Linkages of Sustainability

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and present a thorough review of how biodiversity patterns shift across two of the planet's greatest physical gradients—depth and latitude. *Deep-sea Biodiversity* presents the most convincing case yet for the unimodal pattern of species richness with depth, and provides an excellent discussion of the relative roles of actual ecological processes versus the bias of the mid-domain effect. With regard to the gradient in diversity with latitude, criticism has arisen of the authors' own papers on this subject. To their great credit, however, this section presents a comprehensive review of both sides of the argument, with the admission that low diversity in Norwegian Sea samples heavily (but not completely) influenced the patterns they published in their 1993 paper in *Nature*.

There has been a resurgence of interest in reproduction and dispersal as processes influencing deep-sea diversity patterns. Dispersal is probably a key process driving deep-sea biodiversity from both ecological and evolutionary points of view. One idea that relates dispersal to the bathymetric gradient in diversity is the source-sink hypothesis, first promoted by Rex and coauthors in a 2005 paper in *American Naturalist*. The premise is simple: The food-impoverished abyssal fauna are not reproductively viable, and these small populations are sourced from reproductive propagules that have come from larger populations at bathyal depths—hence the lower abyssal diversity. As with the authors' 1993 latitudinal-gradient paper, the source-sink idea has been criticized for its application only to mollusks from a limited range of samples. Deep-sea biologists (myself included), in discussions and in print, have since been keen to point out various samples containing healthy-looking abyssal species, their stomachs packed with food and their gonads packed with eggs. But, to be fair, Rex and colleagues have always been at pains to emphasize that their hypothesis was specifically to explain molluskan patterns, and they reiterate this here, making little play of source-sink dynamics as a "general theory" in deep-sea biology.

The concept of dispersal reappears in the final chapter on evolution. Here, the authors present what I believe to be one of the main paradoxes in deep-sea biology: If deep-sea species have such powers of dispersal, and if the habitat boundaries are so unconstrained, then how can so much speciation have taken place? There are perhaps two answers. The first is that deep-sea species are not all that good at dispersing across the vast distances of the abyssal plains. Here, Rex and Etter point out that many so-called cosmopolitan species may in fact be "constellations of cryptic species"—a wonderful turn of phrase that reflects the haplotype maps that geneticists use to illustrate them. Molecular genetics is now confirming this for some groups of species, but not all. The second idea, explored extensively in this final chapter, is that changes in depth are the most powerful boundaries to dispersal. I would argue that the deep sea is not characterized by its deepness as much as by its huge range of different depths. In this concept, the bathyal regions are the engines of speciation, fueled by cyclic changes in paleo-oceanographic processes.

Howard Sanders and Robert Hessler published the first comprehensive, quantitative studies on deep-sea biodiversity in the late 1960s. Rex and Etter's book is dedicated to them and is a worthy tribute. Sanders and Hessler would (and will) no doubt be pleased that their ideas have withstood another 40 years of quantitative sampling, and that there is still enormous interest in the undoubted mystery of the deep sea.

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DO WE NEED GEOENGINEERS OF THE EARTH SYSTEM?

Linkages of Sustainability. Thomas E. Graedel and Ester van der Voet, eds. MIT Press, 2009. 430 pp., illus. $40.00 (ISBN 9780262013581 cloth).

Linkages of Sustainability, an edited volume of 25 chapters, intends to document and synthesize the research of nearly 50 contributors, mostly from developed countries, who have attempted to better frame the multiple dimensions of global Earth system sustainability. Known for its interest in basic theoretical research in fields such as biology, the Ernst Strüngmann Forum of the Frankfurt Institute for Advanced Studies outlined the theme for this volume in 2006, and the forum's steering committee identified Thomas Graedel and Ester van der Voet (industrial ecologists and editors of this book) as focal participants. Other participants from various disciplines were then invited to Frankfurt for a weeklong meeting in 2008. A deliberate focus of this meeting was to more fully understand, from the angle of complex systems sustainability, the specific linkages among energy, water resources, nonrenewable resources (i.e., minerals), and renewable land resources (e.g., forests, croplands, ecosystem services, institutions, human and social capital).

Following an introduction by Graedel and Van der Voet (chapter 1), several background chapters offer the essence of "group discussion" for each of the book's four areas—land, minerals, water, and energy—with a summary chapter concluding each grouping. The editorial tandem ends the book with remarks on the emergent importance of better investigating potentially sustainable linkages among these resources. The brief introduction in chapter 1 defines the book's language and specifies the use of related middle-range models such as substance (or material) flow analysis, input-output analysis, trade-off evaluation, and life-cycle assessment (e.g., stocks, flows, rates). The background chapters of each resource area range in style from the data-rich but atheoretical overviews (chapters 2, 7, 23) to the theory-driven critical reflections on methods, concepts, or research strategies (chapters 3, 14, 21) to model-driven research articles

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(chapters 9, 16, 20) to more or less elaborated literature reviews for use in student textbooks (chapters 4, 8, 18) to opinion pieces (chapters 13, 19, 24).

Despite the range in style, most of the chapters in *Linkages of Sustainability* adopt the industrial ecology framework as an overarching, organizing principle, consistently referring to "stocks, flows, and prospects." The summarization of land (chapter 5) stresses that, in the pursuit of "ideal land sustainability," conventional approaches need to be reconceptualized to encompass trade-offs. A "land system" analysis would need a land accounting mechanism linked to remote sensing and GIS (global information system) techniques. It is envisioned that a renewable economy would need to make use of the "engineering and design of nature." The summary of minerals (chapter 11), claiming an "unavoidable" need for primary resources, makes the point that future energy, water, and land requirements will become increasingly constraining factors for metal production as a result of the lower quality of metallic ore resources and mining at greater depths. "Scenarios that will move us toward sustainability" will need a much-improved "quantification of stocks and flows of minerals." The final chapter in the discussion of water (chapter 17) proposes a sustainable water-systems management analysis, combining the "inextricably linked" components of water, energy, and land use through virtual water markets (as part of the wider global agricultural business). Supply-demand metrics are put forward for water provisioning purposes, and metrics are used to "analyze the effect of energy in purifying inflow water or water effluent." Likewise, chapter 22, on energy, introduces various energy scenarios and proposes a data-driven methodology to define and measure relevant, quantitative links to land, water, and minerals. The concluding chapter (chapter 25) is based on the conviction that "a quantitative understanding of the linkages is very important for exploring pathways toward sustainable development," stressing that "dramatically little" is known about constraints and limitations involving such linkages. Therefore, a future research agenda should consider the development of relational databases, methods, and scenarios.

Other than the first and last chapters, there is no need to follow the sequence of *Linkages of Sustainability.* Many cross-references help the reader find his or her way through both proven and assumed linkages among the resource areas—with two exceptions. In the section titled "Next Steps," chapter 23 (on land use, agriculture, and climate change) and chapter 24 (on urban land use and transport) would be better positioned in the section on land. In addition, three appendixes interrupt what is basically a consistent outline; they could have been integrated into the text or even presented in the form of a table.

The original forum's pronounced determination is obvious: to facilitate an expert discussion on land, water, minerals, and energy under the purview of industrial ecology. (The rigid editorial work by Julia Lupp, the series editor, reminds me of the so-called Dahlem workshop model, used at conferences of the Free University of Berlin since 1974.) This common framework (and language) makes a readable prose for those who admire civil engineering language (not me). Having understood the message of the introduction, I found it irritating to see terms such as "quantification," "optimization," and "efficiency" colonizing every subsequent chapter. I find phrases such as "even before focusing on recycling, we must optimize the efficiency of mining" (p. 127) difficult to digest—recycle for what? optimize for whom?

Language indicates underlying motives, which I perceive to be serious shortcomings of an environmentally just discourse on sustainability. First, no joint effort was made to define and clarify "sustainability." The editors widely fail to provide an introductory working definition; they simply posit that "sustainability is a systems problem" and "putting numbers and ranges on key individual resources related to sustainability is not enough" (p. 3). There is some indication of forest engineer thinking (in terms of moving from open to sustained, closed production-consumption systems), but this is not made explicit. Subsequently, various aspects of what are still contested concepts—such as Brundtland's idea of intergenerational equity (pp. 276 and 356) or Elkington's notion of a triple bottom line (pp. 218 and 356)—are haphazardly spread throughout the book. The minerals summary chapter, for example, promotes unabated resource extractivism in stating that "discovery, characterization, and quantification of rocks will be one of the major geological challenges to efforts for long-term sustainability of mineral supplies" (p. 127). And, in a self-defeating statement, the energy summary concludes, "perhaps the most challenging aspect of measuring sustainability is to develop an operational definition of sustainability itself" (p. 417).

Second, the idea of reductionism in achieving sustainability is avoided throughout the book. Instead, growth concepts are merged with notions of "bioeconomies" or "eco-efficient" variants of existing modes of production and consumption. The "defining issue" of the new millennium, as chapter 18 (on resources, reserves, and consumption of energy) puts it, is "providing adequate energy for a growing human population that aspires to a higher standard of living" (p. 323). On the next page, the authors acknowledge, "while the successions of fuels used in specific applications may be seen as increasingly efficient, the absolute quantities of energy expended have been rapidly rising" (p. 324). Typically, the water summary chapter admits that "consumer behavior raises social, cultural, and economic questions that are beyond the scope of this discussion" (p. 310).

In conclusion, it must be doubted whether industrial ecology can stretch the conceptual underpinnings of the biological sciences. I cannot imagine that readers who conceive ecosystems as inherently discontinuous, complex systems with perhaps an array of cascading interactions will greatly benefit from this book. Additionally, the even more complicated socioecological relations are neither theorized nor included in the volume. Instead, a sort of eco-totalitarian "measurement regime" (p. 436) is proposed to address the human-environmental condition, framed predominantly as an issue of carrying capacity. There seems to be agreement across most chapters that this is best achieved in combination with global, investor-driven management solutions such as virtual water trade, carbon finance markets, and "ecosystem services markets" (p. 436). In the editors' concluding remarks, however, two different views are expressed, proposing a co-adaptive rather than a geoengineering approach. *BioScience* readers should perhaps start with this contradiction (p. 470), read the respective background information (chapter 3), turn to pages 462–463 (where the editors wrap up the synthesis chapters, also drawing conclusions for their own industrial ecology agenda), and then decide whether to dive into the details of the full volume.

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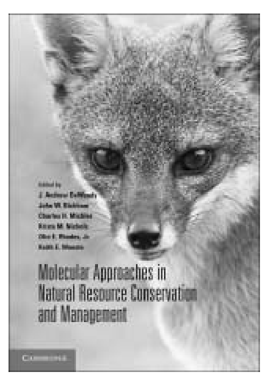
CONSERVATION GENETICS FOR NATURAL RESOURCES

Molecular Approaches in Natural Resource Conservation and Management. J. Andrew DeWoody, John W. Bickham, Charles H. Michler, Krista M. Nichols, Olin E. Rhodes Jr., and Keith E. Woeste, eds. Cambridge University Press, 2010, 392 pp., illus. $55.00 (ISBN 9780521731348 paper).

The use of molecular genetic markers is now widespread in aspects of endangered species conservation, and some geneticists suggest that we are entering the era of conservation genomics (Allendorf et al. 2010, Ooborg et al. 2010). *Molecular Approaches in Natural Resource Conservation and Management*, a compilation of 13 articles with example boxes by other authors in each chapter, attempts to link molecular conservation genetics to species generally associated with natural resource management—that is, species important in forestry, fisheries, and wildlife. In many ways, those species involved in conservation genetics investigations and those in natural resources are at opposite ends of a spectrum. Endangered species are generally rare, not harvested, and not directly selected by humans, whereas natural resource species are common, harvested, and sometimes undergoing direct human-caused selection (think Monterey pines, Pacific salmon, and white-tailed deer).

The 91 contributors to this volume are mostly researchers involved in basic science investigations in molecular ecology, evolution, population genetics, and related topics rather than the applied management orientation traditionally found in the natural resource research community. Their research contributions, first presented at a Purdue University conference in 2008, are spread over a variety of organisms and include chapters with animals, plants, or both as examples. The meeting and this book were supported financially (and logistically) by the Department of Forestry and Natural Resources at Purdue.



Natural resource scientists in fisheries and wildlife often focus on management; those in forestry focus on both management and artificial selection for production. Wildlife biologists have generally been slow to integrate modern techniques into their research and are often resistant to conservation efforts by scientists in molecular ecology and evolution; they may claim to be conservation biologists, but their conservation efforts primarily are directed toward hunted game species. This perspective was dramatically illustrated to me when I attended a bighorn sheep meeting and was surprised to find that I was nearly the only academic scientist present among the many state wildlife managers and trophy hunters. I discovered that the motto of the group was "keeping sheep on the mountain," mainly so they would be there for hunting—hardly "conservation," in my view.

As in all compilations, the articles in this book vary in their level of research sophistication. Here, they also vary in the extent of their focus on current molecular approaches. I highlight five contributions that, in my opinion, provide excellent introductions to their topics in keeping with the theme of the book.

The first article in *Molecular Approaches in Natural Resource Conservation and Management,* by Honeycut, Hillis, and Bickham, discusses biodiversity (the number of species) found in different groups of organisms and shows how molecular genetics and phylogenetics have contributed to our understanding of biodiversity. Their discussion of evolutionary distinctiveness, barcoding, and cryptic species is particularly worthwhile. The only European contribution among the articles is by Kremer, Le Corre, Petit, and Ducousso, on the adaptive differentiation in oak trees. It provides an example of what molecular genetics in an evolutionary context can contribute to the understanding of adaptation in natural resource species. They use Europe-wide pollen data from the past 15,000 years to present an historical perspective, molecular genetics to describe evolutionary and

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