to invade Tuolumne Meadows. Interventions might focus on ensuring that hydrologic regimes remain functional and the regional population viability of meadow species is not threatened.

If they are to intervene, managers must decide whether to be proactive, anticipate change and act in advance, or to respond only after disturbance or extreme events. Waiting to respond might reflect uncertainty regarding the need for action or what actions are likely to succeed. Waiting might reflect a precautionary approach and be preferred by risk-averse actors (Heller and Zavaleta 2009). Alternatively, waiting might reflect a decision that the best time for action, from a scientific or an organizational efficiency standpoint, is after disturbance. Regardless, what is important is to plan ahead, so responses can be quickly implemented when windows of opportunity open (Joyce et al. 2008). For instance, in the Rock Creek Butte Research Natural Area, California, the entire population of rare Brewer spruce (*Picea breweriana*) burned during a 2008 wildfire. Climate envelope modeling for this species suggests that there will no longer be favorable habitat for Brewer spruce in the future of California, and therefore restoration is not appropriate. However, after a fire is the best time to attempt regeneration and establish a refugium for Brewer spruce in its current native habitat.

Proactive, anticipatory responses use "current information about future climate, future environmental conditions and the future context" of protected area management "to begin making changes to policy and on-the-ground management now and when future windows of opportunity open" (Joyce et al. 2008: 3–40). The ability of climate science to make projections about future climate and resultant changes in biota has improved (Intergovernmental Panel on Climate Change 2007). However, as discussed in Chapter 4, the current state of the art suggests it is dangerous to commit to projections as accurate forecasts, especially at the scales relevant to park managers. Model outputs are better viewed as vehicles for organizing thinking, considering different scenarios, and gaining insight into a range of possible futures (Millar et al. 2007).

Adapting to Climate Change

Regardless of whether actions are taken reactively or proactively, the ultimate goal is to help ecosystems, ecological elements, and processes adapt to climate change and accomplish this by increasing the adaptive capacity of protected area policies and institutions. Many ways of adapting have been suggested, but most recommendations are still at the idea stage (Heller and Zavaleta 2009). Most are general rather than specific and actionable, based more on logical thinking than empirical data. This is particularly true for protected areas, where many specific recommendations (thinning forests, creating more diverse stand structures, realigning ecosystems, moving species) are potentially so intrusive and heavy-handed to seem anathema to traditional thinking about what is appropriate in wilderness and some parks. That is why this book emphasizes the need to rethink protected area goals and carefully evaluate whether proposed management actions advance or detract from goal achievement.

Some suggestions focus on ecological interventions, whereas others focus on societal issues, policy, and institutional change. Recommendations vary in the temporal and spatial context of application. In this section we

first explore actions that can be taken in the near term by managers of individual parks and wildernesses. Then we turn to actions that take more time to implement and must be used at large spatial scales.

Near-Term Actions for Local Managers

We begin with near-term actions designed to protect ecosystems, buffering them from effects of climate change and helping them resist change. Ecosystems, their elements and processes, must respond to climate change by adapting in place, or species must migrate someplace else; otherwise they go extinct. Although resistance to change may seem a denial of future change, it is a defensible approach to uncertainty, particularly for highly valued attributes such as endangered or iconic species. Increasing resistance is also a means of buying time. A number of traditional stewardship actions will promote resistance. Managers can promote basic ecosystem functioning and mitigate threats to resources (Heller and Zavaleta 2009). Actions might include more aggressive management of adverse effects posed by invasive species, recreational use, livestock grazing, or water diversion. For instance, groundwater pumping for rural municipal use or for recreational developments such as ski areas can deplete mountain aquifers, causing springs, fens, and wetlands to dry up. Negotiated compromise and enhanced water conservation may reduce water demand.

Maintaining natural disturbance dynamics is another common recommendation (Taylor and Figgis 2007), but this option exposes the conflict between actions that create resistance to change and those that promote adaptive capacity or resilience. For example, climate change is expected to increase fire frequency and intensity, a change already being observed (Westerling et al. 2006). Suppressing unusually severe fires, particularly those that threaten highly valued ecosystem elements, such as old-growth forests, is a means of resisting changes wrought by climate, but this is often not possible. Moreover, doing so ignores the fact that many biotic elements need fire for their persistence. Intervening in fire processes interferes with an important mechanism by which vegetation adjusts to new climatic conditions. As Noss (2001: 585) suggests, "a mixed strategy in which managers let many natural fires burn, protect (to the extent possible) old growth from stand-replacing fires, and manage other stands by prescribed burning and understory thinning to reduce the risk of high-intensity fire, may be the optimal approach." Indeed the very concept of natural disturbance is evolving as changing climate brings fire and insect outbreaks to places that have not experienced them for centuries, at larger spatial scales and at different times of the year than in the past.

Over paleohistorical time scales, climate has acted as a driver of biotic change, with much of that change occurring synchronously across the landscape (Betancourt et al. 2004). At decadal and centennial scales, for example, windstorms in the eastern United States and drought in the West have at times synchronized forest composition and structure across the landscape, possibly making them more vulnerable to climatic shifts. A recent example may be the extensive dieback in some forests as a result of drought (Breshears et al. 2005). This has led some to suggest that vulnerability to climate change might be reduced by deliberate reduction of landscape synchrony (Millar and Woolfenden 1999; Betancourt et al. 2004). Actions that promote diverse age classes, species mixes, and landscape structural and genetic diversity reduce landscape synchrony. This can be done most effectively at early successional stages, when ecological trajectories are influenced more by present and future climatic conditions than by those of the past (Millar et al. 2007).

Peters and Darling (1985) suggest it may sometimes be necessary to undertake heroic rescue efforts, for example by irrigating sensitive species. This might be one response to the potential loss of Joshua trees (*Yucca brevifolia*) in Joshua Tree National Park. Other examples include using attractants to lure songbirds to continue to use specific meadows, providing winter forage during harsh years for endangered species, or providing supplemental forage to encourage dispersal along planned corridors. Such projects illustrate the degree to which enhancing resistance in the face of directional climate change is akin to paddling upstream (Millar et al. 2007). They require ever-increasing effort, of a nature so intensive as to often be deemed undesirable, particularly in wilderness. Moreover, if conditions change enough, all but the most localized and intensive efforts may be futile. Ecosystems are likely to cross thresholds and be lost, perhaps with catastrophic consequences (Harris et al. 2006). Considering this, Millar et al. (2007) conclude that resistance options are best applied for the short term, to buy time, and where values at risk are high or sensitivity to climate change is low.

Complementary to enhancing resistance is facilitating the ability of ecosystems to adapt to climate change. Some options involve increasing capacity to adapt in place; others involve facilitating migration. Where ecosystems have been significantly disturbed, restoration treatments are often prescribed. Rather than restoring ecosystems to historical predisturbance conditions, managers increase adaptive capacity by realigning ecosystems with current and future conditions. Examples include restoration of fire regimes altered by fire suppression or of stream or meadow hydrologic relations altered by water impoundments, diversions, or livestock grazing. In situations where there is substantial confidence in predictions about future conditions, management interventions can be narrowly targeted. Fires may need to burn more frequently or during different seasons than in the recent past. Managers may want to encourage compositional shifts toward more drought-tolerant species where meadows have been altered by grazing or water diversion. More commonly, where the future is quite unpredictable, it might be best to realign ecosystems with a range of possible future conditions, for example using a broad species mix rather than a mix targeted to past conditions.

Traditional genetic management guidelines aim to avoid contamination of populations with ill-adapted genotypes by establishing small seed zones and dictating that seeds (or other plant materials) used for restoration come from small, local zones. This restriction on genetic diversity made sense under the assumption that environments and climates were stable. But relaxing genetic guidelines, for both plants and animals, using germplasm from a wider geographic area and diversity of populations, makes more sense given climatic change (Ledig and Kitzmiller 1992). Managers might use predictions that future climates will be warmer to emphasize germplasm from warmer (often downhill) populations. Alternatively, they might hedge their bets by enlarging seed zones in all directions (Joyce et al. 2008). Best genetic management practices also emphasize equalizing germplasm contributions and enhancing population sizes by maximizing the number of parents and striving for equal amounts of plant material from each parent. These guidelines become especially important in an uncertain future.

Species unable to adapt in place must move. To migrate successfully, species need viable source populations and habitats, appropriate destinations, and a way to get from source to destination (Taylor and Figgis 2007). Managers can assist by identifying and conserving refugia, environments that are buffered against climate change and other disturbances. Refugia provide places where a species might persist even if unfavorable conditions cause it to disappear elsewhere. Refugia can be important sources and destinations. Past climatic refugia can be identified. For example, mountainous landscapes have highly heterogeneous environments, with diverse microclimates, some of which (particularly cool and mesic sites) can act as refugia. Later in this chapter we describe a case in which managers are reorienting goals to optimize an area's value as a climatic refugium. Once identified, refugia and the populations they harbor become high priorities for protection.

Species movement can be facilitated by allowing migration. As rates of species movement increase in response to change, traditional notions of a species range will be challenged, and the line between native and non-native species will blur, as will the definition of an invasive species (Millar and Brubaker 2006). Managers will need to decide whether invasions are beneficial or adverse and manage accordingly. Managers may even manipulate environments to encourage migration, thinning forests, for example, to encourage species that establish and grow better with more light and less competition.

More controversial is assisted migration, actively helping propagules or individuals move to new habitats where they are presumably better adapted. Assisted migration has sparked much interest and debate. Translocations are often unsuccessful, and unanticipated consequences can result from introducing new species into extant communities (Heller and Zavaleta 2009). Hoegh-Guldberg et al. (2008) propose a framework for deciding where assisted migration seems necessary and feasible and where other options are preferred. McLachlan et al. (2006) argue that there is an urgent need for debate and policy development regarding assisted migration. To start the process, these authors identify major policy choices, articulate implications of each choice, and provide a research agenda to inform debate and decision.

The final option is ex situ protection of the species most threatened by climate change, where this is the only option short of extinction. Species could be preserved in zoos and botanical gardens in the hopes that a time will come when the effects of climate change can be reversed and species can be returned to their native landscapes (Noss 2001).

Longer-Term, Larger-Scale Actions

As noted earlier, many near-term actions that local protected area managers might take are likely to be controversial, involving intensive and manipulative actions, often undertaken under conditions of high uncertainty. Perhaps less controversial, probably more important, but more difficult to implement are actions that must be taken at large spatial scales and played out over long timeframes. Chapters 12 and 13, on conservation at large spatial scales and building more adaptability into planning, cover some of

this same material. Consequently, discussions here are brief and more suggestive than definitive.

One challenge to protected area management is that species move but protected area boundaries are fixed. This has long been a problem where protected areas are small and when animal populations migrate. Climate change will exacerbate this problem. The obvious response is to plan for conservation at much larger scales, enlarging the effective size of preserves and reducing limitations associated with their finite locations in space. There are several ways regional and landscape planning can improve adaptation to climate change.

Because species have to move, an obvious goal is to promote landscape connectivity (Noss 2001). Plants (and many animals) move by dying out in places that are no longer hospitable and colonizing newly habitable places. These migrations are inhibited to the degree that landscapes are fragmented and encouraged by the connectivity of the landscape. Landscapes with continuous habitat and few physical or biotic impediments to migration provide good connectivity (Millar and Brubaker 2006). Fragmentation can be avoided (e.g., by limiting roads), and connectivity can be promoted (e.g., by providing underpasses where there are roads) within large protected areas. But if the biotic shifts associated with climate change are substantial, connectivity must extend beyond individual protected areas to networks of protected areas and to the lands that constitute the matrix in which protected areas are situated. As discussed further in Chapter 12, this has led to proposals that core protected areas be linked by corridors to facilitate movement and exchange (see Noss et al. 1999, for example) and proposals for continental-scale corridors and linkages.

Connectivity can be promoted in many ways at various scales. Examples include situating trails in parks where they will have minimal connectivity impacts on small rodents and lagomorphs and building campsites where they will not interrupt migration routes of large mammals. Similarly, vegetation can be managed to maintain unimpaired wildlife movement. For example, prescribed fire has been used in the Sierra Nevada to reduce hiding cover for mountain lions (*Felis concolor*), the presence of which inhibited movement of Sierra bighorn sheep (*Ovis canadensis sierrae*) upslope to cooler, moister summer habitat.

A related action involves managing the matrix, the lands around and between protected areas that are not designated for protection but increasingly influence the integrity of parks and wilderness. The matrix can be a source of threats, especially if some lands harbor invasive species or generate pollution. The matrix can be fragmented and pose significant barriers to connectivity. Ideally, conservation in the matrix would "soften" land use by encouraging less damaging practices, such as practicing low-intensity forestry rather than clearcutting (Heller and Zavaleta 2009). Barriers to this strategy are substantial because many landowners and mangers have goals quite different from those of nearby protected areas, often emphasizing development and commodity extraction. Matrix lands are often owned by other government agencies or are private lands. Collaboration and identification of shared goals are needed, as are innovative mechanisms such as conservation easements and conservation futures (Hannah et al. 2002).

Regional planning is critical to promoting diversity and redundancy in management strategies as a means of managing risk associated with the uncertainties associated with climate change, its biotic effects, and the effectiveness of responses to change. Diversification is a means of hedging bets (Hummel et al. 2008), not putting all one's eggs in the same basket (Millar et al. 2007), and increasing adaptive capacity. Returning to the goals of Part II, the likelihood of optimizing all protected area values is increased if varied goals and strategies are used in different protected areas or different parts of large protected areas. This diversified approach increases the likelihood that if one strategy fails, a different strategy might succeed elsewhere. The complement of diversity, redundancy, is equally important. Diverse management strategies should be replicated across diverse environments. Again, if they fail in one place, they might succeed elsewhere. Ensuring planned, purposeful diversity and redundancy entails regional-scale planning.

The challenge of coordinated planning beyond the boundaries of protected areas and among networks of protected areas suggests the need for innovation. New goals must be articulated. These goals should be diverse, rather than monolithic, if they are to capture the array of protected area purposes and values. In many situations, goals may focus more on function or process than on composition and structure (Millar and Brubaker 2006). They may focus on species persistence in large geographic areas, relaxing expectations that current species ranges will remain constant or that population abundances, distributions, and species composition will remain stable (Millar et al. 2007). Seastedt et al. (2008) note that it may be better to manipulate mechanisms that enhance desirable system components than to remove or suppress undesirable components. A broader range of ecosystem types may be considered desirable (Heller and Zavaleta 2009). Rather than target a single desired future condition, goals might shift to avoiding a range of undesirable conditions (Joyce et al. 2008).

Managers must anticipate, confront, and incorporate uncertainty and the likelihood of surprise into planning and management. They must accept that climate change is likely to push populations beyond thresholds of mortality (Millar et al. 2007), sometimes to highly degraded states, and often to conditions for which there is no analog today or in the past (Harris et al. 2006). Where managers can control ecological processes to a substantial degree, adaptive management is an effective means of dealing with uncertainty. Discussed at length in Chapter 13, adaptive management involves learning by doing. Managers design actions that test uncertainties, monitor results, learn, and adjust practices accordingly.

Where uncertainty is high and managerial control is limited, scenario planning is a useful tool (Peterson et al. 2003). Scenario planning involves articulating and exploring a wide set of alternative futures, each of which is plausible but uncertain. Scenarios provide a mechanism for anticipating and working through conflicts between goals. Contingency plans can be developed for observable undesirable trends that are likely to continue and for catastrophic events with a low probability of occurrence (Baron et al. 2008).

Conflict, trade-offs, uncertainty, and limited resources suggest the need to prioritize and practice triage. Goals must be prioritized, as must the ecological elements and processes managers seek to sustain. Regarding the protection of selected elements or prioritizing of specific management situations, a triage approach might be helpful (Hobbs et al. 2003). In a resource context, triage involves systematically sorting different situations on the basis of urgency, sensitivity, and capacity of available resources to achieve desired outcomes (Millar et al. 2007). Categories range from situations with high urgency, adequate resources, and a proposed treatment that is likely to be effective (treat immediately) to situations that are untreatable, regardless of urgency, because of inadequate resources, catastrophic degradation, or no viable treatment.

Most of the actions discussed here—from planning for diversity and redundancy to prioritization and triage—are best done at scales that extend far beyond the boundaries of individual protected areas. This raises the need for institutional change to improve regional coordination through increased interagency cooperation and cooperation between different field units in the same agency. As discussed in Chapter 12, it is imperative to develop the institutional capacity to produce regional visions and strategies so that local decisions made by managers of individual protected areas add to the diversity, redundancy, and capacity of regional systems. This will be challenging given the decentralized decision-making tradition of public land agencies and traditional lack of cooperation between agencies and between public and private lands.

Equally important are efforts to change policies and institutions to enhance flexibility and the capacity to adapt through learning. To confront uncertainty and avoid paralysis, appropriate risk taking must be encouraged. "Safe to fail" strategies intend to succeed but recognize the potential for failure. Punishing managers who prudently accept risk but ultimately fail will make all managers so risk averse that proactive actions that are needed will never be taken (Baron et al. 2008). Although never desired, failure opens the door to learning and whittling away at uncertainty. But to learn from failure, we must monitor the effects of actions, with lessons learned incorporated into future plans. Managers must develop the capacity to reassess conditions frequently and be willing to change course as conditions change. As discussed in Chapter 13, this will require institutions and policies that emphasize flexibility rather than highly structured decision making (Millar et al. 2007).

Devil's Postpile National Monument as Climatic Refugium: A Case Study

Despite the fact that effects of climate change are already apparent in many protected areas, few have addressed climate change in a substantial manner. Devil's Postpile National Monument in California is one unit attempting to assess implications of climate change for their stewardship program and even revisit park purposes and goals.

Devil's Postpile is a small park unit (325 hectares) located at about 2,300 meters elevation, close to the headwaters of the San Joaquin River in the Sierra Nevada. It is adjacent to Forest Service land, much of it wilderness, not far from Yosemite National Park and the major destination ski resort Mammoth Mountain. The monument was created to protect one of the world's finest examples of highly symmetrical columnar basalt (Figure 11.1) and is known for its fine mountain scenery. Despite its small size, the monument is highly diverse, with more than 400 plant species, 100 bird species, 12 species of bats, and 35 mammal species. Some of the reasons for this biodiversity include the prevalence of wetlands in the monument (8.5 percent of the park) and its location at a low point in the Sierra Divide, where three bioregions converge (Central, Southern, and Eastern Sierra).

Research suggests that the monument might provide an important refugium for many species during a period of climate change because of its

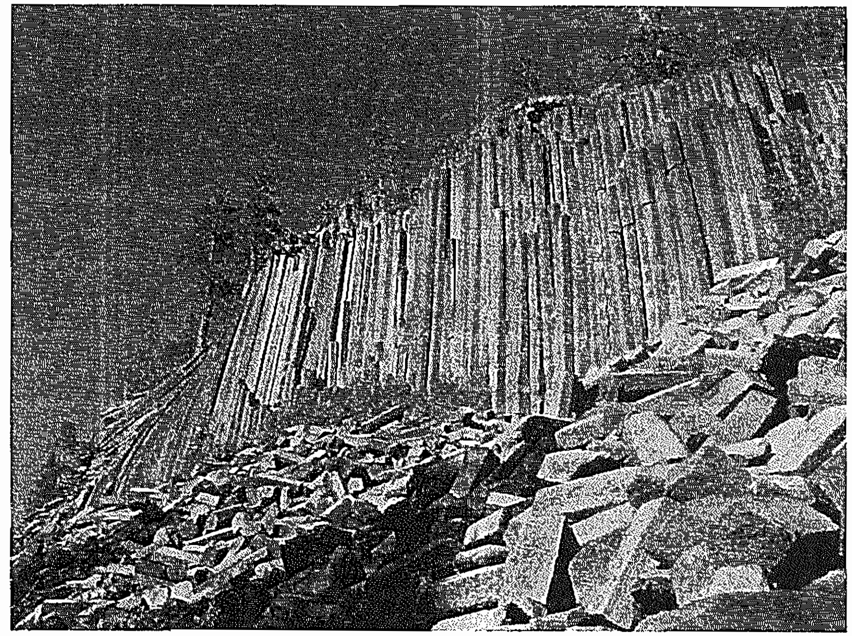

FIGURE 11.1. Devil's Postpile National Monument was established to protect a unique geological resource, perhaps the world's finest example of highly symmetrical columnar basalt. In a future of rapid climate change, it may help sustain regional biodiversity by being an important climatic refugium. (Photo by the National Park Service)

unique topographic position. Located in a deep canyon, running north to south, the monument is subject to substantial pooling of cold air. Projections suggest that this cold air pool might warm more slowly than the surrounding landscape (if it warms at all), buffering the park from predicted warming and drying and allowing the park's wetlands to survive longer than might be the case elsewhere (Lundquist and Cayan 2007). Managers of the monument are considering a reorientation of their goals and purposes to optimize the monument's potential as a climatic refugium, an area that is less affected by climate change than its surroundings.

Monument managers are developing a strategy to build on current programs to increase their capacity to plan for and respond to climate change. They are attempting to obtain additional resources and staff to study, monitor, and manage issues such as climate, past and present, and its effects on native species, invasive species, pest outbreaks, and the need for restoration. In recognition of the need to work at spatial scales much larger than the monument itself, collaborative relationships are being developed with other land management agencies and private entities that own or manage surrounding lands. Interagency workshops have been held, in an effort to manage the Eastern Sierra as more of a unified system. This is extremely important, because the monument functions as a critical migration corridor, connecting lower and higher elevations, and its wetlands are sustained by waters that originate on national forest land and that can be adversely affected by development on neighboring private lands.

Moving Forward in the Face of Uncertainty and Change

Climate change is likely to be the defining issue facing managers of parks and wilderness in the twenty-first century. Ecological changes are already occurring, and there is a rising sense of urgency. But what exactly should be done? In this chapter, we have described a variety of actions that local managers can consider in the near term. Many of these actions are risky. Uncertainty is high, and some actions are so intensive and manipulative as to seem inappropriate on lands that are supposed to be wild and uncontrolled. Less controversial is the urgent need to change policies and institutions to make them more flexible and adaptive and thereby increase the resilience of ecosystems to climate change.

Millar et al. (2007: 2146) describe the institutional milieu that is necessary, one that embraces "strategic flexibility, characterized by risk-taking (including decisions of no action), capacity to reassess conditions frequently, and willingness to change course as conditions change." Park and wilderness goals should be more diverse, both to be responsive to varied park purposes and to reduce risk. Such goals will probably need to be more flexible, allowing for a broader array of desirable futures, more tolerant of biotic changes resulting from human activity (Welch 2005), and couched more in terms of maintaining regional biodiversity and ecosystem function than maintaining contemporary biotic community composition and structure.

Successful regional planning and collaboration beyond protected area boundaries will be critical to responding effectively to climate change. Parks have always been too small to manage in isolation; climate change makes them that much smaller. What are urgently needed are institutions and policies that enable planned diversity and redundancy in goals, strategies, and management practices across large landscapes and promote connected landscapes to ease the movement of species.

BOX 11.1. RESPONDING TO CLIMATE CHANGE

- Managing in the face of climate change requires a toolbox of approaches, including short-term and long-term strategies that focus on ecosystem resistance and resilience and help ecosystems adapt to change.
- Dealing with uncertainty is a fundamental challenge best dealt with through increased flexibility and adaptability, as well as carefully planned diversity and redundancy at multiple scales.
- Near-term actions managers of individual protected areas might consider include the following:
  - Mitigating threats to resources
  - Maintaining natural disturbance dynamics
  - Reducing landscape synchrony
  - Making aggressive but thoughtfully prioritized efforts to rescue highly sensitive species
  - Realigning conditions with current, expected, or a range of possible future conditions
  - Relaxing genetic guidelines where risk is low and adaptive management can be implemented
  - Conserving refugia
  - Allowing or actively assisting migration
  - Cautiously considering the use of nonnative species where they are the best option for maintaining critical ecosystem functions
  - Protecting highly endangered species ex situ
- Longer-term, larger-scale actions include the following:
  - Promoting landscape connectivity
  - Managing the matrix
  - Promoting diversity and redundancy
  - Articulating new goals
  - Incorporating uncertainty and the likelihood of surprise into planning and management
  - Prioritizing and practicing triage
  - Increasing interagency cooperation
  - Increasing flexibility and the capacity to adapt through learning

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