



Conservation of Biodiversity in a Changing Climate

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Introduction

The notion of conserving communities and ecosystems as they presently exist may soon be obsolete. Projections of human-induced climate changes and evidence of past rapid climate shifts indicate that patterns of biodiversity may change over landscape scales over time frames as short as decades. New, dynamic conservation strategies are needed to accommodate the natural and human-induced changes in climate that present evidence suggests are inevitable. At the same time, future climate change must be constrained. If it is not, even expanded, dynamic conservation efforts will ultimately be overwhelmed.

The stakes are high. The political barometer of average global temperature increase in 2100 masks the magnitude of possible effects on biodiversity in both time and space. Changes in temperature over continental areas will be higher, possibly more than double the global average in some areas, because sea surface temperatures are lower and change less. The end-of-the-century global average misleads in time because, under present greenhouse-gas emissions trends and most reduction scenarios, warming will continue well beyond 2100. Biodiversity will have to cope with the ultimate temperature change, not just the end-of-the-century political yardstick. Of course, climate change is much more than just temperature change, so biodiversity also will be con-

fronted with changing rainfall patterns, declining water balances, increased extreme climate events, and changes in oscillations such as El Niño.

A two-pronged response is required. First, those concerned about biodiversity need to become an important voice in the global warming debate. Biodiversity scientists have strong reason to become an active constituency and to advocate that global greenhouse-gas emissions be reduced in real terms. Second, we must use our skills to develop conservation strategies to help biodiversity survive the climate changes that will result from greenhouse-gas emissions, both those already in the atmosphere and those that are apparently unavoidable under present abatement agreements.

Assessing the Changes

Researchers, policymakers, and conservationists now widely agree that the Earth's climate is changing (Peters & Lovejoy 1992; Hughes 2000; Intergovernmental Panel on Climate-Change 2001 [IPCC]). The recently released third assessment report of the IPCC estimates global mean warming this century of up to 5.8° C in the extreme (IPCC 2001a). This report makes it clear that climate-change effects on the distributions, life histories, and even survival of species are already being documented (IPCC 2001b). A series of recent country assessments, such as those for the United States (U.S. National Assessment Synthesis Team 2000), South Africa (Kiker 2000), and Canada (Environment Canada 1997), project major biotic changes in the near future.

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A decade ago, climate change may have seemed distant and uncertain, but these assessments make it clear that this is no longer the case. Instrumental records and a series of proxies show that climate is changing and global mean temperatures are rising. Physical effects, such as the melting of glaciers and the rise of the 0° C isotherm in the tropics are well documented. These changes are already producing measurable ecological changes. Dozens of studies are documenting changes in phenology, species ranges, and ecology due to climate change. Butterflies in North America have shifted northward in range, trees are blooming earlier in Eastern Europe, and tropical bird species are shifting their range upslope (Hughes 2000).

These changes will accelerate with climate change, resulting in serious future changes in biodiversity. For example, the first regional modeling of climate-change effects on biodiversity hotspots, reported in the South Africa country study, suggests major vegetation shifts in the Succulent Karoo and Cape Floristic Region hotspots of South Africa (Rutherford et al. 1999). The highly diverse and endemic arid flora of the Succulent Karoo is projected to collapse southward under a scenario of doubled levels of carbon dioxide (CO₂) (Fig. 1). In this scenario, the Succulent Karoo hotspot loses more than 80% of its range and its future range becomes largely disjunct from its present distribution. Five parks in South Africa are projected to lose more than 40% of their plant species (Rutherford et al. 2000).

The U.S. and Canadian studies reflect the high cost to biodiversity even outside hotspots. In Canada, 75–80% of national parks are expected to experience shifts in dominant vegetation under scenarios of doubled levels of CO₂ (Scott & Suffling 2000). Analysis of vegetation response in the Yellowstone National Park region of the United States revealed regional extinctions and the emergence of communities with no current analogue. Considered together, “. . .the floristic reorganizations are of a magnitude not seen in the late-Quaternary paleoecological record” (Bartlein et al. 1997:788). Warming of 3° C in the Great Basin of the United States has been predicted to result in the loss of between 9% and 62% of mammal species inhabiting mountain ranges in the region (McDonald & Brown 1992).

Finally, assessments from other disciplines indicate that climate change may disrupt human systems and change the context in which biodiversity conservation must take place (Rosenzweig et al. 2000). Human agricultural systems have evolved in the current 10,000-year anomaly of a warm and stable environment and have not had to cope with rapid changes in climate. Although agribusinesses in temperate countries are already investing in developing strategies for response to climate changes, many subsistence farmers will not have ready access to climate information or adaptive options. The lack of information available to small-scale producers of

tropical foodstuffs, including some global commodity crops (i.e., coffee, cocoa, soy), creates the risk both of breakdown in food production and of creating social systems in which management of biodiversity may become impossible. The greatest number of subsistence farmers, and the greatest risk of social breakdown, is in the tropical countries where biodiversity is highest.

Conservation Responses

Conservation of biodiversity in a changing climate requires both limits on change and conservation strategies responsive to changes that are inevitable. Conservation strategies at a scale and with objectives that explicitly address the potential effects of climate change are required. We call these *climate change-integrated conservation strategies* (CCS). Although these strategies must be tailored to individual regions, to be successful each CCS needs to include five key elements:

- (1) regional modeling of biodiversity response to climate change;
- (2) systematic selection of protected areas with climate change as an integral selection factor;
- (3) management of biodiversity across regional landscapes, including core protected areas and their surrounding matrix, with climate change as an explicit management parameter;
- (4) mechanisms to support regional coordination of management, both across international borders and across the interface between park and non-park conservation areas; and
- (5) provision of resources, from countries with the greatest resources and greatest role in generating climate change to countries in which climate-change effects and biodiversity are highest. To adequately respond to the uncertainties posed by climate change, the provision of resources will be required on a much larger scale than has occurred to present.

Our evolving understanding of climate dynamics suggests that natural processes may form the basis of these strategies. Global climate changes on millennial scales were first suggested by Greenland ice-core studies in 1993 (Dansgaard et al. 1993). Since then, changes on time scales of centuries or even decades have been documented and the global nature of these changes confirmed (Broecker 1999). This suggests that a biotic response to rapid climate change has occurred in the past and that response to future rapid human-induced climate change may be possible through natural processes. Artificial translocation, previously proposed as the primary conservation response capable of keeping pace with human-induced climate change (e.g., Peters 1992), can be minimized with the careful design of dynamic conservation systems that operate on a landscape scale.

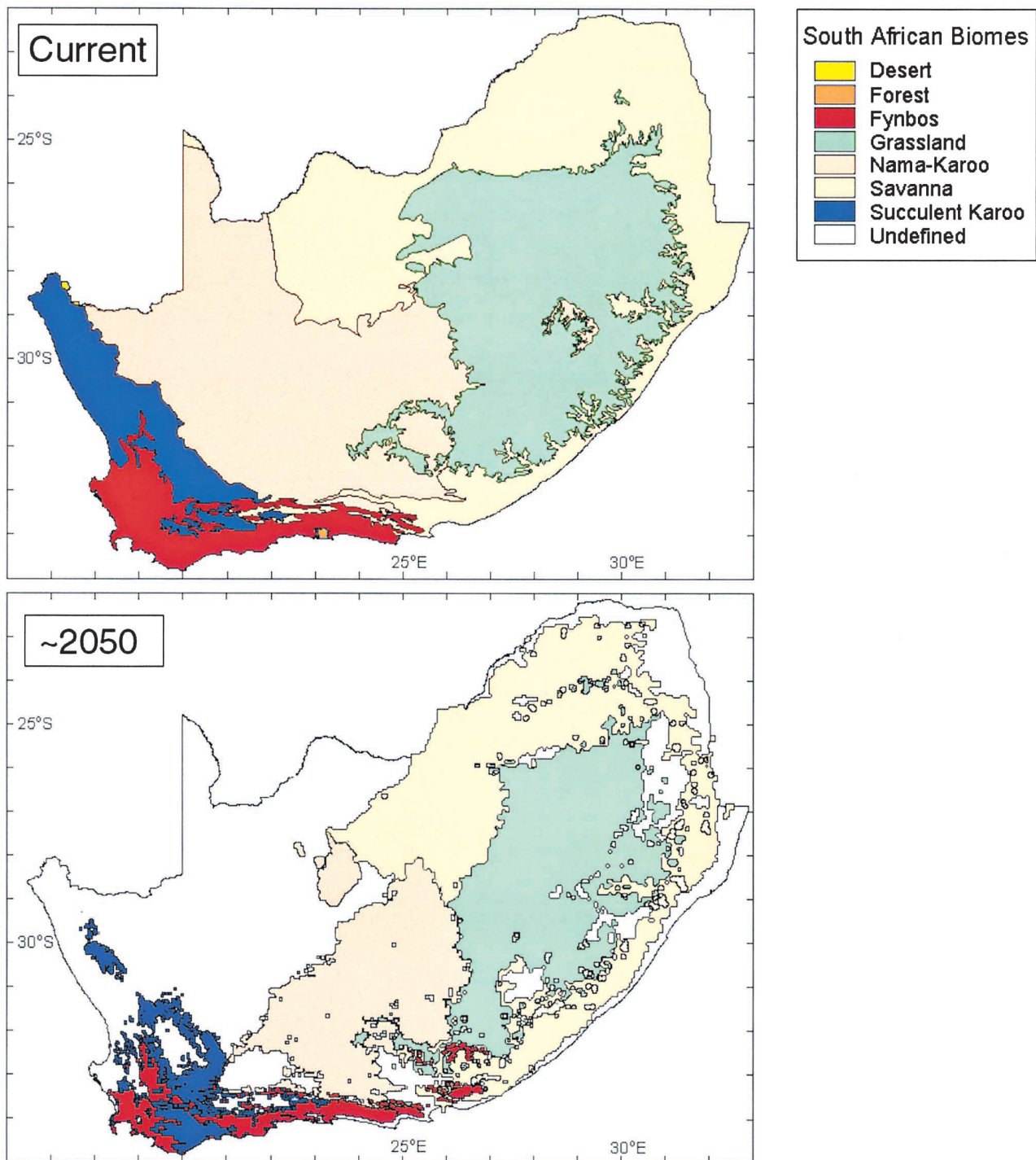


Figure 1. Biome changes projected for South Africa, using the HadCM2 model with sulphate amelioration, in a scenario of doubled carbon dioxide. Major shifts are predicted for all biomes. The Succulent Karoo (orange) and Cape Floristic (red) regions along the west coast are global biodiversity hotspots of high diversity and endemism. Note the southward collapse of the Succulent Karoo hotspot. Source: South Africa Country Study on Climate Change (Rutherford et al. 1999).

Modeling of the magnitude and direction of expected vegetation and habitat changes is an essential first step. Global models have inadequate resolution for conservation planning, so this modeling must be done on a re-

gional level. Known climate tolerances of many species can be used to help predict potential future range changes. This information can be used in the design of protected-areas systems and for the management of the

matrix between protected areas for range movements at a landscape scale.

To allow natural changes in biodiversity across a fragmented landscape during climate change, conservation strategies must expand their planning further into the future, a process that implies protection of future patterns of biodiversity as well as present patterns and thus the expansion of the number of specific sites that must be conserved. Under the present static conservation paradigm, we place little emphasis on changing patterns of biodiversity over time due to either natural or anthropogenic climate change in our protected-areas systems. Strategies now employed to protect and manage biodiversity remain anchored in static views of climate that see the climate of the future much like the climate of the past. Most reserve areas were established on an ad hoc, space-available basis or according to political feasibility, approaches that make systematic response to biodiversity or climate variables impossible (Noss & Harris 1986). Biodiversity analyses in the 1970s spawned a new focus in systematic reserve selection, yet reserve-selection algorithms do not incorporate changes in biodiversity distribution due to global climate change (Cowling 1999). Few reserve systems or reserve management objectives have been formulated with reference to climate change, even in countries where effects are projected to be large (Scott & Suffling 2000). Both the design and functioning of the global protected-areas estate is therefore at risk due to the unspoken assumption of a stable climate. Revision of designs of protected-areas systems based on the CCS approach and regional modeling results can help reverse this vulnerability.

At the same time, a growing conservation movement advocates regional reserve networks, landscape connectivity, and management of the matrix between core reserves, all concepts that are key in effective conservation responses to climate change (Noss & Harris 1986; Noss et al. 1999; Soulé & Terborg 1999; Gascon et al. 2000). The relevance of these tools to climate-change adaptation has been recognized, but not explicitly developed (e.g., Noss & Harris 1986). To be fully effective, regional reserve networks and landscape connectivity must be wed with effective modeling of future climate change and managed specifically for climate change. For example, a multiple-use matrix currently managed primarily to reduce edge effects in core reserves may have to be managed as primary habitat in the future. Landscape connectivity and management of the matrix for biodiversity will be required on an unprecedented scale to avoid large numbers of extinctions due to climate change. The pattern and process of ongoing habitat destruction makes this an immense challenge.

As CCS management expands across protected-area boundaries to include the matrix, it also will have to be coordinated across political subdivisions and international boundaries. Species range shifts will not respect

political boundaries either, so effective conservation will require new regional collaboration in management. Interstate, interprovincial, and international management strategies need to be framed to identify, monitor, and jointly manage species and habitats vulnerable to climate change.

All of these efforts are new and require new resources. Effects on biodiversity will be greatest in tropical countries with the highest levels of biodiversity and the lowest financial and technical capacity. An already strained international dialogue on the origins of and responses to climate change needs to incorporate these issues.

Limiting the Damage

Ultimately, no conservation system, no matter how large or dynamic, can succeed in the face of unlimited change. Temperatures projected for the end of the century may already represent the warmest global climate in over 2 million years. Landmark events, such as the melting of all tropical glaciers, will punctuate an environment different than any in the evolutionary history of most modern species. Further changes may exceed the natural response capacity of a large number of species.

Political advocacy for emissions reductions is essential if biological changes are to be kept within manageable limits. The importance of natural systems as a benchmark of emissions reduction is already recognized in international agreements. The United Nations Framework Convention on Climate Change (Article 2) specifically recognizes the critical link between climate change and the natural capacity of ecosystems to adapt: "The ultimate objective of this convention is. . .stabilization of GHG [greenhouse gas] concentrations in the atmosphere. . .*within a time-frame sufficient to allow ecosystems to adapt naturally to climate change. . .*" (emphasis added).

It falls to biologists to advocate that the benchmark of adaptation is the full complement of the world's species and not just a weedy, fast-dispersing subset. Present international targets for greenhouse gas emissions would allow temperature increases that would result in large-scale shifts in vegetation, risking widespread extinction of species unable to shift due to dispersal limitations or disappearance of suitable habitat. They also risk the breakdown of human food-production systems in ways that will encourage increased pressure on natural areas. Effective lobbying for more rapid emissions reductions and stabilization of greenhouse gas concentrations nearer present levels could help avoid these changes. Essentially, conservationists must extend policy efforts beyond the terrestrial and marine realms to include the atmosphere.

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