

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, multi-level 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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Contents

	<i>Preface</i>	<i>page xi</i>
1	Ecological Processes	1
	Introduction	1
	1.1 Spatial Processes	1
	1.2 Ecological Processes	4
	1.2.1 Spatial Patterns along Gradients	5
	1.2.2 Spatial Associations among Species	6
	1.3 Plant Community Spatial Structure	9
	1.4 Spatial Processes by the Level of Organization	13
	1.5 How to Use This Book	16
2	Spatial Concepts and Notions	20
	Introduction	20
	2.1 The Spatial Context	23
	2.2 Ecological Data	23
	2.3 Spatial Structure: Spatial Dependence and Spatial Autocorrelation	26
	2.4 Spatial Scales	28
	2.5 Sampling Design	31
	2.5.1 The Sample Size (the Number of Observations ‘ <i>n</i> ’)	31
	2.5.2 Spatial Resolution: Grain and Extent	31
	2.5.3 The Size and Shape of the Sampling Units	32
	2.5.4 Sampling Design	33
	2.5.5 The Location in the Landscape	33
	2.5.6 Spatial Lag	33
	2.5.7 Multiscalar Analysis	35
	2.5.8 Effects of Edges	36
	2.6 Stationarity	37
	2.7 Scaling	38
	2.8 Spatial Neighbours	40
	2.8.1 Lattice-based Neighbours	40
	2.8.2 Topological Neighbours	40
	2.8.3 Distance-based Spatial Neighbours	44
	2.8.4 Directional Angle-based Spatial Graphs	48

2.9	Spatial Statistics	49
2.9.1	First-order Statistics	49
2.9.2	Second-order Statistics	50
2.10	Ecological Hypotheses and Spatial Analysis	52
2.11	Randomization Tests for Spatially Structured Ecological Data	54
2.11.1	Restricted Randomizations	55
2.11.2	Markov Chain Monte Carlo	58
2.12	Concluding Remarks	58
3	Spatial Analysis of Point and Quadrat Data	60
	Introduction	60
3.1	Mapped Point Data	60
3.1.1	Introduction: Three Basic Patterns	61
3.1.2	Distances to Neighbours	62
3.1.3	Refined Nearest Neighbour Analysis	62
3.1.4	Second-order Point Pattern Analysis	63
3.1.5	Bivariate Data	66
3.1.6	Thinning or Combining	68
3.1.7	Multivariate Point Pattern Analysis Data	69
3.2	<i>K</i> -function Analysis for Inhomogeneous Point Patterns	73
3.2.1	Regional Expected Values around Events	73
3.2.2	Regional Values for Subareas of the Study Plot	74
3.3	Mark Correlation Function	75
3.4	Point Patterns in One and Three Dimensions	76
3.4.1	One Dimension	76
3.4.2	Three Dimensions	79
3.5	Circumcircle Methods	80
3.6	Areal Unit Analysis	81
3.6.1	Quadrat Variance Methods	81
3.6.2	Two or More Species	84
3.6.3	Two or More Dimensions	86
3.7	Spectral Analysis and Related Techniques	88
3.8	Wavelets	89
3.9	Concluding Remarks	90
4	Spatial Analysis of Sample Data	97
	Introduction	97
4.1	Join Count Statistics	98
4.1.1	Join Count Statistics for <i>k</i> -categories	100
4.2	Global Spatial Statistics	101
4.2.1	Spatial Covariance	101
4.2.2	Spatial Autocorrelation Coefficients for One Variable	102
4.2.3	Variography	109

4.3	Sampling Design Effects on the Estimation of Spatial Pattern	117
4.4	Spatial Relationship between Two Variables	118
4.5	Local Spatial Statistics	119
4.6	Spatial Scan Statistics	122
4.7	Spatial Interpolation	124
4.7.1	Proximity Polygons	125
4.7.2	Trend Surface Analysis	125
4.7.3	Inverse Distance Weighting	126
4.7.4	Kriging	128
4.8	Concluding Remarks	134
5	Spatial Partitioning: Spatial Clusters and Boundary Detection	136
	Introduction	136
5.1	Patch Identification	136
5.1.1	Patch Properties	136
5.1.2	Spatial Clustering	138
5.1.3	Fuzzy Classification	140
5.2	Boundary Delineation	142
5.2.1	Ecological Boundaries	142
5.2.2	Boundary Properties	143
5.2.3	Boundary Detection and Analysis for One-Dimensional Transect Data	145
5.2.4	Boundary Detection based on Two-Dimensional Data	148
5.3	Boundary Overlap Statistics	156
5.4	Hierarchical Spatial Partitioning	158
5.4.1	Edge Enhancement with Kernel Filters	159
5.5	Concluding Remarks	161
6	Spatial Autocorrelation and Inferential Tests	163
	Introduction	163
6.1	Models of Autocorrelation in One Dimension	164
6.2	Dealing with Spatial Autocorrelation in Inferential Models	169
6.2.1	Simple Adjustments	169
6.2.2	Adjusting the Effective Sample Size	170
6.2.3	More on Induced Autocorrelation and the Relationships between Variables	174
6.2.4	Correlation and Related Measures	176
6.3	Randomization Procedures	180
6.3.1	Restricted Randomization and Bootstrap	180
6.3.2	Monte Carlo Markov Chain	182
6.4	Considerations for Sampling and Experimental Design	183
6.4.1	Sampling	184
6.4.2	Experimental Design	186
6.5	Concluding Remarks	187

7	Spatial Regression and Multiscale Analysis	189
	Introduction	189
	7.1 Spatial Causal Inference	189
	7.2 Correlation between Spatially Autocorrelated Variables	192
	7.3 Mantel Test	193
	7.3.1 Partial Mantel Tests and Multiple Regression on Distance Matrices	197
	7.4 Spatial Regressions	200
	7.4.1 Spatial Filtering Using Autoregressive Models	204
	7.4.2 Other Spatial Filtering Models	205
	7.4.3 Spatial Error Regression	206
	7.4.4 Geographically Weighted Regression	206
	7.4.5 How to Remove Spatial Autocorrelation from the Residuals	208
	7.5 Canonical (Constrained) Ordination	210
	7.6 Multiscale Analysis	211
	7.6.1 Generalized Moran’s Eigenvector Maps	214
	7.6.2 Multiresolution Spectral Decomposition Analysis with Wavelets	218
	7.7 Concluding Remarks	225
8	Spatio-temporal Analysis	227
	Introduction	227
	8.1 Spatial Statistics Reassessment	229
	8.2 Spatio-temporal Join Count	229
	8.3 Spatio-temporal Analysis of Clusters and Contagion	230
	8.4 Spatio-temporal Scan Statistics	237
	8.5 Polygon Change Analysis	237
	8.6 Analysis of Movement	241
	8.7 Spatio-temporal Networks	249
	8.7.1 Phenology	251
	8.8 Spatial Aspects of Synchrony	253
	8.9 Concluding Remarks	256
9	Spatial Diversity Analysis	258
	Introduction	258
	9.1 Space and Diversity	258
	9.1.1 Spatial Scale	259
	9.1.2 Spatial Location and Environmental Gradients	260
	9.1.3 Spatial Heterogeneity	260
	9.1.4 Spatial Dependence	261
	9.2 Application: Why Spatial Diversity	261
	9.2.1 α -Diversity	262
	9.2.2 β -Diversity	265
	9.2.3 γ -Diversity	270

9.3	Combinations and Composition: Agreement and Complementarity	270
9.3.1	Species Combinations	271
9.3.2	Nested Subsets, Constrained Compositional Diversity	275
9.4	Spatial Diversity: Putting It All Together	278
9.5	Concluding Remarks	282
9.5.1	Temporal Aspects	282
9.5.2	Complexity	282
9.5.3	Space and Time	283
10	Points and Lines, Graphs and Networks	284
	Introduction	284
10.1	Lines Alone: Fibre Pattern Analysis	286
10.1.1	Aggregation and Overdispersion of Fibres	287
10.1.2	Fibres with Properties	288
10.1.3	Curving Fibres	291
10.2	Points and Lines Together	292
10.3	Points and Lines: Spatial Graphs and Spatial Networks	295
10.3.1	Spatial Nodes	295
10.3.2	Neighbour Networks	296
10.3.3	Signed and Directed Graphs and Networks	299
10.3.4	Creating Subgraphs	301
10.4	Network Analysis of Areal Units	301
10.5	Spatial Analysis of Flow	309
10.6	Testing Hypotheses with Spatial Graphs	311
10.7	Concluding Remarks	312
11	Spatial and Temporal Analysis with Multilayer Networks	313
	Introduction	313
11.1	Multilayer and Multiplex Networks	315
11.2	Multilayer Metrics for Emergent Properties	316
11.2.1	Node Degree and Related Measures	316
11.2.2	Walks and Paths	317
11.2.3	Centrality and Node Ranking	318
11.2.4	Clustering	319
11.2.5	Spectral Properties	321
11.2.6	Resilience, Robustness and Fragility	322
11.3	Null Randomization Procedures	322
11.3.1	Replica Node Randomization	322
11.3.2	Independent Layer Randomization	323
11.3.3	Randomization Preserving Multidegree Sequences	323
11.4	Getting the Most from Multilayer Networks	323
11.4.1	Behavioural and Disease Ecology	323
11.4.2	Metawebs	325
11.4.3	Multispecies Connectivity	327

x	Contents	
	11.5 Multilayer Networks and Spatio-temporal Analysis	329
	11.6 Concluding Remarks	330
12	Closing Comments and Future Directions	331
	12.1 Reminders and Challenges	331
	12.1.1 Reminders	332
	12.1.2 Challenges	334
	12.2 Back to Basics	336
	12.3 Numerical Solutions: Software Programs and Programming	337
	12.4 Statistical and Ecological Tests	338
	12.5 Complementarity of Methods	338
	12.6 Looking Ahead	342
	12.6.1 Ongoing Development	342
	12.6.2 The Bayesian Approach	344
	12.6.3 Spatial Causal Inference	354
	12.6.4 Artificial Intelligence: From Machine Learning to Deep Learning to AI	355
	12.6.5 Geometric Algebra	358
	12.7 Other Future Directions	359
	<i>References</i>	361
	<i>Index</i>	394

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-too-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, . . .