

# Changes in Biodiversity and Their Consequences for Human Health

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Human actions and their effects on the environment are indisputably the major forces driving changes in biodiversity at both global and local levels. Human-driven climate change, habitat destruction, invasive species introductions, and nitrogen deposition all result in biodiversity losses (Sala et al. 2000). Some of the general impacts of impoverished biodiversity include decreased food production, decreased food security, the loss of resources for indigenous medicine, diminished supplies of raw materials for new pharmaceuticals and biotechnology, and threats to water quality (Grifo and Rosenthal 1997). There is general agreement among the scientific community that maintenance of natural levels of biodiversity is necessary for proper ecosystem functioning and the provision of ecosystem services (e.g., the benefits people receive from nature) to humankind (Chapin et al. 2000; Schulze and Mooney 1994). Research indicates that it is the diversity of biota across the world's ecosystems that underpins the capacity of the Earth's ecosystems to provide most of its goods and services (MEA 2003; Rapport, Costanza, and McMichael 1998; Sala et al. 2000; Schulze and Mooney 1994; WRI 2000).

However, impacts on human health have largely been focused on direct impacts, such as rising human disease exposure due to increased disease vector populations left unchecked by predators. While such blatant consequences of anthropogenic disruption are important, they represent only a fraction of unwanted outcomes. More subtle and more indirect effects have often been suggested, but very few rigorous scientific studies document explicit links between natural biodiversity, its degradation, and human health.

Several authors have addressed the link between biodiversity and ecosystem functioning (Chapin et al. 2000; Folke, Holling, and C. Perrings. 1996; Schulze and Mooney

1994; Schwartz et al. 2000), but it is still unclear which ecosystem functions are primarily important to sustain our health. Nonetheless, four general types of “human health functions” of ecosystems can be distinguished. First, ecosystems provide us with basic human needs, such as food, clean air, clean water, and clean soils (i.e., ecosystem services). Second, they prevent the spread of disease through biological control. Third, ecosystems provide us with medical and genetic resources that are necessary to prevent or cure diseases. Finally, biodiversity contributes to the maintenance of mental health by providing opportunities for recreation, creative outlets, therapeutic retreats, and cognitive development (de Groot et al. 2002). Thus biodiversity loss may result in compromised ecosystem functions, which, in turn, may negatively influence human health, both directly and indirectly. In this book, we review each of the four general human health functions of ecosystems in turn, highlighting the urgent need for more detailed and comprehensive research on the human health consequences of biodiversity loss.

### Previous Efforts

In 1997, Island Press published a volume titled *Biodiversity and Human Health*, edited by Francesca Grifo and Joshua Rosenthal (Grifo and Rosenthal 1997). In this work, contributing authors discussed the benefits and drawbacks of mining biodiversity for herbal and pharmaceutical medicines, and the role of bioprospecting in both exploiting and conserving biodiversity. In the same year, *Nature's Services: Societal Dependence of Natural Ecosystems*, by Gretchen C. Daily (Daily 1997), was also published by the same press. Although neither of these books directly addressed human health issues, they eloquently summarized the critical role that ecosystem services play in society (e.g., decomposition and recycling of wastes, pollination of food crops, and pest control). These three research areas have begun to converge, as evidenced both in primary literature (e.g., Daszak, Cunningham, and Hyatt 2000, Dobson et al. 2006) and by recent international efforts, such as the Millennium Ecosystem Assessment publication *Ecosystems and Human Well-Being* (MEA 2003), in which ecosystem change, ecosystem services, and human health are addressed in concert.

Along the way, there have been many other important contributions aimed at increasing awareness and understanding of these relationships by the policy sector and by the general public. Early contributions, such as *The Biophilia Hypothesis*, edited by S. R. Kellert and E. O. Wilson (1993), were very successful in reaching out to a lay audience. This growing panoply continues with *Sustaining Life: How Human Health Depends on Biodiversity*, edited by Eric Chivian and Aaron Bernstein, published in 2008 (Chivian and Bernstein, 2008). In this volume, contributors present multiple, and sometimes opposing, views on the benefits, consequences, and trade-offs involved with preserving biological diversity while sustaining human health and well-being.

More policy-oriented initiatives are also emerging in addition to the Millennium Ecosystem Assessment. In a multi-institutional effort, the U.S. Environmental Protec-

tion Agency National Center for Environmental Research (US EPA NCER), the World Conservation Union (IUCN), the Smithsonian Institution, and the Yale Institute for Biospheric Studies organized a multi-institutional, interdisciplinary forum and workshop on biodiversity and human health, which was held in Washington, DC, in September 2006. A specific research solicitation on the topic was issued by the EPA and a proceedings was published (EPA 2006; Pongsiri and Roman 2007). The assembled papers examine such topics as epidemiology and vector ecology, climate change, biodiversity, and health; wildlife trade and the spread of exotics and disease; pharmaceuticals; the role of biodiversity in natural catastrophes; the valuation of biodiversity for public health; and applications of research to the Global Earth Observation System of Systems (GEOSS) (EPA 2006).

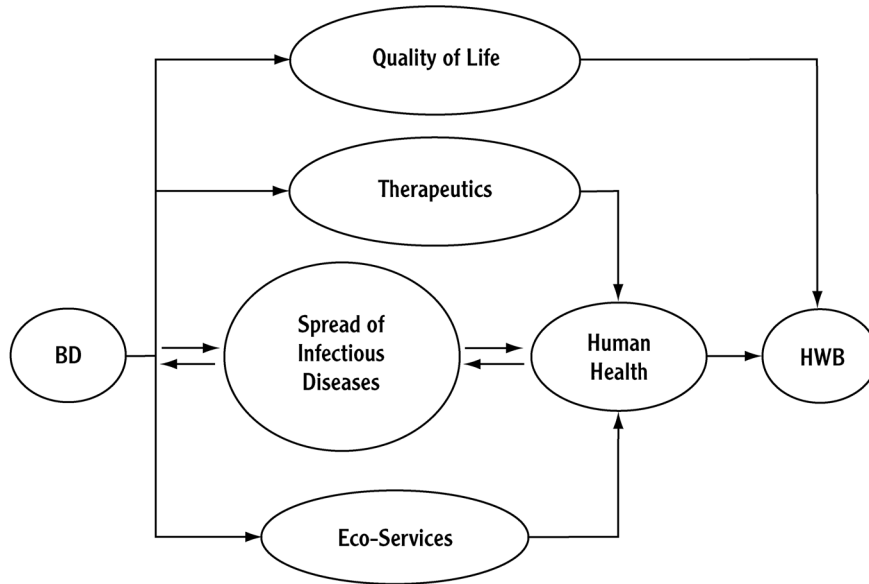
### **The Purpose of This Book**

The present volume is the end product of a workshop, Biodiversity, Health, and the Environment (March 14–18, 2005), organized by the Scientific Committee on Problems of the Environment (SCOPE), Diversitas, and the United Nations Educational, Scientific and Cultural Organization (UNESCO). A week of intense work at UNESCO headquarters in Paris resulted in a working draft, followed by extensive editing, incorporation of additional material from outside contributors, and repeated updates as new literature came out. Our aim has been to synthesize the current state of science on the relationships between biological diversity and human health by bringing together information and perspectives from the natural and social sciences as well as the medical community.

The chapters in this book explore the explicit linkages between human-driven alterations of biodiversity and documented impacts of those changes on human health. Our emphasis throughout has been to clearly distinguish the results of rigorous scientific studies from conjecture based on indirect evidence or expert opinion. We also wanted to encompass the broader definition of health used by the World Health Organization as not only physical measures, but overall well-being and quality of life as well. To fulfil this broader mandate, in addition to experts in ecology, evolution, and medicine, our group also included experts from the health-related fields of psychology and sociology. With this diverse group of researchers, we formulated critical assessments of the trade-offs and synergies between human well-being and biodiversity. Finally, we explored potential points of crossover among disciplines, in ways of thinking and in specific methodologies, which we believe could ultimately expand opportunities for humans both to live sustainably and to enjoy a desirable quality of life.

### **Four Ways in Which Biodiversity Affects Human Health**

When biodiversity is considered to be critical to human health and well-being, four major “biodiversity drivers” of human health can be identified: quality of life, medicinal



**Figure 1.1.** The four health functions of ecosystems. Biodiversity and human health can be related through the four “biodiversity drivers” of human health and well-being: quality of life, medicinal and genetic resources, constraints on infectious disease, and ecosystem services. BD = biodiversity; HWB = health and well-being.

and genetic resources, constraints on infectious disease, and ecosystem services (figure 1.1):

- *Quality of life* (including human health) has been defined by the World Health Association as “an individual’s perception of their position in life, in the context of the culture and value systems in which they live and in relation to their goals, expectations and concerns (WHOQOL Group 1994; see also this volume, chapter 7). Health includes not only the absence of disease or infirmity, but also physical, mental, and social well-being.
- *Medicinal and genetic resources* are defined as drugs, in pure form or as crude extracts of fauna and flora, used in treatment of illness.
- *Constraints on infectious disease* refers to situations in which higher levels of biodiversity reduce the spread of infectious diseases and in which depleted biodiversity may accelerate the spread of diseases to human populations.
- *Ecosystem services* are defined as those benefits that humans receive from ecosystems (MEA 2003).

Figure 1.1 demonstrates the interrelationships between biological diversity, human health, and these four drivers that are integral to health and well-being and are products

of biodiversity. For example, ecosystems can prevent the spread of infectious diseases through biological control of disease vectors and can also provide humans with medicinal and genetic resources. Biodiversity contributes to the maintenance of mental and spiritual health (part of the quality of life) through opportunities for recreation and cognitive development (de Groot, Wilson, and Boumans 2002). Biodiversity loss could therefore negatively affect human health and well-being.

We acknowledge the overlaps among the drivers that we have identified. For example, the provision of medicinal and genetic resources from flora and fauna is also considered an ecosystem service. However, addressing the drivers separately facilitates discussions relating specifically to human health. Identifying the trade-offs and synergies among these biodiversity drivers of human health potentially offers decision makers and resource managers a clearer array of choices when making natural resource decisions that allocate biodiversity among the drivers.

## The Structure of This Book

Figure 1.1 is the foundation on which the workshop was based and provides a structure for this book: following this introductory chapter, 11 of the book's 16 chapters focus on one of the biodiversity drivers of human health and well-being. We begin, however, with 4 cross-cutting chapters resulting from the discussions that occurred during early spring workshop in Paris. These chapters reflect interdisciplinary work and highlight the connections among biodiversity drivers.

While there is much agreement across disciplines about the importance of biodiversity to human health and well-being, the contrasts in perspectives that arise in the chapters that follow are both enlightening and at times startling. Part I (chapters 2–5) tackles issues that cut across many disciplines, and that require true interdisciplinary research for further progress to be made. Chapter 2 explores the linkages and feedbacks between biodiversity, agriculture, human health, and ecosystem functioning. Chapter 3 argues for comprehensive policies that both protect human health and biodiversity by reducing human stressors and achieving healthy ecosystems. Chapter 4 explores the application of social science methodologies and economic models to decision-making to maximize human health and well-being while simultaneously minimizing negative biodiversity impacts. Chapter 5 explores the theme of sustainability in more detail, discussing the relationships, trade-offs, and synergies that exist between biodiversity, human health, and sustainable development.

Parts II (chapters 6 and 7) and III (chapters 8–10) provide up-to-date syntheses of the different component issues that form the basis of the cross-cutting chapters in part I. Chapters 6 and 7 address the effects of biodiversity on quality of life that have developed over both ecological and evolutionary time, but which in many ways remain cryptic because of the paucity of quantitative approaches to empirically define these relationships. Chapters 8–10 discuss how changes in biodiversity affect the provisioning of eco-

system services, and ultimately human health, by focusing, in turn, on aquatic biodiversity, alterations in the global nitrogen cycle, and microbial biodiversity.

Part IV (chapters 11–14) explores the role of biodiversity on the spread of infectious disease. Chapters 11 and 12 review both the positive and the negative impacts of microbial biodiversity on human health and ecosystem functioning, while chapter 13 reviews mechanisms by which biodiversity can affect the risk and spread of infectious disease. Chapter 14 synthesizes existing evidence that the documented impacts of climate change on the geographic ranges, phenologies, and population dynamics of wild species may have already affected human health, and the implications for future impacts.

Part V (chapter 15) examines biodiversity as a resource for medicinal uses. The part provides two perspectives on the roles of indigenous and modern Western medicine in human health, sustainable biodiversity, and the environment.

## Tools for Developing Management Policies for Biodiversity

This book as a whole attempts to synthesize our current understanding of the effects of human-driven alterations of biodiversity on human health and well-being. It is tailored to a scientific audience, and would also serve well as a graduate student text on this topic. We hope that this synthesis contributes novel tools to develop policy at the same time as it highlights research needs. The book emphasizes the fact that issues of biodiversity, human health, development, and conservation are extremely complex. Some chapters stress the multiple benefits of biodiversity for human health through our four drivers, whereas other chapters see biodiversity as a risk associated with the appearance of new diseases for humans and their crops and animals. Consequently, management of biodiversity to benefit human health and well-being will require policies tailored to specific regions. These policies will need to strike a balance between the multiple tensions described throughout the chapters of this book.

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