SCOPE 64

Sustaining Biodiversity and Ecosystem Services in Soils and Sediments

EDITED BY
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Foreword by Harold A. Mooney

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Foreword

During the past couple of decades, two seemingly unrelated themes have emerged, sequentially, as new focal points in the study of ecological systems. In addition to adding to the fund of knowledge about ecosystem science, the results of these studies, in combination, have had a large impact on how knowledge about the status and operation of ecosystems is conveyed to nonspecialists. One of these themes is the concept that biodiversity, *per se,* plays a role in the functioning of ecosystems. The second theme is that of linking ecosystem processes to the delivery of services to society.

The prevailing studies of ecosystem functioning up to this period concentrated on understanding the interactions of the most fundamental ecosystem units, that is, trophic levels, and their operation in controlling the fluxes of carbon, energy, water, and nutrients. This simple but powerful paradigm enabled great advances in our understanding of ecosystem dynamics.

There has been a growing concern in recent times, however, with the increasing loss of species from ecosystems due to impacts of biotic disruptions of various kinds (hunting, selective harvesting, invasions), land-use change, and pollution. The question arose of how these losses of species were affecting ecosystem functioning. This issue resulted in a large-scale international effort to probe this question across the major biomes of the world. The initial effort relied mostly on information gathered for other purposes, but it nevertheless was useful for analyzing this new question. More recently there has been a shift toward experimental approaches to this question, with a considerable body of literature resulting.

At the end of the initial global synthesis, which was run under the auspices of the Scientific Committee on Problems of the Environment (SCOPE), it was concluded that the analysis was hampered by our lack of knowledge of underground biodiversity and processes. The decision to initiate a new study on belowground biodiversity and ecosystem functioning was the genesis of this book and much of the work that led to it. Further discussion, however, led to the innovation that is captured in this volume. Rather than merely looking at soil biodiversity, it was proposed that the analysis focus on below-surface processes, including terrestrial and aquatic. This was a very bold move, since it brought two very disparate scientific communities together, yet these commu-

nities, as was suspected early on, shared commonality in the processes that they studied. Bringing these communities together also had the important result of focusing on the linkages between below-surface terrestrial, freshwater, and marine systems.

As our knowledge of biodiversity and ecosystem functioning was accumulating, another somewhat independent line of inquiry was developing. This was the consideration of how the results of ecosystem processes produces the goods and services upon which human societies depend. This has proven to be a very powerful extension of our understanding of the role of biodiversity in ecosystem functioning in terms that are extremely relevant to policies relating to the use of biotic resources. This work has turned out to be intellectually challenging. It focuses attention on ecosystem linkages in a whole new manner. It forces us to look at the whole train of ecosystem processes that result in clean water, for example, including all of the biological, physical, and chemical processes involved. Importantly, in the larger analysis, it involves the assessment of how those processes that deliver clean water, in this example, can be compromised by the alteration of ecosystem properties resulting from management practices designed to deliver different services, which we also value, such as food.

There is another important thread that is captured in this book in addition to system functioning, services, and linkages: the vulnerability of these systems to continue to provide services under global changes. Thus this volume is innovative in its scope and important in its conclusions. An excellent team under the leadership of Diana Wall has produced a volume that no doubt will be a template for future syntheses as well as an important guidepost of the crucial research needs in this vital area of research.

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Preface

This book about the biodiversity in soil, freshwater sediments, and marine sediments and their role in the operation of ecosystems and provision of ecosystem services is a project developed under the Scientific Committee on Problems of the Environment (SCOPE). SCOPE's mandate is to assemble, review, and assess available data on human-made environmental change and the effects of these changes on people. In doing so, SCOPE has collected and synthesized scientific information on the complex and dynamic network of flows and interactions of the major biogeochemical cycles over the last three decades (SCOPE 61). When this project was started in 1996, one phase of the SCOPE Global Carbon Cycle project on the flow, interaction, and fate of carbon and other nutrients from land via lakes and rivers to deep oceans was being finalized (SCOPE 57), and a major synthesis of the transfer cycles and management of phosphorus in the global environment had been published, as had aspects of sulfur cycling in wetlands, terrestrial ecosystems, and associated water bodies (SCOPE 48, 51, 54). The first workshop on nitrogen cycling in the North Atlantic ocean and its watersheds was also underway (Howarth 1996). All of these projects, along with a workshop on biodiversity and ecosystem functioning (Schulze and Mooney 1994), drew attention to a lack of science-based knowledge in the area of soil and sediment biodiversity and their influence on ecosystem functioning, and the need for a thorough review and synthesis of the information available, as it posed a significant impediment to achieving sustainability.

Since then, nearly 100 scientists and students from more than 20 countries have voluntarily contributed their time and intellectual knowledge toward achieving a better understanding of soil and sediment biodiversity and biogeochemical cycling, and the consequence of loss on ecosystem services. The productivity of this group over the intervening eight years has been prodigious (see the SCOPE Soil and Sediment Biodiversity and Ecosystem Functioning [SSBEF] Committee Publications Resulting from Three Workshops in the back of this volume).

The SCOPE Committee on Soil and Sediment Biodiversity and Ecosystem Functioning held its final international workshop in Estes Park, Colorado, in the fall of 2002;

the results of their deliberations are presented in this volume as a synthesis of their current understanding.

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Literature Cited

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The SCOPE Soil and Sediment Biodiversity and Ecosystem Functioning Committee began in 1996. The Steering Committee, composed of Margaret Palmer, USA; T. Henry Blackburn, Denmark; Fred Grassle, USA; Patricia Hutchings, Australia; Timo Kairesalo, Finland; Isao Koike, Japan; Josef Rusek, Czech Republic; David Hawksworth, Spain; and especially Lijbert Brussaard, the Netherlands, was instrumental in the direction of the SSBEF synthesis workshops and publications. Holley Zadeh devoted countless hours to preparation of this book, and her energy, patience, excellent organizational and scientific editing skills strengthened this book, for which I am ever so grateful. Additional thanks go to Véronique Plocq Fichelet, Executive Director, SCOPE, and Susan Greenwood Etienne, SCOPE secretariat; the many reviewers who contributed their time to the quality of this book; to Lily Huddleson for her work on the cover design and many of the figures; and to Laurie Richards, Patti Orth, and Stella Salvo at the Natural Resource Ecology Laboratory. Gina Adams added greatly to the success of the SSBEF Committee over the years, by co-authoring proposals, organizing interactive workshops, and editing publications. Hal Mooney and Alan Covich gave me unlimited and frequent encouragement and added scientific focus. Wren Wirth energized and enabled a real contribution to knowledge on life below the surface. To all of these friends and colleagues, my sincere thanks.

Diana H. Wall

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The Need for Understanding How Biodiversity and Ecosystem Functioning Affect Ecosystem Services in Soils and Sediments

Diana H. Wall, Richard D. Bardgett, Alan P. Covich, and Paul V.R. Snelgrove

There is an astonishing diversity of life in mud and dirt. Much of life as we know it is supported by the soils and sediments of freshwater lakes, ponds, streams, and rivers, and the vast sediments of estuaries and the ocean floor. Together, soils and sediments form an interconnected subsurface habitat that teems with millions of species providing essential ecosystem services for human well-being, such as cycling of nutrients, soil stabilization, and water purification. Like microbes, plants, and animals in more visible habitats across the earth, the below-surface habitats and their biodiversity are being modified at an unparalleled rate. Land use change and sediment change (trawling, dredging, damming, drying up of rivers), the movement and introduction of biotic species, changes in atmospheric composition (CO_2, increasing availability of fixed nitrogen), climate change, and pollution are all agents of change to subsurface ecosystems. These alterations of soil and sediment habitats, and their biota, have major consequences for humans. Soils, freshwater and marine sediments and their biota are nonrenewable natural resources that humans depend on for the many goods and services that are so tightly linked to the economic basis of societies. Former US President Franklin D. Roosevelt once noted, "A nation that destroys its soils, destroys itself."

In the face of the rapid and massive transformation of global ecosystems, we need to assess the vulnerability of soil and sediment biodiversity to change and, in turn, to assess how this affects the nature of ecosystem services provided to humanity. This becomes increasingly important as we ask how we can sustainably conserve and manage these biota and habitats to ensure that future generations receive their critical ecosystem services.

This book addresses these and other important questions relating to how soil and sediment biodiversity contribute to human well-being and overall ecosystem function.

Freshwater Sediments, Marine Sediments, and Soils

Freshwater sediments, marine sediments, and soils cover the Earth's surface (Table 1.1) and are critical links between the terrestrial, aquatic, and atmospheric realms (Figure 1.1). These below-surface habitats are arguably the most diverse on the planet, teeming with a complex assemblage of species. The profusion of organisms and the composition of the biotic assemblages are integral to the maintenance of below-surface and above-surface habitats, to ecosystem functioning, and to the provision of ecosystem services that are crucial for human well-being (Wall et al. 2001b).

The public, farmers, gardeners, tourist industries, shoreline residents, and fishers are interested in the maintenance of sediments and soils for production of harvestable crops, recreation, and beauty of the landscape. These land users typically have high regard for the ecology of the habitats that they rely on for their livelihoods. They need to know: Will these shared resources—the soils and sediments and their biodiversity—be sustained in the future given increasing human populations and numerous and rapidly occurring changes in the environment? This has not been an easy question for scientists to answer.

Until recent decades, scientists considered the biota in the Earth's soils and sediments to be a "black box": They monitored the physical and chemical components of these environments, but treated the diverse, smaller organisms that comprise the soil and sediment community as an "unknown, undefined" set of functional groups. Now, facing this era of unprecedented anthropogenic disturbance resulting in biodiversity and habitat loss and the spread of invasive species, an urgent question facing both scientists and decision-makers is: Which taxa, and how much biodiversity, must be conserved to maintain or restore essential ecosystem functioning such as plant and animal production, breakdown of organic wastes and nutrient cycling?

Table 1.1. A general comparison of global characteristics of soils, freshwater sediments, and marine sediments.

Parameters	*Soils*	*Freshwater sediments*	*Marine sediments*
Global coverage	1.2×10^8 km^2	2.5×10^6 km^2	3.5×10^8 km^2
Carbon storage	1500 Gt	0.06 Gt	3800 Gt
Organic content	High	Low	Low
Oxygenation	Oxic	Oxic-anoxic	Oxic-anoxic
Salinity	Low	Low-High	High
Pressure	Low	Moderate	High

Modified from Wall Freckman et al. 1997.