BOOK REVIEW

Scaling and Uncertainty Analysis in Ecology: Methods and Applications

Jianguo Wu, K. Bruce Jones, Harbin Li, and Orie L. Loucks, editors. 2006. Dordrecht, The Netherlands: Springer. 351 pages, $119.00, ISBN 978-1-4020-4662-9 (hardcover); $49.95, ISBN 978-1-4020-4664-3 (softcover).

This book reviews past literature on ecological scaling in a forum explicitly designed to promote better practice in the future. By presenting a combination of concepts and theory, methods, and case studies from many authors and a wide range of ecological topics, the editors aim to interest both basic and applied ecologists. The book's emphasis is on landscape ecology and spatial scale for both general and case study chapters, but the issues considered apply more widely. Contributions in this volume (mostly developed from a 2002 workshop) vary widely in their writing style, method of approach, and detail, but even chapters heavily sprinkled with equations are readable. For the most part, authors present their choice of approach and level of detail as appropriate for their particular subdiscipline, thus contributing to the overall value of the book to practitioners. A few big players in the recent scaling literature are missing from the list of contributors, consistent with the book's workshop origin, and emphasis on contributions from practitioners rather than theoreticians, but citations of relevant literature seem comprehensive. The book achieves its primary goal; it is a practical review of scaling for ecologists and practitioners will benefit from sampling the chapters offered here.

Chapters 1–3 (Wu and Li, trading first authorship) in Concepts and Methods introduce the topic with useful reviews of definitions of scale and scaling terms for ecology as compared with other disciplines. Their adoption of the broad general definition of scaling as the translation of information across scales is particularly relevant for ecology; it fosters discussion of similar issues in the same forum whether solutions to these issues come as elegant formally linked mathematical treatments or much more complicated quantitative to semiquantitative multifaceted treatments. These chapters clearly explain to readers why it is essential to be able to estimate uncertainty associated with every process involved in generating the predictions that are usually the primary goal of scaling operations. General explanations in this section, followed up by particular examples in almost all subsequent chapters, make it obvious why uncertainty assessment has been done so incompletely in most ecological studies—because it is so difficult to do appropriately. I particularly like their emphasis on model evaluation rather than validation; we know, but often play down the fact, that ecological models are inherently imperfect.

Some curious dichotomies present in Concepts and Methods reflect the ambivalence of most ecologists. We wistfully yearn for elegant, general, and scale-independent solutions to widespread problems. In contrast, most of us accept that many important ecological patterns and processes are (even from theory) context and scale dependent, and need to be addressed with more complicated analyses. Wu and Li highlight three primary dimensions of scale: space, time, and organizational level. Space and time scales almost always involve strictly nested hierarchies of scales, whereas hierarchies of organizational levels do not require strict nestedness. In these introductory chapters, two assertions are repeatedly presented: (1) Fundamental linkage of space and time scales is an important concept, and it holds widely. When this assertion is first presented, Wu and Li point out that for some ecologically important phenomena, space and time scales do not strictly correspond. (2) Levels of organization are most useful when they are consistent with spatial and temporal scales and thus are themselves strictly nested. Counter examples in ecology are not presented, and the limitations to this assertion are not clearly discussed in these chapters.

Wu's "scaling ladder" concept, represented by the volume's cover graphic and reviewed in chapter 2 as an appropriate framework for organizing ecological scaling questions in general, accepts both these assertions a priori. In addition, it fosters the assumption that the linkage of space and time scales not only is linear across some units of space and time but also has the same linear relationship for multiple processes of interest at multiple scales. The symmetry of the portrayal of processes across space and time as circles of gradually increasing size further invites the user to assume an underlying global symmetry when framing scaling questions. This is in contrast to explicit discussions in other chapters of nonlinearity and thresholds (e.g., table 6.1 of Bradford and Reynolds chapter 6), decoupling of spatial and temporal scales (fig. 9.1 of Law et al. chapter 9; Groffman et al. chapter 10), and at best "vaguely nested" hierarchies of organizational levels implied in other chapters. These examples reflect what is found in many studies of particular ecological systems, illustrated, for example, by figure 3 of Levin's (1992) famous MacArthur award lecture.

It is unfortunate that a graphic representing such a particular and narrow set of assumptions was

chosen as the cover illustration because it belies the much broader perspective of the book's editors and contributors as a whole. True, even this set of narrow assumptions is broader than many, as it presumes that different models (the overlapping circles) are applicable to different subsets of the space-time range. The most mathematically elegant of scaling models assume self-similarity across the entire space-time range to be considered, corresponding to the domain of only one of the circles on Wu's scaling ladder. This limitation is pointed out in chapter 2 and reiterated in other chapters. When such strict assumptions can be met (or approached) in ecology, several mathematical approaches may be applied (e.g., chapters 4 and 5, each with a clear presentation of limitations). Another recent review (Allen 2007, of Solé and Bascompte 2006) highlights a complementary book featuring elegant models that assume strict self-similarity across scales.

The editors, in particular Wu and Li, missed an opportunity here. Space-time correspondence, concordance of scaling relations among multiple phenomena, and concordance of organizational levels with space-time scales are narrow, limiting, and misleading if they are seen as assumptions that can/should be made a priori, or goals to be met before conducting scaling operations. However, if they are seen as ecological scaling "neutral models "—"straw men" to test against so to characterize a system but not to be assumed without testing—then these become aids for better framing our understanding of how and why ecological systems depart from "neutral" rather than limitations to successful investigations. Most contributions from chapter 5 on take this latter attitude either directly or implied, and it is to the editors' credit that they include and highlight the many different ways other chapters point out the shortcomings of these limiting assumptions for their particular systems.

Chapters 5–8 in Concepts and Methods each present methods, along with concepts, for a particular subject that could be considered a case study of an important operation related only to some kinds of scaling operations. Authors of these chapters make stronger efforts to evaluate the generality of their approaches than those in Case Studies. These four chapters all are well worth reading carefully. They range from presentation of the mathematical details of a single group of methods (chapter 5) to well-written discussions of scaling issues and where, how, and why investigators should adopt different approaches (chapter 6 on model vs. intact field systems, chapter 7 on when to use simpler or more complicated scaling operations, and chapter 8 on remote sensing).

Chapters 9–17 in Case Studies follow up with clear discussions of context and the limitations on scaling operations in different examples and how these limitations affect scaling, even though they do not always present clear solutions. As would be expected from an emphasis on landscape ecology and spatial scaling issues, temporal scaling is addressed in only three chapters (9–11). Assessment of uncertainty is mostly explicit, sometimes implicit, but always included. Discussions of constraints range from pointing out that lack of adequate empirical data at multiple scales can be more important than methodological limitations (chapter 12) to illustrating the difficulty of ensuring that uncertainty of all components is adequately incorporated into results from multidisciplinary projects (chapter 13). Case studies contribute nicely to an underlying message of the book—that the best approaches to scaling and the likelihood of success in the effort are context dependent: dependent on the scope and scientific or management goals of the endeavor, and on the spatial, temporal, and especially organizational constraints that limit the endeavor.

Political, social, land-use, and other explicitly anthropocentric organizational levels involving incomplete nesting of hierarchies are the focus of chapter 17 and are woven into several other case studies. Inconvenient (for modeling) end-runs around a hierarchical control structure are acknowledged characteristics of human systems and are being gradually, albeit grudgingly, acknowledged in ecological and environmental systems as well. For example, populations of any migrating bird have a spatial extent much larger than any of the communities, ecosystems, or biomes they inhabit. A system that includes such organisms cannot be described using a simple spatial expansion "ladder;" an assumed regional coupling of spatial and temporal scales thus can be misleading (e.g., chapters 13 and 14). Scaling up of a forest plot via species composition to successional stage or community "type" is independent of scaling up the same plot via nutrient cycling or other process to watershed or other ecosystem unit, precluding a single spatial expansion "ladder" for both (e.g., chapters 9 and 15). When both watersheds and airsheds are involved in nutrient cycling, space and time scaling of important processes cannot be simply coupled (e.g., chapters 10–12).

The succinct but quite useful summary chapter 18 reviews this book's compendium of disparate contributions. All in all, this book admirably achieves its goal of reviewing relevant theory and presenting a wide range of practical approaches to generating predictions about ecological systems via scaling operations; it is a worthy addition to the ecological literature.

Its eclectic contents offer much valuable food for thought to any scientist involved in scaling. I would not recommend it as a textbook, but I might well suggest selected chapters for graduate student class or seminar discussions. Anyone designing a project that involves scaling across wide ranges of space, time, and/or organizational levels can glean many insights from the concepts and methods chapters and relevant case studies.

Susan Will-Wolf, *Department of Botany, University of Wisconsin, 430 Lincoln Drive, Madison, Wisconsin 53706-1381, U.S.A. Email swwolf@wisc.edu*

LITERATURE CITED

Allen, T. F. H. 2007. A natural history of equations. Review of Solé and Bascompte. 2006. Self-organization in Complex Ecosystems. Monographs in Population Biology 42. Princeton University Press, Princeton, NJ. Bioscience **57:**286–287.

Levin, S. A. 1992. The problem of pattern and scale in ecology: the Robert H. MacArthur Award Lecture. Ecology **73:**1943–1967.