Structural Equation Modeling and Natural Systems

This book presents an introduction to the methodology of structural equation modeling, illustrates its use, and goes on to argue that it has revolutionary implications for the study of natural systems. A major theme of this book is that we have, up to this point, attempted to study systems primarily using methods (such as the univariate model) that were designed only for considering individual processes. Understanding systems requires the capacity to examine simultaneous influences and responses. Structural equation modeling (SEM) has such capabilities. It also possesses many other traits that add strength to its utility as a means of making scientific progress. In light of the capabilities of SEM, it can be argued that much of ecological theory is currently locked in an immature state that impairs its relevance. It is further argued that the principles of SEM are capable of leading to the development and evaluation of multivariate theories of the sort vitally needed for the conservation of natural systems.

Supplementary information can be found at the author’s website, accessible via www.cambridge.org/9780521837422.

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Structural Equation Modeling and Natural Systems

JAMES B. GRACE
To my wife Peggy,
for her joyous spirit, wisdom, and laughter.

To my mother and my sister, Diane,
for a lifetime of love and support.

and

To Robert Wetzel, my Major Professor,
for his example of dedication to the pursuit of knowledge.
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This book is about an approach to scientific research that seeks to look at the system instead of the individual processes. In this book I share with the reader my perspective on the study of complex relationships. The methodological framework I use in this enterprise is structural equation modeling. For many readers, this will be new and unfamiliar. Some of the new ideas relate to statistical methodology and some relate to research philosophy. For others already familiar with the topic, they will find contained in this volume some new examples and even some new approaches they might find useful. In my own personal experience, the approaches and methods described in this book have been very valuable to me as a scientist. It is my assessment that they have allowed me to develop deeper insights into the relationships between ecological pattern and process. Most importantly, they have given me a framework for studying ecological systems that helps me to avoid getting lost in the detail, without requiring me to ignore the very real complexities. It is my opinion, after some years of careful consideration, that potentially they represent the means to a revolutionary change in scientific inquiry; one that allows us to ask questions of interacting systems that we have not been able to ask before. These methods provide many new opportunities for science, I believe, and it is my hope that others will see their value as well.

It is important for the reader to keep in mind throughout this book the distinction between statistical procedures and the scientific enterprise. The application of structural equation modeling (SEM) to research questions embodies both elements, but the priorities of one do not necessarily match with those of the other. My approach to this book is from the perspective of a researcher, not a statistician. My treatment is not designed to satisfy the requirements of statisticians nor those interested in the mathematics. Rather, I strive to keep the focus on developing models that match the questions being addressed. Many treatments of statistical methods are prescriptive and based on protocols that have been
worked out on the basis of statistical requirements. While I could simply present SEM protocols for use by the natural scientist, I am of the opinion that protocols are commonly an impediment to the best use of statistical methods for research purposes (see also Abelson 1995). For this reason, my emphasis is on fundamental issues that provide the reader with the material to make their own decisions about how to apply statistical modeling to their particular research problems.

The general arena of studying complex relationships and the specifics of SEM is one where subject matter and statistical analysis intertwine to a greater degree than is customary for researchers or statisticians. What is distinctively different about the study of complex, multivariate relationships compared with univariate hypothesis testing is the degree to which the analyst has to know both the subtleties of the methods and the particulars of the system being studied. The goal of this book is to show why it can be worth the effort to develop and evaluate multivariate models, not just for statistical reasons, but because of the added scientific insights that can be gained. Those who apply these methods to their own data may find, as I have, that it is quite enjoyable. Hopefully the reasons for excitement will be evident as the reader explores the chapters ahead.
I have a great many people to thank for helping me along the way in this major venture. I thank Alan Crowden, Dominic Lewis, Emma Pearce, and Graham Bliss of Cambridge University Press for their support with this project. If this book is at all readable, it is because of the help of a great many individuals who provided numerous comments. I especially thank Glenn Guntenspergen, who not only read the whole volume in both first and last drafts, but who provided sage advice from beginning to end. To him, I owe the greatest debt of gratitude. I also wish to express special thanks to Sam Scheiner for many insightful suggestions on both content and presentation, as well as for advising me on the best way to present an illustration of SEM practice in the Appendix. I am appreciative of the USGS National Wetlands Research Center for their history of supporting the application of SEM to natural systems. Several examples in this book came from their studies.

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