1. The Future of Biodiversity in a Changing World

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The expansion of human populations and their increasing consumption rate and access to technology have led to two general environmental concerns (NRC 1994; Vitousek et al. 1997): (1) the increasing human impact on the earth's environment and ecosystems through changes in the carbon pools of the biosphere, element cycling, and climate, and (2) changes in the earth's biota and communities, including species introductions and extinctions, and the fragmentation of natural communities through changes in land use. These changes are occurring more rapidly than at any time in the last several million years. These two areas have received largely separate research efforts to date, the first by ecosystem ecologists and the second by conservation biologists and community ecologists. Individual organisms, however, gain carbon and nutrients from the environment, transfer plant tissues to higher trophic levels, and decompose plant litter, and these organisms function within a complex landscape mosaic. It would be surprising, therefore, if the traits of individuals and their abundances and diversity did not determine ecosystem and landscape traits and processes (e.g., the pool sizes and rates of energy and material flux at local or regional scales). Species also have substantial indirect effects on ecosystem processes through shading, thermal insulation, tissue-quality effects on decomposition, and the like. We therefore expect that global environmental change could have substantial *indirect* effects on ecosystem processes through its effects on the species composition and diversity of communities and landscapes.

Changes in biota of ecosystems result from habitat conversion and land-use change, which reduces genetic and species diversity, from environmental changes, which causes changes in competitive balance, and from the introduction of exotic species, which leads to a gradual homogenization of the global biota. In addition to the ethical, aesthetic, and economic concerns raised by this situation, these biotic changes will likely influence ecosystem processes sufficiently to alter the future state of the world's ecosystems and the services that they provide to humanity (Chapin et al. 1997). The current global extinction rate, which is 100- to 1000-fold greater than prehuman levels (Lawton and May 1995; Pimm et al. 1995), and the loss of local diversity due to management practices have the potential to affect ecosystem processes strongly at both local and global scales.

It is becoming increasingly clear that biotic change is not simply a consequence of global environmental change; rather, it is also an important *driver* of global change through massive increases in both species invasions and extinctions. Humans depend strongly on biological resources for food, construction materials, medicine, and energy. Humans currently directly or indirectly use most of the available resources of the biosphere (Vitousek et al. 1986). These resources are in principle renewable and, with proper management, can be used sustainably. Human use unfortunately often exceeds the renewal capacity, after which the biological resource base becomes degraded. Resource management thus ultimately defines the fate of biodiversity.

The recognition of the functional importance of biodiversity resulted in the wide adoption of the Convention on Biological Diversity at the UNCED Earth Summit in Rio de Janeiro in 1992. The main objective of this convention (Article 1) is to conserve biodiversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising out of its utilization. The convention encourages parties to develop national strategies for conservation and sustainable use, which are linked with other environmental and societal issues (Article 6), and to develop monitoring systems to identify and quantify the processes and activities that threaten biodiversity (Article 7). The convention focuses on protected areas as a strategy to conserve biodiversity (Article 8). These are areas where natural habitats and viable populations can be maintained and the influence of humans and exotic species is reduced. The convention also promotes the development of research, training, educational, and awareness programs (Articles 12 and 13). Finally, the convention urges the parties to develop the appropriate assessment capacity to evaluate processes and activities that potentially can have an adverse impact (Article 14). This article led to the Global Biodiversity Assessment (Heywood and Watson 1995), which presents and discusses many aspects of biodiversity, changes therein, and some of the causes of change. Some central questions arising from the Convention on Biological Diversity are:

1. How do humans influence biodiversity?
2. What are the underlying causes for these influences?

3. What are the sociocconomic and ecological consequences of changes in biodiversity?

The ultimate question is probably:

4. How do human-induced changes in biodiversity (and the species and ecosystems responses to these changes) affect the societal goods and services provided by biodiversity?

These questions remain largely unresolved. Most of the literature on global change and diversity focuses at the genetic and population levels or describes regional variation in species and community diversity (Leemans 1996). There has been surprisingly little attention in the global change literature to the patterns or causes of change in diversity or its ecosystem and societal consequences. Arising from the growing concern about loss of biodiversity, an international program (Diversitas) was launched to (1) monitor changes in biodiversity, (2) determine the origin and maintenance of biodiversity, and (3) determine the causes and consequences of these changes. The Scientific Committee on Problems of the Environment (SCOPE) launched a program in 1991 that synthesized the current scientific understanding of the relationship between ecological complexity and ecosystem functioning (Schulze and Mooney 1993; Mooney et al. 1996). This international synthesis provided evidence suggesting that biodiversity might affect both the day-to-day functioning of ecosystems and the resilience with which ecosystems respond to environmental change. It also provided a framework for predicting how future changes in biodiversity might influence ecosystem processes that are relevant to society.

The Intergovernmental Panel on Climate Change (IPCC) developed scenarios of changes in climate, atmospheric composition, and land use. These scenarios have had considerable impact on national and international policy and in guiding research. As described earlier, however, biological diversity is changing simultaneously with these other global changes. Because of the rapid changes in biodiversity, it seems equally critical to develop plausible scenarios of future change in biodiversity to guide researchers in understanding its ecological consequences and to guide policy makers in carrying out the agreements reached in the Global Biodiversity Convention.

The purpose of this book is to develop future scenarios of biodiversity for the twenty-first century in 10 terrestrial biomes and in freshwater ecosystems based on global scenarios of changes of the environment and the understanding by ecological experts of the sensitivity of biomes to these global changes. Chapters 2 and 3 describe the general patterns at the global scale of the drivers of biodiversity change. Chapters 4–14 describe, for each biome, patterns of biodiversity, the major threats, and the expected patterns of change. Finally, Chapter 15 synthesizes all of the biome information into a common framework and develops global biodiversity scenarios.

Our definition of *biodiversity* includes diversity at levels from genetic diversity within species-to-species diversity to landscape diversity. The long-term goal of these biodiversity scenarios is to describe the ecosystem consequences of its change in terms that are useful to ecologists, managers, and policy makers so this information can be used to guide policies influencing land development, reserve design, and so on. The information here in is intended as the first step toward the development of that framework. Future efforts must provide sufficient regional detail to be useful for development of management policies at national and regional scales.

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