Preface

Scale is a unifying concept that cuts across all natural and social sciences. At the same time, scaling is a common challenge in both basic and applied research. Accordingly, scale and scaling have become two of the most widely used buzzwords in ecology today. Over the past two decades, more than a dozen books and many more journal papers have been published on the problems of scale and scaling in ecology and geophysical sciences. These publications, as reviewed in the chapters of this book, have contributed significantly to our current understanding of scale issues. A little more than 30 years ago, the noted geneticist and evolutionary biologist, Theodosius Dobzhansky, stated that "Nothing in biology makes sense except in the light of evolution" (The American Biology Teacher 35:125-129). Today, there seems a growing consensus in ecology that pattern and process make little sense without consideration of scale.

While scale issues are widely recognized, a comprehensive understanding of scaling theory and methods still is missing. In this book we make several observations on the status of research on scale in ecology. First, while ecologists have played an active role in the application of scale-related theories such as hierarchy, self-similarity, and self-organized criticality, a number of pragmatic scaling methods have developed in geophysical disciplines. Many of them may be quite appropriate for a range of ecological problems, but are yet to be fully explored in ecology. Second, some of the most frequently mentioned scaling theories are often seen as being at odds with each other. For example, hierarchy theory implies scale-multiplicity and thresholds, while self-similarity and self-organized criticality suggest scale invariance. A full understanding of the relationships among different scaling theories is needed, and this requires critical examination of recent theoretical and empirical studies. Third, most scaling studies in ecology have either ignored or inadequately addressed the issues of uncertainty and error propagation, which should be an integral part of scaling. We argue that scaling, without considering uncertainty, is easy but relatively trivial; scaling with known uncertainty is challenging but essential. Fourth, scaling often requires field-based data from multiple spatial and temporal scales, but these data rarely exist for many ecosystems. Such inadequacies of data further elevate the demand for effective scaling approaches. Finally, scaling theories and methods have seldom been applied explicitly in the contexts of environmental management, planning, and decision-making processes, where the scale of social, economic, political, and ecological processes may clash with each other. A pluralistic and interdisciplinary approach is needed to resolve scaling problems in such complex situations.

To address these problems, a workshop entitled "Scaling and Uncertainty Analysis in Ecology: Methods and Application" was held during September 17-19, 2002 at Arizona State University, Tempe, U.S.A., supported through a grant from the United States Environmental Protection Agency (EPA). The major objectives of the workshop were to identify approaches and methods in scaling and uncertainty analysis, and to consider a series of case studies illustrating how scale issues are dealt with in various areas of research. More than 20 active researchers in scaling and uncertainty analysis were invited to participate in the workshop, many of whom were recipients of EPA's Science To Achieve Results (STAR) program (Regional Scale Analysis and Assessment). This book has evolved out of the scaling workshop, and is comprised primarily of the papers remaining after a critical external review process.

The book, therefore, presents a comprehensive and up-to-date review and synthesis of concepts, theories, methods and case studies in scaling and uncertainty analysis that are relevant to ecology. The series of case studies included here illustrate how scaling and uncertainty analysis are being conducted in ecology and environmental science, from population to ecosystem processes, from biodiversity to landscape patterns, and from basic research to multidisciplinary management and policy-making issues. The book explicitly considers uncertainty and error analysis as an integral part of scaling. While the theme of this book focuses primarily on spatial scaling, several chapters deal as well with aspects of temporal scaling. It is not intended to be a handbook of "scaling recipes," but we hope that it will help readers gain a fuller understanding of the state-of-the-science of scale issues. We expect that this book will be of interest to a wide range of audiences, including graduate students, academic professionals, and applied researchers and specialists in ecological, environmental, and earth sciences. It may be used as a text or reference book for graduate courses in ecology and related disciplines. This book should be particularly appealing to scientists and practitioners working on broad spatial scales. Also, the book can be useful to decision makers who are conscious about scale issues as they translate science into resource use policies.

We are most deeply indebted to the contributors of papers included in the book, whose enthusiasm and dedication have made this book a reality. Many other individuals also were instrumental to the completion of the book. We especially thank the following people for providing valuable reviews of book chapters: Dennis Baldocchi, Klaus Butterbach-Bahl, Mark Castro, Jiquan Chen, Mark R. T. Dale, Dean Gesch, Phil A. Graniero, John Harte, Geoffrey J. Hay, Louis R. Iverson, James R. Karr, Madhu Katti, Richard G. Lathrop, Helene Muller-Landau, John Ludwig, James R. Meadowcroft, Garry Peterson, Geoffrey C. Poole, Edward B. Rastetter, Helen Regan, Christine Ribic, Steven W. Running, Santiago Saura, Matthew Williams, and Xinyuan Wu. We are extremely grateful to Chuck Redman (Director), Nikol Grant, and Shirley Stapleton at the Center for Environmental Studies of Arizona State University who provided wonderful logistic support during the scaling workshop in Tempe. We also thank Barbara Levinson and Jonathan Smith at EPA

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Finally, we should note that several chapters originally had color images which later were converted to grayscale. We have made these color figures available online at a web site specifically for this book, which also contains the abstracts of all chapters and additional information on scaling and uncertainty analysis. The web address can be freely accessed at: http://LEML.asu.edu/ScalingBook/.

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