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Gentle Introduction to Complexity on Landscapes

Green, David G., Nicholas Klomp, Glyn Rimmington, Suzanne Sadedin. 2006. **Complexity in landscape ecology.** Landscape Series. Volume 4. Springer, New York. x + 208 p. $139.00, ISBN: 1-4020-4285-X (acid-free paper).

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Why are starfish like an atomic bomb? The answer, according to the co-authors of *Complexity in landscape ecology*, is that like the chain reaction of atomic fission, starfish larvae set off a chain reaction of outbreaks by first settling on a coral reef and then, with help of oceanic currents, dispersing to other reefs. Such a dynamic occurred in the early 1980s along Australia's Great Barrier Reef, when the Crown of Thorns starfish (*Acanthaster planci*) literally ate away vast stretches of the famous reef network. However, the authors posit, it was only by appreciating the biological connectivity of these organisms in fragmented reef landscapes that the disruption of the reef community could be understood. This example highlights the authors' thesis and the general and rapidly emerging consensus in ecology that the ability to interpret and predict ecological behavior of populations across spatial landscapes is critical for understanding such processes as disease spread, evolutionary genetics, and species dispersal.

This book is meant to be a "gentle introduction" to the field of complexity and landscape ecology (David Green, Preface). The authors begin with a general overview of human development in the Amazon basin as an example of how "simple assumptions about ecological systems can lead to disastrous mistakes in land management." According to the authors, the tragic mistake made in opening the Amazon for development was to assume that the forest results simply from suitable climate and soils, rather than as a result of complex dynamic processes—processes that ultimately make the land unsuitable for continuous agricultural development. Similarly, the plight of the Murray River in Australia cannot be appreciated without understanding the accumulation of local behavior along its entire length. Grounded in these examples, the authors present their idea that complexity, i.e., the "richness and variety of form and behavior that is often seen in large systems," is at the root of these and similar ecological conundrums. Biodiversity is touted as the most common example of complexity in ecology. Specifically, they argue that the variety and ways in which species interact with each other and across space, not just the number of species involved, makes biodiversity a rich subject for studying complexity in ecological systems.

In the early chapters, David Green and colleagues explore biological complexity in detail. They explore plant growth through modulation and repetition that makes plant growth self-similar, e.g., fractal (Chapter 2). Following a perhaps overly long discussion of L-systems ("a technique for constructing complex objects by successively replacing parts of simple, initial objects using rewriting rules"), the authors go on to show that simple interactions among animals (ants, bumblebees, starfish) result in complex behavior. Then, the authors move, finally, to landscapes (Chapter 3), and following a rudimentary discussion of geographic information systems, discuss cellular automata models of landscapes. The authors review the essential features of cellular automata models and their application in studying important processes (e.g., fire spread, spread of epidemics, biological invasions). They review concepts of connectivity, percolation and critical phase changes. The roots of complexity theory, networks, connectivity, and self-organization are explored further in Chapter 4. Basic concepts of equilibrium using classic examples of predator-prey systems are addressed in Chapter 5. Distributions of populations in landscapes based on nonlinear and complex biotic interactions are discussed in Chapter 6 and 7. While the latter chapters begin by reviewing concepts familiar to ecologists, they end with discussions of attractors and chaos theory (Chapter 5) and network interactions (Chapter 6 and 7) that are both interesting and approachable.

Whereas the foregoing chapters show how biological complexity has helped explain observable dynamics among individuals and populations, the remaining chapters highlight potentially new ways of appreciating these dynamics. For example, the authors suggest that landscape genetics and evolutionary theory may be informed by understanding phase changes in landscape connectivity at many scales (Chapter 8). They suggest that simulation models could be used to explore both virtual and real worlds to determine when our understanding of complex dynamics is supported (or fails), and to reconstruct worlds based on this understanding (Chapter 9). But, they caution, learning about complexity requires an infrastructure for information management that is attuned to issues of data quality, control, and cost (Chapter 10). In the final chapter, the authors discuss the interactions between humans and the global landscape, exploring the implications for human societies and the environment.

Surprisingly (based on its title) the authors do not emphasize landscape ecology and some of its main contributions. Thus the book is more a gentle introduction of complexity to landscape ecologists (or, ecologists generally) than it is a gentle introduction of landscape ecology to complexity theorists. For example, some of the seminal literature in landscape ecology (by, for example, Richard Forman, Simon Levin, Monica Turner, Dean Urban, John Wiens) are glaringly absent. While complexity is defined, landscape ecology is not. Scale is defined in the context of fractal dimension, i.e., a measuring stick, rather than with concepts common to landscape ecologists, e.g., grain and extent. Similarly, a "patch" is not defined and thus patchy landscapes are defined from a modeling context as "a grid in which each cell represents an area of the land surface." Interested readers may also find contributions from spatial statistics or spatial ecology to be missing, even in a discussion of sampling and scale. Instead, the focus, perhaps refreshingly, and appropriately, based on the experience of the authors, is on the field of complexity and its contribution to understanding ecology on landscapes rather than the discipline of landscape ecology per se.

The intended audience is a little unclear in another way too. The authors go to the trouble of defining techniques or concepts that most literate ecologists should be familiar with (e.g., a quadrat, GIS, a food chain, location; do you really need to have latitude and longitude defined for you?). Yet the book is not organized as to be used as teaching material. There is a quick mention in the preface of a webpage (http://www.complexity.org.au/vlab/) with online demonstrations to accompany the book, but although many of the figures directly result from the models on this webpage, there is no direct mention of it in the text. The webpage itself is a fun tour of cellular automata models and might serve as the basis for laboratory activities. Yet, if on the other hand, the book is meant to be a resource for ecologists who are eager to grasp complexity theory, some may be disappointed by the erratic use of citations (some chapters are full of citations, while others are almost absent) and the fact that many of the citations were very old, i.e., I counted only 12 peer-reviewed references from 2003 or later. The fact that I was inspired to count them is perhaps evidence enough!

The most frustrating aspect of the book for me was that concepts, analogies, examples, and even definitions were repeated among chapters. For example, discussions of emergent behavior, the reductionist approach, and fractals were repeated in several chapters, which caused me to wonder "didn't I already read this?" Although this may not bother the casual reader interested in a single chapter or two, and may have been intentional, it detracted from the logical progression of the book's thesis.

Despite these caveats, the book succeeds in its goal to be a gentle introduction to these subjects for several reasons. First, the integration of concepts as diverse (and yet interconnected) as genetics, complexity, information theory, virtual worlds, and biodiversity is rarely attempted. The authors present a compelling thesis that understanding the complexity of these interactions is necessary for being able to interpret and forecast ecological change. There are a number of persuasive examples within the book that serve as good lessons for appreciating the extent of these biological interactions. Second, by integrating these subjects in one book, they are made more accessible to a wider audience. For example, field ecologists wedded to a particular species, process, or place in space may be enlightened about the role of cellular automata models in simulating dynamic processes using simple information; landscape ecologists may find a greater appreciation of landscape genetics (I did); educators may be inspired by virtual tools and techniques of communicating complexity. Moreover, the general conclusion that local action has global consequences is affirming to most ecologists, though not entirely new.

Finally, the most inspiring idea in the book is that seemingly complex ecological phenomena can often be explained by simple assumptions grounded in complexity theory. As such, this book could serve as a springboard for stimulating research about other general ecological principles that could better explain populations in landscapes. Unfortunately, the book falls short of providing these synthetic answers itself. Rather, I recommend the book to those who need a simple introduction to this complex topic from the perspective different from the traditional ecologist or landscape ecologist. Those already embedded in questions of biocomplexity, or with perspectives not centered on biodiversity and species interactions, or who want a tighter and more sophisticated read, may be somewhat disappointed.

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