

Contents

	<i>page xi</i>
Preface	
1 Spatial concepts and notions	1
Introduction	1
1.1 The spatial context	3
1.2 Ecological data	4
1.3 Spatial structure: spatial dependence and spatial autocorrelation	4
1.4 Spatial scales	9
1.5 Sampling design	11
1.5.1 The sample size (the number of observations 'n')	11
1.5.2 Spatial resolution	11
1.5.3 The size of the study area: extent	12
1.5.4 The location in the landscape	14
1.5.5 The size of the sampling or observational units: grain	14
1.5.6 The shape of the sampling or observational units	14
1.5.7 The spatial sampling design	14
1.5.8 Spatial lag	15
1.5.9 Edge effect	16
1.6 Stationarity	16
1.7 Spatial statistics	21
1.7.1 First-order statistics	21
1.7.2 Second-order statistics	21
1.8 Ecological hypotheses and spatial analysis	22
1.9 Randomization tests for spatially structured ecological data	25
1.9.1 Restricted randomizations	27
1.10 In conclusion: what is space?	30

2	Ecological and spatial processes	32	4.1	Mapped point data in two dimensions	88
	Introduction	32	4.1.0	Introduction: three pattern types	88
2.1	Ecological processes and spatial structure	32	4.1.1	Distance to neighbours methods	89
2.2	Spatial processes by species level of organization	40	4.1.2	Refined nearest neighbour analysis	90
2.3	Spatial process	43	4.1.3	Second-order point pattern analysis	91
3	Points, lines and graphs	46	4.1.4	Bivariate data	96
	Introduction	46	4.1.5	Multivariate point pattern analysis data	98
3.1	Points: spatial patterns of point events	50	4.2	Mark correlation function	105
3.1.1	Topological neighbours	50	4.3	Ripley's <i>K</i> -function for inhomogeneous point pattern analysis	106
3.1.2	Distance-based spatial neighbours	55	4.3.1	Bivariate and multivariate non-stationary point patterns	109
3.1.3	Directional angle-based spatial neighbours	59	4.3.2	Quantitative marks: mark correlation	110
3.2	Lines: fibre pattern analysis	61	4.4	Point patterns in other dimensions	111
3.2.1	Aggregation and overdispersion of fibres	62	4.4.1	One dimension	111
3.2.2	Fibres with properties	65	4.4.2	Lacunarity	112
3.2.3	Curving fibres	65	4.4.3	Three dimensions	115
3.2.4	Branching curved fibres	66	4.5	Circumcircle methods	116
3.2.5	Congruence and parallelism of curved fibres	67	4.5.1	Univariate analysis	116
3.3	Points and lines together	67	4.5.2	Bivariate analysis	117
3.4	Points and lines: spatial graphs	69	4.5.3	Multivariate analysis	119
3.4.1	Signed and directed graphs and networks	70	4.6	Concluding remarks	119
3.4.2	How to create subgraphs	71	5	Contiguous units analysis	123
3.4.3	Graph models	72		Introduction	123
3.5	Network analysis of areal units	72	5.1	Quadrat variance methods	123
3.6	Spatial analysis of movement	77	5.2	Significance tests for quadrat variance methods	126
3.6.1	Transport and gravity models	77	5.3	Adaptations for two or more species	127
3.6.2	Least-cost paths	77	5.4	Two or more dimensions	129
3.6.3	Circuit theory	79	5.5	Spectral analysis and related techniques	133
3.6.4	Spatial graphs and movement	79	5.6	Wavelets	134
3.6.5	Corridors	79	5.7	Concluding remarks	135
3.7	Testing hypotheses with graphs	80	6	Spatial analysis of sample data	140
3.7.1	Comment on spatial graph randomization	83		Introduction	140
3.8	Concluding remarks	84	6.1	Join count statistics	141
	Glossary: graph definitions and properties	84	6.1.1	Join count statistics for <i>k</i> -categories	142
4	Spatial analysis of complete point location data	88	6.2	Global spatial statistics	144
	Introduction	88	6.2.1	Spatial covariance	144
			6.2.2	Spatial autocorrelation coefficients for one variable	145

6.2.3 Variography	152	8.3 Randomization procedures	224
6.2.4 Fractal dimension	158	8.3.1 Restricted randomization and bootstrap	224
6.3 Sampling design effects on the estimation of spatial pattern	159	8.3.2 Markov Chain Monte Carlo	226
6.4 Spatial relationship between two variables	163	8.4 Spatial regressions	227
6.5 Local spatial statistics	164	8.4.1 Spatial filtering using autoregressive models	230
6.6 Spatial scan statistics	168	8.4.2 Spatial filtering using moving average models	232
6.7 Interpolation and spatial models	170	8.4.3 Spatial filtering using Moran's eigenvector maps	233
6.7.1 Proximity polygons	171	8.4.4 Spatial error regression	233
6.7.2 Trend surface analysis	172	8.4.5 Geographically weighted regression	234
6.7.3 Inverse distance weighting	172	8.4.6 Remove spatial autocorrelation from the residuals	234
6.7.4 Kriging	173	8.4.7 Example of the use of non-spatial and spatial regressions	236
6.8 Concluding remarks	178	8.5 Considerations for sampling and experimental design	239
7 Spatial relationship and multiscale analysis	182	8.5.1 Sampling	239
Introduction	182	8.5.2 Experimental design	241
7.1 Correlation between spatially autocorrelated variables	182	8.6 Concluding remarks	241
7.2 Correlation of distance matrices	183		
7.2.1 Mantel test	183	9 Spatial partitioning: spatial clusters and boundary detection	244
7.2.2 Partial Mantel tests and multiple-matrix regression	189	Introduction	244
7.3 Canonical (constrained) ordination	192	9.1 Patch identification	244
7.4 Multiscale analysis	194	9.1.1 Patch properties	244
7.4.1 Generalized Moran's eigenvector maps	195	9.1.2 Spatial clustering	245
7.4.2 Multiresolution spectral decomposition analysis based on wavelets	198	9.1.3 Fuzzy classification	249
7.5 Concluding remarks	203	9.2 Boundary delineation	251
8 Spatial autocorrelation and inferential tests	206	9.2.1 Ecological boundaries	251
Introduction	206	9.2.2 Boundary properties	251
8.1 Models dealing with one-dimensional autocorrelated data	207	9.2.3 Boundary detection and analysis for one-dimensional transect data	253
8.2 Dealing with spatial autocorrelation in inferential models	213	9.2.4 Boundary detection based on two-dimensional data	262
8.2.1 Simple adjustments	213	9.3 Boundary statistics	270
8.2.2 Adjusting the effective sample size	214	9.4 Boundary overlap statistics	271
8.2.3 More on induced autocorrelation and the relationships between variables	218	9.5 Hierarchical spatial partitioning	273
8.2.4 Correlation and related methods	220	9.5.1 Edge enhancement with kernel filters	274
		9.6 Concluding remarks	275

10	Spatial diversity analysis	278	11.7.3	Population synchrony	343
	Introduction	278	11.7.4	Spatio-temporal chaos	346
10.1	Space in diversity analysis	278	11.8	Spatio-temporal graphs	350
10.1.1	Spatial heterogeneity	279	11.8.1	Characteristics and classification	351
10.1.2	Spatial location and environmental gradients	280	11.8.2	Animal movement with spatio-temporal graphs	353
10.1.3	Spatial scale	280	11.8.3	Other applications	355
10.1.4	Proximity and spatial dependence	281	11.8.4	Final comment on spatio-temporal graphs	359
10.2	First-order diversity	283	11.9	Concluding remarks	360
10.2.1	α -diversity	284	11.9.1	Recommendations	360
10.2.2	β -diversity	287	12	Closing comments and future directions	361
10.2.3	γ -diversity	293		Introduction: myths, misunderstandings and challenges	361
10.2.4	Why space in first-order diversity analysis?	293	12.1	Back to basics	367
10.3	Species combinations and composition: agreement and complementarity	295	12.2	Numerical solutions: software programs and programming	368
10.3.1	Species combinations	296	12.3	Statistical and ecological tests	370
10.3.2	Comments on species compositional diversity	302	12.4	Complementarity of current methods	371
10.3.3	Nested subsets, constraining compositional diversity	303	12.5	Analyses in both space and time	373
10.4	Multiple classifications	311	12.5.1	Analysis of permanent sample plot data	373
10.5	Spatial diversity: putting it all together with spatial graphs	314	12.5.2	Spatially linked time series	379
10.6	Temporal aspects of spatial diversity	315	12.5.3	Spatial analysis of animal-vegetation according to data types	382
10.7	Concluding remarks	317	12.6	Future work	388
11	Spatio-temporal analysis	319	12.6.1	Ongoing development	388
	Introduction	319	12.6.2	The hierarchical Bayesian approach	389
11.1	Change in spatial statistics	323	12.6.3	Hypothesis testing with spatio-temporal graphs	395
11.2	Spatio-temporal join count	324	12.7	Other future directions	396
11.3	Spatio-temporal analysis of clusters and contagion	325	References		398
11.4	Spatio-temporal scan statistics	329	Index		425
11.5	Polygon change analysis	329			
11.6	Analysis of movement	333			
11.7	Process and pattern	341			
11.7.1	Tree regeneration, growth and mortality	341			
11.7.2	Plant mobility	342			