

Book Reviews

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MEETING THE CHALLENGES OF MOVING ONTO LAND

de Kroon, Hans, and Eric J. W. Visser, editors. 2003. **Root ecology**. Ecological Studies. Volume 168. Springer-Verlag, New York. xxi + 394 p. \$149.00, ISBN: 3-540-00185-9 (alk. paper).

After decades of being characterized as “the hidden half” of plant biology studies or relegated to a “black box” for community and ecosystem ecology research, interest in root ecology has moved from the margins of ecology to a central position. Contemporary ecologists are demanding a better understanding of how roots function, how roots respond to their environment, and how roots influence their environment. This volume joins a handful of recent publications illuminating root lives and livelihoods in the soil habitat. Its focus is narrower than some, and its organization and themes reflect the ecological orientation of its contributors. A special strength of this work is its evolutionary context: although many root ecologists have spent untold hours separating roots from soil, the editors and their colleagues remind us that we have a lot to learn by exploring root interactions with the complex abiotic and biotic components of soil.

In designing their edited volume for the wide-ranging audience of Springer-Verlag’s Ecological Studies series, de Kroon and Visser have charged their participating authors to provide an up-to-date evaluation of our understanding of the mechanisms by which roots have adapted to the soil environment and the roles roots play in this habitat. This guiding evolutionary perspective leads readers to consider the roles of roots from their most ancient origin, and to approach the understanding of root function as a set of innovations based on some fundamental themes. About a third of the authors made explicit connections between root function or root roles and evolutionary processes. While the scope of this volume ranges from biochemistry to ecosystem process, it is pervasively root centric. Beginning with a thought-provoking overview of root form and function, followed by chapters assessing our understanding of root distribution in time and space, and evaluations of key areas of root growth and function considered at a whole plant level, the book addresses how roots respond to the physical structure of soil, and then ventures into root interactions with soil biota, considering competition with other roots, the complex array of interactions with rhizosphere fungi and bacteria, and responses to herbivory. By encouraging the authors to draw attention to specific challenges in root ecology research and to identify promising approaches and techniques, the editors serve the needs of specialists in each field as well as those of more general ecology readers.

As a whole, this volume offers the reader a thorough grounding in several key areas of root ecology, and it also includes a few more narrowly focused reviews elaborating how roots cope with specific soil environments. Some chapters are magnificent both as stand-alone pieces and as com-

ponents of an integrative examination of the status of our understanding of root ecology. For example, Robinson, Hodge, and Fitter organized their review of constraints on root system form and function much like an architectural charette, first considering the challenges of the soil environment, then discussing what aspects of root structure and physiology enable roots to meet these challenges, and finally linking these primary characteristics to emergent properties of whole root systems. This design-centered approach and the authors’ effective linkage of root function and evolutionary ecology make this chapter an exciting introduction to the realm of root ecology.

A. G. Bengough’s consideration of root growth and function in relation to soil structure, composition, and strength is similarly refreshing, in part because his focus on the soil environment as habitat is unusual in the plant ecology literature. After introducing the soil environment and evaluating the contributions and promise of imaging technology for better understanding root-soil interactions, Bengough summarizes common effects of various soil physical conditions on root elongation rate, and he promotes employing the concept of least limiting water range (one of several developments in agronomy that this volume brings to the attention of ecologists working in natural systems) as a tool to predict root growth and functional responses to specific measurable soil parameters. Such a tool might also provide a useful framework for ecosystem and global process modelers to link root growth response and root function to static and dynamic soil physical properties.

Smith, Smith, and Timonen’s review of mycorrhizal relationships and mycorrhizal ecology is remarkably accessible and thorough, introducing plant ecologists to the kinds and distribution of mycorrhizal associations, the nature of resource exchange between plant and fungal symbionts, the range of plant responses to mycorrhizal symbiosis, and the synecology of mycorrhizas in both rhizosphere and plant community contexts. The authors’ rigorous and up-to-date engagement of the latter two areas makes this chapter valuable for mycorrhizal researchers as well. Drawing upon their discussions of resource exchange and the mycorrhizal response of the plant partner, they reveal how little we know about mycorrhizal roles in community structure, from potential impacts on competitive interactions to the process of succession. Looking forward, the authors articulate a need for interdisciplinary research and they emphasize the limitations of pursuing ecological research on naturally mycorrhizal plants in the absence of their mycorrhizal associations.

Although these three chapters and several others satisfy the reader with critically evaluative, synthetic, and forward-looking reviews, some veer toward compendia and some are quite narrow in scope. While most chapters succeed in introducing the non-specialist to specific aspects of root ecology, a few speak primarily to those already working in a particular subfield. Chapters on root exudates, root-animal interactions, and

root physiological adaptation to flooded environments were particularly disappointing in these areas.

The authors did a great job of identifying useful approaches and methods, including emerging technologies and applications. It is especially encouraging to read about the development and utilization of tools to observe roots and the rhizosphere with reduced disturbance. Results from *in situ* studies were distributed throughout the volume, from the use of a high-pressure flow meter to measure hydraulic conductance through root systems to the employment of microelectrodes to measure sub-millimeter scale variation in oxygen concentration in the rhizosphere. The promise of molecular and genetic tools is obvious, although their use is largely restricted to studies involving microbes or to studies of root biochemistry or physiology. In contrast, new variations of more traditional isotopic and imaging tools are in use throughout the discipline.

If the literature cited in this volume is representative of root ecology research in general, and I think this is likely, our understanding of root systems is biased strongly toward annual and herbaceous plants, especially toward common crop plants. It is clear that we ecologists have much to learn from research published in the agricultural literature; it is likewise clear that we have yet to learn much about the root systems of perennial plants and of a greater diversity of plants in general.

With a few exceptions, the volume lacks integration among chapters. Although this lack does not detract from the overall high quality of the individual chapters, it is a missed opportunity to explore, for example, the implications of root roles at the whole-plant scale for community and ecosystem properties and processes. Greater integration may also have led to additional insights, including into the evolutionary dynamics among plant roots, rhizosphere organisms, and the terrestrial environment. Alternatively, the addition of a synthesis chapter, considering the key themes and lingering questions raised by each author in the context of a broader evolutionary ecology perspective, might have served these ends and provided the basis for a research agenda.

Root ecology offers an opportunity to learn about the innovations and developments occurring throughout this field. In addition to enhancing our understanding of the diversity and complexity of the root habitat and root lives, approaching root ecology research with a good grasp of evolutionary history may also help us to envision how root-soil interactions are likely to respond to changes in our environment.

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OCEAN BIOGEOCHEMISTRY: AN OVERVIEW OF THE JOINT GLOBAL OCEAN FLUX STUDY

Fasham, Michael J. R., editor. 2003. **Ocean biogeochemistry: the role of the ocean carbon cycle in global change.** Global Change—The IGBP Series. Springer-Verlag, New York. xviii + 297 p. \$119.00, ISBN: 3-540-42398-2 (alk. paper).

The goal of Joint Global Ocean Flux Study (JGOFS) was to understand the processes controlling the time-varying fluxes of carbon into and within the ocean and to enable prediction of the response of these processes to climate change. The 11 chapters of this volume (by 41 authors) evolved from plenary talks at the JGOFS Open Science Conference in Bergen (Norway) in 2000 by representative members of the ocean biogeochemistry community.

The volume consistently conveys both the importance of the ocean in the global carbon cycle and the uncertainty of the oceanic response to global change. The authors coincide in highlighting various directions of research, such as the importance of understanding and modeling ocean circulation (Chapters 2, 5, 6, 7, and 9), refinements of the definition of the biological pump (Chapters 4, 6, 7, and 10), and uncertainties in the length scale of remineralization (Chapters 2, 5, 6, 8, and 9). Non-Redfield stoichiometry, atmospheric iron

supply, planktonic community structure, and decadal scale variability, as well as the challenge of incorporating these complexities into numerical models, appear repeatedly throughout the text (e.g., Chapters 2, 4, 6, 7, 8, 9, and 10). The concept of biogeochemical provinces, where the dynamics of the marine ecosystem respond consistently to large-scale physical and atmospheric forcing, is first presented in the Introduction (Chapter 1), examined in Chapter 2, and revisited in Chapters 3, 4, 7, 9, and 10.

General frameworks for ocean carbon research are provided by Chapter 1, “Biogeochemical provinces: towards a JGOFS synthesis,” and Chapter 2, “Physical transport of nutrients and the maintenance of biological production.” Ducklow shows in Chapter 1 that JGOFS station-based primary production measurements are generally higher than those of the corresponding biogeochemical provinces of Longhurst, modeled from chlorophyll concentrations measured by the Coastal Zone Color Scanner (CZCS) satellite. An updated comparison with ocean color measurements by SeaWiFS would have been interesting. The discussion of the regional contrast between the relative rates of bacterial and primary production seems tantalizingly short. Williams and Follows do an excellent job in Chapter 2 of placing nutrient supply and biological rates into the context of physical transport and mixing. They use

a broad-based overview of both field and modeling studies to illustrate the key physical processes.

The initial background on plankton community processes in the euphotic zone is given in Chapter 4, "Phytoplankton and their role in primary, new, and export production," and expanded upon in Chapters 7 and 10, which address the interrelationship between biogeochemistry and climate. In Chapter 4, Falkowski et al. explain the evolution of methods to estimate primary, new, and export production, define the biological pump, and discuss the role of functional groups (diatoms, calcifiers, and nitrogen fixers) in export (these topics reappear in Chapters 6, 8, and 9). Boyd and Doney present an exhaustive and valuable review of the community structure of the planktonic ecosystem in the context of temporal variability (Chapter 7, "The impact of climate change and feedback processes on the ocean carbon cycle"). Unfortunately, the lengthy initial discussion of feedback analysis is not integrated in the remainder of the chapter and there is no apparent distinction between interannual and climate variability or between biological response and biological regime shifts. Karl et al. summarize the eight JGOFS-sponsored time-series programs in Chapter 10 ("Temporal studies of biogeochemical processes determined from ocean time-series observations during the JGOFS era"), highlighting findings that can only be obtained with multi-year high-frequency sampling, such as temporal variability in nutrient limitation or event-driven atmospheric supply of iron.

Two chapters address modeling of the ocean carbon cycle. In Chapter 5 ("Carbon dioxide fluxes in the global ocean"), Watson and Orr show how models and observations of the atmosphere and ocean are used to quantify the patterns and variability of oceanic uptake and storage of anthropogenic carbon. Results from the Ocean Carbon Model Intercomparison Project (OCMIP) show the abilities of current models as well as the uncertainty of future predictions. In Chapter 9, Doney et al. illustrate progress in "Global ocean carbon cycle modeling," including models of inorganic carbon transport, models of biogeochemical cycles, and models of ecosystem dynamics, by comparing observations and simulations. Chapter 9 conveys a balanced perspective of the modeling successes, limitations, and future directions.

Three chapters address areas of less traditional emphasis in JGOFS: continental margins, carbon processes below the euphotic zone, and paleoceanographic proxies of biogeochemical cycles. In Chapter 3, "Continental margin exchanges," the difference in approaches used by Chen et al. to estimate carbon budgets for select margins fails to convey an effective synthesis. The Eastern Boundary Current section includes a confusing compilation of unrepresentative data (the primary production values of Table 3.4 are too low for the Humboldt and too high for the Canary or California Currents). The East China Sea, a recycling margin, is extrapolated globally without justifying whether it is representative.

Carbon dynamics in the "twilight" or mesopelagic zone, between 100 and 1000 m depth, is addressed by Tréguer et al. in Chapter 6 ("Water column biogeochemistry below the

euphotic zone"), while those of the ocean bottom are studied by Lochte et al. in Chapter 8 ("Benthic processes and the burial of carbon"). Both chapters compare export estimated from different approaches, such as remote sensing/remineralization models, sediment traps, benthic flux chambers, and the inversion of numerical models. Lochte et al. discuss the advantages and limitations of a suite of paleoceanographic proxies of ocean biogeochemistry. Although outside of the mainstream in JGOFS, this topic takes on incalculable value when attempting to understand oceanic responses to long-term climate change.

The stated objective of *The IGBP Series*, to present key results of the JGOFS project, is accomplished. As to be expected in such an interdisciplinary arena, the tone of the chapters varies along a continuum between explanation and review of current research. Although some chapters tend more towards the "big picture" (e.g., Chapters 4, 8, and 9), in most cases the intended audience appears to be peers within the biogeochemical or climate change community. Almost all of the chapters are appropriate for graduate courses, but most are likely too complex for the undergraduate level.

Perhaps due to uneven peer review throughout the volume, there are some science-related typographic errors (e.g., the units for Figure 2.10 or the lack of axis labels, symbol identification, and station acronym identification in Figure 9.11). Although never substantive, there were more errors in spelling and grammar than expected for a publication of this caliber. "Coccolithophorids" has three mistaken spellings and surnames often fared poorly (e.g., Kosro rather than the correct Korso, and Iglesias-Rodriguez rather than the correct Iglesias-Rodriguez). The design of the book is very attractive, the type clear, and the figure size appropriate. However, identical formatting of the first three levels of headings is occasionally confusing.

It is disappointing that there is no unifying synthesis chapter bringing together the research topics that weave throughout the volume under slightly different guises. Biogeochemical provinces could have provided an excellent context to compare export, primary production (all mentions of global estimates are ~45 Gt C except the value of 90 Gt C on p. 240 which must refer to gross photosynthesis), or the definition of the biological pump. Despite this missed opportunity to underline the encompassing conclusions and future avenues of research, this volume provides a valuable state of the art of ocean biogeochemistry for those interested in the carbon cycle or climate change.

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RECONCILIATION ECOLOGY, OR RESIGNATION ECOLOGY? THE CHALLENGE OF LIVING WITH NATURE

Rosenzweig, Michael L. 2003. **Win-win ecology: how the earth's species can survive in the midst of human enterprise.** Oxford University Press, New York. 211 p. \$27.00, ISBN: 0-19-515604-8.

Walk into any well-stocked bookstore, and you will find that its environmental section bulges with jeremiads—tomes that describe in depressing and convincing detail the many dimensions of the biodiversity disaster looming all around us. It is a welcome contrast to read instead a volume that frankly admits these sobering facts, yet also champions a potential strategy for sustaining a reasonable fraction of the earth's fauna and flora. In this gracefully written, thoughtful and timely book, aimed as much at the general nonspecialist reader as at professional scientists, Rosenzweig sketches a hopeful vision of the future for biodiversity. The central plank of this vision involves the development of a new subdiscipline of applied conservation ecology, which Rosenzweig dubs "reconciliation ecology." The basic aim of reconciliation ecology is to deliberately design human-dominated habitats—those places people live and work—so as to not shut out the rest of life. As the author puts it, a central goal of conservation efforts should be "sharing our habitats deliberately with other species." The book lays out an argument for why this strategic readjustment in our thinking is necessary, and describes a number of case studies where the strategy appears to be working.

The central dilemma faced by conservation today can be stated quite simply, and Rosenzweig does an excellent job in describing this dilemma in non-technical terms. Most conservation biology focuses on the scientific and societal dimensions of identifying and protecting patches of natural areas, with the aim of preserving those species now found there—an agenda of land preservation the author dubs "reservation ecology." In recent years, there has also been a great deal of attention given to reconstituting degraded habitats into some semblance of their original selves—restoration ecology. The ultimate combined outcome of these efforts are sets of parks and nature reserves, both pristine and restored, scattered in landscapes dominated by human activity. Rosenzweig compellingly argues that although both reservation and restoration ecology may be necessary components of the conservation agenda, they cannot be sufficient, and indeed can only achieve the objectives of conservation if combined with reconciliation efforts. The reason reflects one of ecology's most general empirical laws—the fact that the number of species increases with area.

Elsewhere Rosenzweig has examined species-area relationships in authoritative detail, and in this book in a chapter titled "The tyranny of space" he crisply revisits this issue, with an eye towards conservation. The increase of species richness with area is particularly pronounced when considering units of land that are sufficiently isolated that immigration does not bolster local assemblages, and that are far enough apart that evolution can proceed independently in

different areas. A useful rule-of-thumb is that at these broad spatial scales, the number of species expected to be maintained in a dynamic equilibrium (including both ecological and evolutionary processes) scales directly with area. In the following chapters, Rosenzweig then draws out the sobering consequence of this conclusion for the science of biodiversity. He suggests that roughly 5% of the world's terrestrial habitats is currently in a near-pristine form. If all this land were to be instantly protected in reserves from further development, and the remaining fauna and flora completely restricted to this reserve system, then in the long run approximately 95% of all species would be expected to be lost. This staggering magnitude of projected loss is probably an underestimate of the potential drain of species from the reserve network, given the vicissitudes of climate change and the challenge of invasive species pressing in from all sides.

So what is to be done? As Rosenzweig says, "We must abandon any expectation that reserves by themselves, whether pristine or restored, will do much more than collect crumbs. They are the 5 percent. We need to work on the 95 percent." The first few chapters of the book describe a number of examples where biodiversity is being maintained either deliberately or accidentally in human-dominated landscapes, ranging from Israeli staging grounds for migratory Palearctic shorebirds, to settling pools at a Florida power plant (within which the American crocodile happily resides), to efforts to foster red-cockaded woodpecker numbers on an army base.

Visionaries and prophets are often a bit hazy when it comes to the practical details of crafting tactics for creating in reality the world they dream about. This book fits squarely in that tradition, and it would be carping and unfair to criticize it based on the absence of a detailed coherent program for executing its vision. But it may be useful to reflect briefly on a few issues that must be addressed, if reconciliation ecology is not to become merely a prelude to "resignation ecology," where we learn to become resigned to living in and coping with the devastated, defaunated world we are creating at breakneck speed.

A central agenda in community ecology today is understanding how patterns of species richness reflect the interplay of regional, large-scale processes and local population dynamics and interspecific interactions. Making advances in this agenda, I suggest, is key to developing conservation strategies that combine reconciliation with preservation and restoration. For instance, if a species that is largely restricted to reserves can utilize a human-dominated landscape to some extent, this creates a buffer that can help mitigate against unexpected catastrophes in the reserves (even if the buffer population itself is not completely self-sustaining). A "sink" population is not necessarily a complete dead-end, but could play a vital role in long-term persistence. Conversely, mobile species that adapt to and then become abundant in anthropogenic landscapes may pose risks to species confined to reserves. As an example, restrictions on hunting can foster populations of large vertebrates, and so might be viewed as a social mechanism for reconciliation. But in some case this tactic can have

devastating consequences for other species (e.g., white-tailed deer in the eastern United States have burgeoned in numbers and severely harmed native herbaceous plants such as *Trillium*). One potential hazard in piecemeal, species-by-species approaches to reconciliation (along the lines of the interesting case studies presented by Rosenzweig) is that most of us are ill-equipped to predict and monitor the long-term consequences of how a given habitat change will shift relevant landscape and community dynamics. Moreover, many species exist because of large-scale disturbances (e.g., flood regimes in freshwater communities, severe fires in prairies and chaparral). Articulating how human activity can be made compatible with the persistence of these large-scale disturbance regimes is a significant challenge in reconciliation efforts.

Another important issue is that most conservation planning takes species' properties as fixed, and then attempts to identify the set of environmental requirements that permit long-term persistence. Yet as evolutionary biologists, we know that species evolve in changed environments, and that such evolution can influence persistence in a variety of ways. In the first chapter of this book, Rosenzweig notes that "The habitats we create around us will be novel, so the species that we hope they save will not be particularly well adapted to them." Yet if we can create persistent populations, then we expect adaptive evolution. Making predictions about evolution in changing environments is challenging, but one general consequence can be readily foreseen—if a species is found both in reserves and in human-dominated landscapes, evolution in the latter novel environments will occur. Adaptive evolution in these commensal populations can then filter back to influence the traits of populations found in protected reserves, with reverberating consequences in the latter (e.g., on coevolutionary processes). Reconciliation ecology will need a hefty dose of applied evolutionary biology.

Finally, it is noteworthy that most of the concrete examples of successful reconciliation efforts Rosenzweig recounts

come from developed countries, where reconciliation may be readily achieved with only modest impacts upon local economies, and where population growth is moderate. Most biodiversity, however, resides in tropical developing nations, where local population pressures upon the land is intense and mounting, leading to habitats habitable by few living things (e.g., much of the upland plateau of Madagascar), and where there may be few mechanisms in place to withstand the rampant onslaught of habitat destruction driven by the impersonal, non-local forces of global capitalism (e.g., as in multinational logging and mining operations). It is difficult to imagine how this juggernaut will be slowed, must less modulated in the direction of reconciliation, without the determined cooperative action of local, national, and transnational governments and agencies. I thus must disagree on this one point with Rosenzweig, who suggests in the final chapter that the role of government in reconciliation should be limited. Incentives and restrictions applied by governments can have profound consequences upon local behaviors. Just imagine what a difference one might see in, say, the mid-western U.S., if federal subsidies to farmers reflected a standard of biodiversity maintenance. Maybe instead of sterile homogeneous Illinois corn fields and Kansas wheat fields stretching unbroken, horizon-to-horizon, we could instead enjoy vistas enriched by scattered hedgerows, copses, and pocket wetlands.

Despite these caveats, I can warmly recommend this book. It is peppered with personal reminiscences and touches of humor, and it is a pleasure to read. Indeed, I think this book is a "must-read" for conservation biologists, natural resource managers, and concerned citizens.

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