Spatial Analysis

A Guide for Ecologists

Third Edition

Designed for researchers in ecology at all levels and career stages, from students and postdoctoral fellows to seasoned professionals, this third edition reflects the significant advances in quantitative analysis of the past decade. It provides updated examples and methods, with reduced emphasis on older techniques that have seen limited use in recent ecological literature. The authors cover new and emerging approaches, including Hierarchical Bayesian analysis and spatio-temporal methods. A key feature is the integration of ecological and statistical concepts, highlighting the critical role that this type of analysis plays in ecological understanding. The book provides up-to-date summaries of methodological advancements in spatial and spatio-temporal analysis, along with insights into future developments in areas such as spatial graphs, multilevel networks and machine learning applications. It also offers practical examples and guidance to help researchers select, apply and interpret the appropriate methods.

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Preface

Spatial analysis, and its extension into spatio-temporal analysis, has been a rapidly growing field for at least two decades (consider that our first edition was 20 years ago: Fortin & Dale 2005!). The growth can be attributed to (1) ecologists' increasing awareness of the essential role of spatial and temporal structure for understanding ecological systems, (2) concern about the effects of the all-to-obvious alteration of landscapes around us and (3) increasing sophistication and technical scope of resources to make such analyses possible. The large range of choices for analysis brings its own problems in the form of questions about which methods to use and what the conditions are for their correct application. It is easy to use them incorrectly: (1) by not realizing the difficulties related to different spatial and temporal scales; (2) inadequately accounting for autocorrelation which creates puzzles and uncertainty for parametric analysis; and (3) lack of clarity about spatio-temporal structure's effects on ecological processes and how it can best be incorporated into experiment and analysis. This book is designed to be helpful for all those difficulties by going beyond specific spatial statistics to treat spatio-temporal analysis more generally and by showing which methods are most appropriate for given circumstances and how those chosen are best interpreted.

This purpose makes the book broad in scope, especially with an increased emphasis on spatio-temporal data, including dynamic spatial graphs and spatio-temporal networks. The intent is to help both those who are new to the topic and those that are familiar with some (or even many) aspects of such analysis but are unsure of how to start. Our goal is, therefore, to provide a broad overview of well-established methods, thus easing in through the more familiar, but then moving on to those that are unfamiliar and recent or currently under development. The less familiar includes approaches that have arisen in fields other than ecology, such as geography, geology and epidemiology, and we also look ahead to future developments from more distance disciplines such as applied mathematics and machine learning (Chapter 12).

In order to answer our ecological questions, we begin by detecting patterns in the data, and then investigate further to understand the processes that give rise to the patterns we observe. Pattern recognition is an important part of the endeavour of discovery that includes observation, experimentation, analysis with interpretation and various forms of modelling. In trying to understand ecological processes, we must acknowledge that most of what we study occurs within complex systems, with complexity taking many forms: great biological diversity, different kinds of

hierarchical organization, many levels and layers of multispecies interactions and stochastic components in multi-level dynamics. Consider the complexities of the processes that give rise to the spatial structure and temporal dynamics of 20 species of trees in a temperate forest . . . and then those for a tropical forest with hundreds of tree species . . . and then for all the insects and fungi in that tropical forest . . . Challenges indeed for spatial analysis and spatio-temporal interpretation!

This book stems from years of teaching at our respective universities, as well as research into many of the methods represented here and their application to diverse data by ourselves and colleagues including students and post-doctoral researchers. We acknowledge and thank all those who have helped with our teaching, methodological research and data analysis, but there are really too many to thank in lists of names (thank you all!). The one exception is to thank Cheryl Smyth for her meticulous attention to detail in preparing the text, figures and references. Lastly, we will acknowledge with great appreciation all the sources of funding that supported our research efforts and this project, including NSERC, U of T, UNBC, . . .