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Comparing Experiments Across Different Scales

Gardner, Robert H., W. Michael Kemp, Victor S. Kennedy, and John E. Petersen, editors. 2001. **Scaling relations in experimental ecology.** Columbia University Press, New York. xxx + 373 p. $65.00 (cloth), ISBN: 0-231-11498-2 (alk. paper); $32.50 (paper), ISBN: 0-231-11499-0 (alk. paper).

The increasing trend in ecology to conduct small-scale, highly replicated experiments, combined with the difficulty of manipulating whole ecosystems makes the problem of scaling (and particularly ''scaling up'') a central problem in ecology. Yet, to many of us it is often not clear exactly what ''scale'' is (or should be), and we are led to wave our arms somewhat wildly in attempts to explain the relevance of our studies to other scales. This frustration is also sometimes perpetuated by the view that ''scaling theory'' is about allometric relationships (e.g., Schneider in this book), which may not be relevant to a particular study system. This interesting book attempts to illuminate and demystify scaling, and to make scaling theory useful to a broad audience. Potentially, scaling theory is an extremely valuable tool that could be used to form a link between large-scale observational phenomena and small-scale experiments. It is a tool that could allow us to utilize both the large statistical power that can be obtained from highly replicated small-scale manipulative experiments and the known relevance of observed large-scale phenomena. Similar arguments could be made about scaling across space, time, or organizational scales (such as from individual physiology to ecosystems, leaves to forests). This edited volume summarizes studies in a wide range of systems, and offers some fruitful directions for both the experimental and theoretical approaches to scaling. The book currently represents the most thorough attempt to apply scaling theory to the problems faced by experimental ecologists.

The book is fueled by the observation that the experimental ecologist is hard-pressed to find guidance about how to conduct experiments that adequately deal with scale-dependent effects, and which would allow results to be extrapolated across scales. Furthermore, the identity of effects likely to be scale-dependent and the likely form of scaling relations are also open to question. Therefore, at this early stage in our understanding, experiments are also needed to test and develop scaling theory. The editors also question whether the artifacts inherent in particular experimental systems will prevent us from extrapolating across scales, and whether the scaling relations in one habitat (e.g., oceanic systems) can be applied to other habitat types. Answering these questions is a lofty aim for any volume, but despite a somewhat uneven content across chapters this book does start to provide some useful answers. I put down the book feeling that I had learned something about both experimental design and scaling theory.

In this book, scaling concepts are primarily spatial and temporal extent, and grain (aggregation). Chapters explore both experimental and natural extents and grains. Authors of individual chapters also adopt various additional working definitions of ''scale,'' including the level of organization under investigation such as organisms, populations or ecosystems, the number of biogeochemical pathways, or the number of different habitats.

The book has four sections. Section one reviews background material about scale dependence and the problem of extrapolation. Section two presents three chapters describing both verbal and mathematical scaling theory and illustrates a good breadth of approaches. Next are four short chapters about scaling from mesocosms to nature, a topic that has attracted heated debate during the last decade. The final section of the book is, in my view, the most interesting. It synthesizes the relevance of scaling issues to different types of experimental systems, specifically freshwater, terrestrial, marine, and terrestrial-marine interface systems (e.g., estuaries, lagoons, salt marshes). These chapters are especially informative—perhaps because they were written by diverse groups of authors that met, discussed the topics, and challenged each other periodically throughout a workshop held in Maryland in 1997.

There is a sense from the preface and first chapter that the editors would like scaling theory to encompass a wide a range of factors to make the theory as general as possible. The goal of developing scaling theory would perhaps have been better served by more clearly defining the scaling relationship(s) under consideration. For example, while discussing spatial and temporal scales (within habitats) the authors include examples which are not necessarily limited to spatial and temporal scaling; specifically, scaling across depths within marine systems or to different heights within a forest canopy could be interpreted as differences in habitats. This kind of confusion, together with different factors that are considered within scaling by different authors, sometimes makes it unclear exactly what is intended by ''scale'' or ''scaling.'' While it is useful to assess the limits to extrapolation and understand why extrapolation might fail (which is done in several chapters), the arguments throughout the book would have been strengthened if different definitions of scale were kept separate.

The organization of the book is logical and the chapters provide access to most of the literature on the topic. However, readers specifically interested in guidance on scale considerations in experimental design will need to rely on the book's careful indexing, because this guidance is scattered throughout the book. The reader will not want to overlook the last section of the book, which contains several of the most informative and synthetic chapters. Some of the middle chapters are overly long for their content, and some chapters are also rather similar. For example, both Pace's and Nixon's chapters come to essentially the same conclusions about our ability to extrapolate from nutrient enrichment experiments in mesocosms to larger field systems. Like many edited volumes, the readability and clarity of chapters are also variable. This is a pity because it is somewhat difficult to extract the intended information from some chapters.

As somebody who has used microcosm experiments as a

tool to test theories that cannot easily be tested in the field, I found Michael Pace's chapter ''Getting it right and wrong: extrapolations across experimental scales'' to be annoyingly blinkered in its interpretation. For example, the chapter is openly critical of some of the first mesocosm experiments on biodiversity and ecosystem function (led by Shahid Naeem), based on the assumption that the primary goal was immediate extrapolation to a broad range of systems, rather than development of theory. Pace's discomfort with microcosms and mesocosms is evident throughout the chapter, and he does not adequately address the power of microcosms as a tool to develop theory that can then be tested at broader scales. By contrast, Naeem's chapter in this volume takes a refreshingly broad and appropriately cautious approach, relating the internal and external validity of experiments to different kinds of studies along a continuum between theory and observation. The power of the mesocosm approach, as well as some of its limitations, are well summarized in Nixon's chapter ''Some reluctant ruminations on scales (and claws and teeth) in marine mesocosms.'' Nixon's chapter is also refreshingly amusing.

Overall, the volume occasionally falls somewhat short of its broadly defined goals, but this is only to be expected from a topic that is still in its infancy. The volume is valuable reading for graduate students and other ecologists. It seems particularly appropriate for group discussion. The book gave me mainly general ideas about how to design experiments that are sensitive to the issues of scale and how to think about whether particular experiments were conducted at scales which were appropriate for their aims. Not surprisingly, the questions of what scaling rules should look like and how to best develop and test these are also still open. I do, however, believe it will fill an empty niche in the bookshelves of most ecologists by offering appropriate advice about how to correctly interpret experiments at a particular scale and it will also be instrumental in furthering the subject.

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