Conservation Biology

Special Section: Ecological Responses to Contemporary Climate Change within Species, Communities, and Ecosystems

Introduction

Changes in contemporary climate are profoundly influencing most, if not all, aspects of ecology and human society (e.g., Randolph 2001; Brook 2008; McClean et al. 2008; Williamson et al. 2009). Recent shifts in species ranges and phenologies, and changes in hydrology, fire regimes, and the distribution of pests and pathogens are just a few of the now well-documented changes that have been linked to recent climatic changes (Parmesan 2006; Westerling et al. 2006; IPCC 2007). Projected future climate-driven changes in the Earth's physical and biological processes will likely result in dramatic changes in ecological systems and the provision of ecosystem services (IPCC 2007). To address climate change, conservation biologists and practitioners will need a diverse array of information including estimates of its present and projected ecological effects.

The increasing demand for information that will help conservation scientists and natural resource managers better respond to these new challenges stimulated a special symposium on rapid climate change at the 14th Annual Conference of The Wildlife Society. The papers in this special section resulted from that symposium. These papers provide a foundation for interpreting and understanding key aspects of climate (Serreze 2010 [this issue]); consider future responses at species, community, and ecosystem levels (Previtali et al. 2010 [this issue]; Cole et al. 2010 [this issue]); explore the issues of scale when translating climate-change projections into conservation action (Wiens & Bachelet 2010 [this issue]); and evaluate the adequacy of current conservation approaches (Hannah et al. 2010 [this issue]).

Basis of Change

An understanding of the climate system is crucial for forecasting changes and developing climate scenarios for conservation planning. Serreze (2010) introduces key concepts and addresses several questions related to model sensitivity and feedback mechanisms critical to the ability to model the Earth's climate. He describes climate forcings and feedbacks, such as the Arctic amplification process associated with sea-ice losses. Serreze relates these arctic changes to global changes and cautions that although virtually all climate models suggest declines in sea-ice cover in the Arctic, most models underestimate the magnitude of loss. Better understanding of the relative roles, various radiative forces and feedbacks have on climate change, will undoubtedly lead to refinement of future predictive models and thus improve climate-change projections.

Effects on Species, Communities, and Ecosystems

Several of the papers in this section address observed and expected effects of climate change across a broad range of spatial and temporal scales. Previtali et al. (2010) describe a long-term study of degus (*Octodon degus*), a small Chilean rodent, that clearly links changes in fecundity and survival to El Niño Southern Oscillation events at the northern geographic extent of the species' range. This is one of only a few studies that reveal an empirical link between changes in climate and small-mammal population dynamics. Specifically, Previtali et al. found that variation in rainfall across years is the main driver of temporal variation in survival and fecundity in this species. Wetter conditions, a consequence of El Niño events, results in longer degu breeding seasons and a higher proportion of reproductively active females. Under such conditions, degus fare better than smaller-bodied, more-irruptive mammal species. Consequently, this represents one of few instances in which long-term monitoring data at the species level have been clearly linked to higher-order changes in communities and ecosystems.

Cole (2010) and Lawler et al. (2010 [this issue]) take a broader view of the impacts of rapid climate change. Although most of the papers in this special section rely on contemporary data, Cole used packrat-midden data representing a 23,000-year paleorecord to provide a perspective on secondary succession of plant communities in response to ecological disturbances such as rapid climate warming. The most recent period of relatively rapid warming—approximately 4 °C over less than a century—occurred about 11,700 years ago, at the start of the early Holocene. Fossil plant assemblages from the Grand Canyon, Arizona, illustrate that plant community composition, especially in low-productivity systems, may lag behind contemporary climate by millennia, rather than being in perpetual equilibrium or equilibrating in several decades, as is often assumed. Cole's results suggest that vegetation mapping over time should separate

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rapid- from slow-colonizing species to most sensitively detect secondary succession. His results also have implications for forecasting future distributions of exotic and ruderal native plant species.

Lawler et al. (2010) analyzed potential effects of climate change on species distributions over a much larger area. They linked climate projections with data on amphibian species distributions to estimate likely climate-driven turnover in species assemblages for more than 400 amphibian species in South, Central, and North America. The projected impacts are substantial, with average turnover rates exceeding 60% in the most severely affected regions. Lawler et al. augment the results of their climate-envelope modeling by analyzing the potential for climate-driven changes in hydrology and by summarizing the distributions of an additional 1099 amphibian species with relatively restricted ranges—species with distributions that cannot be easily modeled, but that will likely be disproportionately affected by climate change. Together, these analyses provide a geographic assessment of climate-change vulnerability for amphibians of the western hemisphere. The assessment highlights the potential for changes in the abundance and distribution of amphibians throughout the western hemisphere, but especially in Central America, the Andes, and several other regions. The results provide yet another prediction of biotic change, characterize the potential magnitude of the effects of rapid climate change that may occur in the 21st century, and highlight the need to establish regional-scale conservation plans that better link protected areas and provide for the movement of species that must track habitat shifts to persist.

Issues of Scale

To incorporate climate change into conservation planning, planners and scientists will have to overcome some significant challenges. Perhaps one of the most pressing is the mismatch between the scale at which conservation planning and management occur and the scales at which climate projections are made. In their essay, Wiens and Bachelet (2010) discuss the need for climate-change and climate-impact projections at the multiple scales relevant to conservation planning. They discuss the uncertainties inherent in climate projections, focusing on multiple issues associated with downscaling of climate data from coarse-resolution, general-circulation-model and regional-climate-model output, to finer resolutions needed for some regional and local planning and management. They also provide examples of metrics that can facilitate integration of climate change and conservation across spatial and temporal scales.

Responding to the Challenge

The final pair of papers in this section address the need for conservation practitioners to integrate effects of climate change into existing management strategies (Hansen et al. 2010 [this issue]) and the need for a vastly expanded set of partnerships to effectively preserve biodiversity in the face of rapid climate change (Hannah 2010). Hansen et al. 2010 address the currently widespread practice of conservation planning that is based on a static climate and suggest a more appropriate approach which they base on four tenets that incorporate temporal shifts in species' distributions and ecosystems in the face of rapid climate change. The authors describe the adaptability required in management strategies necessary to aid in reduction of environmental effects of climate change and emphasize the need to address root causes of change. Hansen et al. then provide a series of examples in which these strategies are in various stages of implementation, from conservation efforts to mitigate bleaching of coral reefs in Florida to a national vulnerability assessment in response to climate change for marine and terrestrial ecosystems in Madagascar. The authors recognize the challenges associated with shifting conservation paradigms; however, they suggest that consequences of retaining current practices are dire.

In the final paper, Hannah (2010) critically evaluates international policy, worldwide efforts, and changes that will be necessary to face the challenges of the future. Hannah reviews evidence that suggests that as climates change, species' ranges will shift, disturbance regimes will be altered, and ecosystems will undergo profound changes. In his essay, Hannah suggests that one of the best responses to these changes will involve expanding reserve networks in a systematic, coordinated way. To be effective, he argues, international coordination will be necessary. His essay outlines a strategic framework for an international approach to conservation planning and management to address climate change. Hannah illustrates this approach with examples of how such a framework could address conservation of large marine species in international waters, of Edith's checkerspot butterfly in Mexico and California, and the quiver tree in southern Africa. Implementing such a framework will be costly. Hannah provides suggestions for funding mechanisms based on carbon credits that specifically provide subsidies to countries that emit fewer greenhouse gases, but will bear disproportionate impacts of climate change.

Conclusion

These papers underscore the breadth, extent, and magnitude of challenges posed by rapid climate change. Climate change is certain to affect virtually every aspect of not only conservation science but society as a whole, and development of effective responses requires an unusually inclusive and deep knowledge. Collectively, these papers reflect this breadth, and provide insights from disciplines ranging from physical climatology, to community ecology, to international policy. They contribute to a deeper understanding of the challenges conservation practitioners and natural resource managers face and to development of more-informed and appropriate responses to those challenges.

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