Conservation and Global Climate Change
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One of the most challenging issues for conservation during the coming decades will be preserving biodiversity in the face of climate change. It has become increasingly apparent that the climate is changing because of human activities—the chemical composition of the atmosphere has been modified, record-breaking temperatures are becoming more common on an annual basis, and polar ice caps are melting. Ecosystems will respond to these changes in a variety of ways; some may be deemed beneficial and others detrimental. The question for ecologists and conservationists then becomes how do we conserve ecosystems, ecological processes, and species under conditions of a changing climate?

GLOSSARY

assisted migration. Directed dispersal or translocation of organisms across the landscape
bioclimatic envelope models. Models that use statistical methods to correlate species occurrences with environmental predictor variables to define a species’ environmental niche and predict the species’ occurrence across a broader landscape
greenhouse gases (GHGs). Gases such as carbon dioxide, methane, nitrous oxide, tropospheric ozone, or chloroflorocarbons that absorb solar radiation and reflect it back down to earth, creating a “greenhouse effect” that warms the earth’s surface
interannual. Between years
lake turnover. The mixing of deep anoxic (oxygen-poor) and shallow oxygen-rich water in lakes that occurs in fall and spring when water hits the threshold temperature of 4°C
oceanic conveyor belt. Ocean circulation pattern driven by temperature and salinity gradients across the globe that moves warm and cold water around the globe, moderating temperatures and salinity patterns
phenological changes. Timing of life cycle events that are related to seasonality of the organism such as hibernation, bud burst, flowering, egg laying, etc.
Quaternary period. The geologic time period beginning roughly 1.8 million years before present
stepping stones. Small, unconnected portions of suitable habitat that an organism uses to move from one place to another
trophic cascades. Changes at one level of the food chain that percolate through many other levels of the food chain, causing both direct and indirect effects on species composition
vagility. An organism’s ability to move through the landscape

1. INTRODUCTION

In this chapter, we describe how climate is changing, including both paleoclimatic and anthropogenic changes. We then discuss how the Earth is responding, both from an abiotic perspective (including atmospheric changes, temperature fluctuations, and ocean circulation patterns) and from the perspective of biotic communities. We describe some of the research approaches that have been used to examine and anticipate the types of responses of ecological communities to climate change and how scientists might prioritize and manage areas for conservation under conditions of a changing climate. Finally, we end with a discussion of
the missing links—the need for research that will allow us to better predict responses and to manage for change in the coming decades.

2. HOW CLIMATE IS CHANGING

Paleoclimatic Changes

Changes in the Earth’s climate over the past thousands of years can be reconstructed using a combination of direct measurements from land and ocean weather stations and indirect proxy methods, which include tree rings and pollen and plankton from lakes and ocean sediment cores. These records indicate that the Earth’s climate has cycled through many warming and cooling periods over geologic times. Ancient samples of atmospheric gases from ice cores reveal that the concentration of greenhouse gases (GHGs) in the atmosphere has also fluctuated in the past, with high GHG levels being correlated with warmer global temperatures. Cycles in temperature and GHG concentrations over geologic time scales have been caused by natural fluctuations in incoming solar radiation and the chemical composition of the atmosphere.

Anthropogenic Climate Changes

The 2007 Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) details the unequivocal warming of the Earth’s climate over the last 50 years, most of which is very likely a result of increases in anthropogenic GHG emissions. There has been a rapid 35% rise in atmospheric GHG concentrations since preindustrial times, and in 2005, atmospheric GHG concentrations were higher than any levels recorded or estimated for the previous 650,000 years. Although the magnitude of warming has varied across the Earth’s surface, globally averaged temperature has risen ~0.6°C over the last 50 years. It is likely that average Northern Hemisphere temperatures during the last 50 years were warmer than during any other 50-year period over the previous 1300 years. Precipitation trends have been more variable, with some regions of the world showing significant increases and others significant decreases. Using a range of projected GHG emissions scenarios, the IPCC’s best estimates of global anthropogenic warming range from 1.8 to 4.0°C over the next century, with an even greater magnitude of warming expected at high northern latitudes. Annual precipitation is very likely to increase in high latitudes, and the subtropics are likely to experience decreased precipitation over the next century.

In addition to changes in temperature and precipitation means, greenhouse warming will also lead to increased climate variability and the occurrence of climatic extremes. For example, many areas across the globe are predicted to experience more severe droughts, floods, large-scale erosion and soil wasting, landslides, and extreme heat events. Changes in these extreme events will have significant impacts on disturbance processes that are important to many ecosystems. Wildfires are influenced by the availability of fuel loads and occurrence of ignition triggers, but climate conditions are also critical in determining the severity and extent of wild fires. Extremely hot and dry conditions can lead to more ignition-prone fuel as well as to fires that burn hotter and therefore can have more extreme effects on vegetation. Fire trends from 1970 to the present in the western United States have increased in frequency and duration, and fire seasons have become longer since the mid-1980s (Westerling et al., 2006).

Reducing anthropogenic GHG emissions is necessary to avoid the most drastic climatic changes. However, even if the input of GHGs to the atmosphere is greatly reduced, scientists claim that the Earth is already “committed” to a certain level of warming and sea level rise because of the effect of GHGs that we have already emitted and oceanic thermal inertia (Wigley, 2005). Therefore, the conservation community has become focused on developing strategies that allow species to adapt and ecosystem processes to function in light of inevitable climate change.

3. ENVIRONMENTAL RESPONSES TO CLIMATE CHANGE

Abiotic Responses

Abiotic changes drive biotic responses in ecosystems. Thus, in considering climate change, we must start with the abiotic responses that change the physical environment that organisms inhabit. Issues related to climate change include sea level rise, melting sea ice, melting glaciers and permafrost, altered precipitation patterns, and changes in global circulation patterns and disturbance regimes (e.g., wildfire, drought, floods, and coastal erosion).

The 2007 IPCC report summarized the state of our current knowledge. The assessment of global data shows that it is “likely that anthropogenic warming has had a discernable influence on many physical and biological systems.” For example, there is high confidence that lakes and rivers will become warmer and that hydrological systems will be affected by increased runoff and spring discharge. These changes will in-
creases ground instability, erosion, and rock avalanches. Disturbances such as flooding, wildfire, and ocean acidification will likely increase in frequency, and drought-affected areas will increase in extent. However, all of these changes are superimposed on background climatic cycles and circulation patterns of both air and water. Background climatic cycles that affect temperature and rainfall over decadal time scales include the Pacific Decadal Oscillation, El Niño Southern Oscillation, and the North Atlantic Oscillation. The oceanic “conveyor belt,” which is driven by temperature and salinity gradients, moves warm and cold water around the globe, moderating temperatures and salinity patterns. We focus our discussion here on how the organisms that inhabit these ecosystems respond to abiotic changes, but it is important to remember that these abiotic cycles and circulation patterns create the backdrop within which ecological communities exist.

Biotic Responses

Paleoclimate Changes

Changes in climate are known to affect the distribution of species across landscapes. Paleoclimatologists document changes in vegetation over many centuries and millennia using sediment cores sampled from lake bottoms. Within the sediments are pollen granules that provide detailed chronologies of the local plant life. Over thousands of years, the same site may have been inhabited by very different vegetation communities. Davis and Shaw (2001) documented such changes in the forests of eastern North America from the Quaternary period to the present. As the climate warmed over that time period, tree species established themselves at higher latitudes and elevations. These types of large-scale changes usually occur relatively slowly, and organisms have a long time to adapt to changing conditions. The types of changes that have been documented over the past 200 years and the conditions that we expect to see in the future indicate that the rates of future change may be faster than in previous evolutionary time.

Responses to Recent Climate Changes

Scientists have already measured significant changes in local conditions and habitat suitability, shifts in phenology (timing of life-cycle events), and altered species distribution patterns in response to human-induced climate changes over the last ~30 years. Several analyses have shown that the timing of spring events (e.g., breeding, nesting, egg laying, flowering, budburst, and arrival of migrants) are occurring significantly earlier in response to recent warming for many species and all across the globe (IPCC, 2007; Parmesan, 2006; Root et al., 2005). Hibernation patterns are also being modified. Landscape responses to climate change can be monitored at continental scales using remote sensing technology. Satellite imagery allows scientists to monitor the timing of seasonal “green-up” of vegetation across a continent. Scientists have observed a trend in many regions toward earlier green-up since the early 1980s. In addition to phenological changes, many plant and animal species are showing signs of shifting range boundaries, both poleward in latitude and upward in elevation (IPCC, 2007).

Aquatic systems are also responding to recent climate changes. Changes in water temperature, dissolved oxygen, stream flow, and salinity are affecting the distributions of both freshwater and saltwater organisms from plankton and algae to large predatory fish. Glaciers are melting earlier and at an increased pace, with the potential to increase sizes of lakes and create flooding events until the glaciers are reduced in size. Sea level rise, in combination with human development, has contributed to increased erosion of coastal wetlands and mangroves. Coral reef habitats are threatened by many human activities, with warmer ocean temperatures blamed for increases in the global extent of coral bleaching. Coral bleaching is a stress response that involves the whitening of coral colonies because of the loss of symbiotic algae from the tissues of polyps. Bleaching can either slow or stop growth and reproduction of the colony. Changes in ocean acidity could have significant effects on shell-building organisms.

In some instances, the observed impact of climate change on individual species has had significant landscape-scale consequences. One example in the terrestrial world relates to changes in the mountain pine beetle life cycle that could alter forest wildfire regimes. A warmer climate allows insect pests that normally have a 2-year life cycle to complete their life cycle within 1 year. Being able to complete their life cycle within 1 year allows insect pests to survive in areas where their survival is currently limited by cold winter temperatures. For the pine beetle, this life-cycle change could portend more severe infestations with a warming climate. In fact, scientists have been monitoring the mountain pine beetle populations in Idaho since the late 1980s, and beginning in 1995, what had previously been small spot infestations in thermally favorable habitats grew into full-blown outbreak events. Extensive beetle damage to pine forests then plays a role in wildfire ecology by altering fuel loads. This example shows how minor changes in microclimate
can have significant effects on species distribution patterns and disturbance regimes at large geographic scales.

The ultimate concern from a conservation perspective is how climate change might affect species survival. Research by Pounds and Crump (1994) since the late 1980s suggests that the golden toad and Monteverde harlequin frog in Costa Rica are among the first documented species to have become extinct in response to recent climate changes. Their disappearance is linked to an increase in a fungal disease outbreak during warmer and drier conditions. Extinction rates are already considered elevated over natural background levels because of habitat modification and loss. Climate change is likely to exacerbate the challenges of preservation for many species already at risk.

Projecting Responses to Future Climate Change

As climate continues to change in response to human greenhouse gas emissions, we expect species distributions to generally shift poleward and up in elevation as the climate warms (figure 1). Relationships may not be quite that simple, however. Changes in precipitation patterns across the landscape may cause species to shift along other types of gradients that may not be north–south oriented. There may be decreases in suitable habitat or limitations on dispersal. Some habitats may disappear, and other new habitats may evolve (figure 2). Of particular interest is the possibility for the creation of nonanalogous climates or combinations of climate conditions that do not currently exist anywhere in the world. For example, what happens to a tropical rainforest when it gets hotter?

Complex interactions within communities also make predicting responses to future climate change difficult. As one portion of the community changes in response to climate change, there is the potential for a cascade of events to occur. Each individual species will not necessarily shift its behavior and geographic distribution in isolation, and different species will have different abilities to respond to change in a given time period based on the breadth of their niche as well as their dispersal abilities. The addition or subtraction of key species can have significant effects. This is why it becomes so difficult to make predictions at the community level. Classic examples of what are termed "trophic cascades" have shown that changes at one level of the food chain can percolate through many other levels, causing both direct and indirect effects on species composition. Understanding the importance of complex interactions among species will be important in predicting the potential consequences of climate change on ecological communities.

It is also important to remember that extinction has many causes. In many portions of the globe, multiple threats (e.g., habitat destruction or modification) will work in concert with climate change to affect future species distribution patterns. Jetz and colleagues forecast the numbers of birds likely to be endangered by climate change versus direct habitat destruction over the next 50–100 years. They foresaw a marked latitudinal difference: in the tropics, deforestation is likely to be the main driver of species extinction, whereas in the higher latitudes, it will be climate change (Jetz et al., 2007).

The main approaches scientists use to examine potential future impacts of climate change include experimental manipulations, analyses of historical observational records, and modeling. Experiments in the field and laboratory allow us to monitor ecosystem responses to directly manipulated climate conditions (box 1; Shaw et al., 2002). These experiments are usually conducted at a scale appropriate for the structure of the plant community being examined (i.e., tens of square meters for grasslands versus hundreds of square meters for forests), but they are often small in scale from the perspective of vagile organisms that may inhabit these locations. Manipulating ecosystems at the landscape rather than the patch scale becomes much more challenging in terms of both cost and logistics. Thus, scientists can examine some phenomena experimentally, but others are primarily studied via observational methods and models.

Figure 1. As climates warm, we may expect species to move up in elevation. For example, species A, B, and C exist on mountain ranges. Species A is restricted to the coldest habitats. As warming occurs, species A is left without suitable habitat, and species B and C move up the mountain. A new species, D, which previously occurred at lower elevations, is now found at the base of the mountain.
BOX 1. CLIMATE CHANGE EXPERIMENTS

There are many research methods that scientists use to manipulate global change factors. The most common warming manipulation techniques include active warming via suspended infrared heat lamps or electric coils buried in the soil and passive warming via greenhouse-like structures that raise ground level temperatures by trapping the heat from the sun (plate 18, upper left). Warming has been shown to modify important patterns and processes such as nutrient cycling rates, plant productivity, and plant community composition and diversity.

To examine the impacts of elevated CO₂ on plant communities in the field, a new technology was developed that pipes CO₂ into experimental plots (plate 18, lower left). Elevated CO₂ experiments in a variety of forest and grassland ecosystems suggest that increasing CO₂ levels will increase plant productivity, but that availability of other nutrients (e.g., nitrogen) could limit productivity increases.

Several field experiments have manipulated precipitation levels, using rain shelters to reduce the amount of precipitation entering plots or manual water applications to augment incoming precipitation amounts. For many of these studies, the timing and variability in precipitation extremes are as important as changes in the total amount of moisture entering experimental plots.

Multifactor experiments manipulate several of these environmental factors (e.g., temperature, precipitation, and CO₂) simultaneously (plate 18, right). These experiments provide insight into the ways in which factors interact to influence ecosystems and often show that the addition of multiple change factors does not result in additive effects on ecosystem response variables. For example, the CO₂, temperature, precipitation, and nitrogen deposition field experiment at Jasper Ridge, CA, found that each of those factors separately increased plant productivity; but when CO₂ was increased in conjunction with the other treatments, it served to suppress the positive response in plant growth (Shaw et al., 2002).
models include dynamic interactions, they are not able to capture species-level responses and can only predict changes in vegetation structure through the use of broad vegetation classes (e.g., alpine/subalpine forest, evergreen conifer forest, mixed evergreen forest, grassland, or shrubland).

**BOX 2. BIOCLIMATIC ENVELOPE MODELING**

Bioclimatic envelope modeling is based on Hutchinsonian niche theory and understanding the environmental conditions necessary for a species to survive and grow. The model-predicted species distributions are therefore related to the species’ climatic tolerances, and as climatic conditions change, so too will the location of a species’ bioclimatic envelope. Bioclimatic models assume that species track environmental changes by moving to keep up with the changing location of their bioclimatic envelope. Pearson and Dawson (2003) reviewed the use of bioclimate models and argue that bioclimatic envelopes might provide a first approximation regarding the changes that could be expected in species distribution patterns with climate change. Some problems with using bioclimatic envelope models to project impacts of climate change include the following: (1) limits to dispersal, which could make model predictions overly optimistic because some species may become extinct locally before they have a chance to move; (2) uncertainties related to model choice and future climate projections, which are often not considered; and (3) the difficulty of validating a model’s ability to predict future distributions.

**4. CONSEQUENCES OF CLIMATE CHANGE FOR CONSERVATION**

The ecological effects of climate change will have significant consequences for biodiversity conservation. Species and ecosystems that are currently protected in reserves may shift outside of fixed reserve boundaries, possibly rendering the original conservation intent of such protected areas obsolete. The loss of some species and additions of others may lead to novel species assemblages and to possible problems with exotic invaders. Although some species may theoretically be able to move in response to changing climate conditions, habitat fragmentation may impede the ability of other species to migrate and disperse.

The challenge for conservationists is determining how to manage and conserve the landscape in order to facilitate the adaptation of species and ecosystem processes to a changing climate. This is primarily being addressed through two approaches: changes in the way we manage areas that are currently under some form of conservation, and the prioritization of land areas for future conservation given the threat of changing climate.

**Managing for a Changing Climate**

The science of managing for climate change is currently in its infancy, and the language of this field is still developing. Strategies include whether to manage for resistance options (e.g., those that delay the effects of climate change), resilience options (e.g., those that increase the ability of the ecosystem to return to previous conditions following a disturbance), or response options (e.g., those that facilitate ecosystem changes brought about by a changing climate) (Millar et al., 2007). Monitoring to establish baseline conditions and quantify change is a first step in providing scientists with the tools to understand how ecosystems are responding to a changing environment. Adaptive management—modifying management approaches over time as the manager obtains a better understanding of the system—will be an important approach to dealing with climate change. For example, if wildfire frequency increases with warmer temperatures, a manager might want to modify the way that wood is harvested to maximize the placement of fire breaks or minimize the amount of standing dead trees that could provide fuel for a fire. However, even if a manager knows the current status of the system, there are several challenges inherent in dealing with climate change: (1) developing a baseline for comparison; (2) understanding time lags; and (3) consideration of entirely new management approaches.

Establishing target conditions for an ecosystem is contingent on (1) knowing the preexisting conditions of an ecosystem at particular times in the past and (2) deciding what time period is appropriate to use as a baseline. With respect to carbon dioxide and other greenhouse gases, we can compare the concentrations of gases in the atmosphere to those of preindustrial times. However, it may be more difficult to decide on baselines with respect to the distribution and abundance of species or the frequency of disturbances such as fire or flooding. We know that humans have changed the frequency and the distribution patterns of both biotic and abiotic components of the ecosystem. However, determining what is a “natural” level of variation and what baseline is appropriate as a goal can provide fodder for a plethora of scientific discussions.

We also know that in studying climate change, there are ecosystem memories, time lags, and threshold responses that may blur our ability to discern direct effects of climate change. As an example of an ecosystem
“memory,” decades after a modification such as plowing, the attributes of the soil reflect that previous management. Time lags may be apparent in the ways that plants and animals respond to drought, one of the conditions predicted to become more severe for some portions of the globe. For example, plants with deeper root systems may be able to obtain water from deep within soil horizons, whereas plants with shallow roots may be more immediately affected. Multiple years of drought may be needed before woody plants such as trees and shrubs exhibit any significant changes (a threshold effect), whereas grasses and flowering plants may show changes much more quickly. Aquatic ecosystems may also have lag times in responding to climate change. Ice-out and freeze-up dates for lakes are already changing, modifying the length of the growing season. Lakes in temperate areas are driven by fall and spring turnover events, which occur when lake water hits a threshold temperature. If temperatures change dramatically, the frequency and/or timing of lake turnover could change, affecting the distribution of dissolved oxygen and nutrients within the water column. Such changes could have significant ramifications for all portions of the aquatic community. So, in analyzing responses to climate change, it will be essential to remember that time lags and threshold effects may blur our ability to detect change and that the patterns we discern may not always be linear.

Managers dealing with climate change will need to think outside of the box and contemplate new management approaches for conservation. For example, in some cases managers may consider assisting the movement of those species that cannot move fast enough to keep up with the rapid pace of climate change. This “assisted migration” approach to management will undoubtedly be costly, and managing so intensely for one species may preclude the options for another species. A variety of other management approaches that have not previously been used may need to be considered. There will undoubtedly be trade-offs in prioritizing such actions. The bottom line is that systems will be operating outside of the bounds of what was previously considered normal, and creative solutions may be in order.

**Prioritizing Landscapes for Conservation under a Changing Climate**

Our current network of fixed-boundary protected areas will be insufficient in the face of climate change. Therefore, we need to think about the conservation of additional areas and the linkages between them. Over the last few decades, one focus of conservation biology research has been on how to systematically select a portfolio of conservation sites in order to maximize their ability to protect biodiversity. A particular challenge is how to design reserves that protect the “persistence” of biodiversity through time, not just the presence of a species or a type of landcover at one point in time. Several studies have shown that efficient reserve networks that represent the optimal number of species given the cost do not necessarily protect that entire set of species over time because of fluctuating metapopulation dynamics. The challenge presented by the issue of biodiversity persistence is similar to that presented by future climate change, where we are interested in preserving the persistence of biodiversity on the landscape under changing climate conditions. A particular concern is how protected areas with fixed boundaries will be able to protect species that move across the landscape in response to changing climate.

Some initial ideas on how to design reserves in the face of climate change were based on simplified assumptions about how species distributions might respond to changing climate, including connecting reserves at different latitudes or creating reserves that stretch up and down mountains. To more rigorously examine how climate change–induced species range shifts might affect conservation planning efforts, researchers are combining bioclimatic envelope models (box 2) with systematic reserve design selection tools (see chapter V.3). In one study, Araujo et al. (2004) found that reserve designs that were optimized for species protection under current climate conditions in Europe could lose ~6–11% of plant species by 2050 because of climate change–induced shifts in species distributions. Using similar modeling approaches in Europe, Mexico, and South Africa, Hannah and colleagues demonstrated that taking into account the effect of future climate change on species ranges when planning conservation areas today was less costly (in terms of area) than delaying action to a later date (Hannah et al., 2007). Moreover, the habitat areas these species will need in a warmer world may not be around if we wait too long to acquire or protect them. These results argue for increased consideration of climate change in systematic reserve design approaches being applied today.

Across the globe, centers of species distribution may move toward poles or up in elevation. In some cases, species may be stranded and literally have no place to go. Species that live in alpine habitats may simply lose their habitat if there is no additional space further up the mountain (figure 1). Alternatively, species that exist nowhere near another suitable habitat patch may not have many options for dispersal. In many small native prairies and wetlands in the Midwestern United States, species are barely hanging on and are surrounded by a
of inhospitable landscape dominated by intensive agriculture. Movement across such areas could effectively be “suicidal dispersal.” There have been some efforts, especially at the local level to create roadside prairies and riparian buffers between cropfields and waterways. These areas may provide “stepping stones” for some species (e.g., butterflies, birds, small mammals), but it is unrealistic to envision a future where large organisms (e.g., bison) travel between prairies via roadsides.

Synergies with other environmental changes, such as habitat loss and fragmentation, will potentially have large effects on species’ abilities to adapt to changing climate. Habitat loss and fragmentation caused by human modification of the landscape are some of the most significant threats to species worldwide. In many areas, the landscape is sufficiently fragmented to inhibit the movement of species as they attempt to track changing climate conditions. The concept of using corridors to connect fragmented habitats and create a more permeable landscape is a popular idea, and scientists are beginning to document the effects of corridors. However, creating corridors that facilitate movement of species from one patch to the other is easier said than done. A corridor that provides connectivity for large mammals may create a predation trap for smaller mammals, reptiles, or amphibians. In addition, the construction of large corridors can be extremely expensive, as observed by the cost involved in creating highway overpasses to connect large blocks of habitat fragmented by the Trans-Canada Highway in Alberta’s Banff National Park. Furthermore, we cannot simply focus on reserves and corridors but must consider the matrix of landscapes and land uses that occur between them.

5. THE MISSING LINKS

Present models of climate change are primarily global models. Scientists are working to “scale down” these models to create regional models. However, they are still a long way from providing specific information about how each portion of the globe is expected to change. Regional predictions will be essential to planning conservation efforts for most species of concern.

Even after more specific regional models are developed, scientists will need to better understand how species move through landscapes and what types of habitats are acceptable in order to make predictions regarding the effects of climate change at a species-specific level. Reserves that were previously acceptable habitat may become unacceptable. Vigilance will be a key predictor of response. Those species that are able to disperse sufficiently to keep up with the pace of changing climate may be able to maintain viable populations, whereas less mobile species may become stranded in unsuitable habitats. Behavioral and demographic studies will be needed to quantify habitat use and to classify sites as sources or sinks. Finally, many traditional conservation efforts have been species specific and focused on a few charismatic megafauna. The pervasive nature of climate change demands that landscapes be managed from the perspective of preserving biodiversity and the larger ecological communities. This does not reduce the importance of species-specific conservation measures and research, but it means that conservation must be approached from multiple perspectives.

From the community perspective, there has been some progress in combining biogeographic models with reserve design algorithms to consider the impacts of climate change on reserve design. However, there have been relatively limited on-the-ground efforts at putting that theory into practice. Experimental manipulations as well as long-term monitoring efforts will be needed to test the adequacy of existing reserve systems over time.

Finally, in planning for climate change, one of the most important things to remember is that scientists and managers will need to examine issues from a global perspective. Planning at the regional and continental scale may be adequate for some issues, but weather patterns, ocean circulation, and many climatic phenomena occur at a global scale. Narrow corridors connecting small patches of landscape may not be adequate to deal with this scale of change. Neither the forces of climate change nor the organisms of concern will pay heed to political, state, or national boundaries. Management will need to be envisioned at large geographic scales. A global approach will require that managers, politicians, and scientists work together in ways that they have not done so before. Just as our economy has become a global economy, our solutions to climate change will undoubtedly require international cooperation in terms of resource use, species conservation, and landscape management.

FURTHER READING


