

Contents

Contributing Authors

page

xiii

1 Introduction

Richard Law, Ulf Dieckmann, and Johan A.J. Metz

1

A Empirical and Statistical Background: A Plant Ecological Perspective

7

2 A Neighborhood View of Interactions among Individual Plants 11

Peter Stoll and Jacob Weiner

2.1	Introduction	11
2.2	Competition Mechanisms	12
2.3	Moving from the Population to the Individual Level	18
2.4	What is a Plant's Neighborhood?	19
2.5	Challenges for a Neighborhood Perspective of Plant Interactions	24
2.6	Suggestions for Modelers	26

3 Spatial Interactions among Grassland Plant Populations 28

Jonathan Silvertown and J. Bastow Wilson

3.1	Introduction	28
3.2	Methods for Measuring Competition in the Field	29
3.3	Results of Field Experiments	32
3.4	Competition Matrices	38
3.5	Community Consequences of Spatial Interactions	42
3.6	Concluding Comments	46

4 Spatio-temporal Patterns in Grassland Communities 48

Tomáš Herben, Heinjo J. During, and Richard Law

4.1	Introduction	48
4.2	Spatio-temporal Patterns in Plant Communities	48
4.3	Externally versus Internally Generated Spatial Patterns . .	52
4.4	Concepts in Spatio-temporal Processes in Plant Communities	54
4.5	Ergodic and Non-ergodic Communities	60
4.6	Concluding Comments	64

5	Statistical Modeling and Analysis of Spatial Patterns	65
	David R. Cox, Valerie Isham, and Paul Northrop	
5.1	Introduction	65
5.2	Descriptive Analysis	66
5.3	Stochastic Models	70
5.4	Model Fitting	80
5.5	Concluding Comments	88
B	When the Mean-field Approximation Breaks Down	89
6	Grid-based Models as Tools for Ecological Research	94
	Christian Wissel	
6.1	Introduction	94
6.2	Grid-based Simulation Models	95
6.3	Spread and Control of Rabies	97
6.4	Dynamics of a Dwarf Shrub Community	104
6.5	A Generic Forest Fire Model	109
6.6	Concluding Comments	114
7	Coexistence of Replicators in Prebiotic Evolution	116
	Tamás Czárán and Eörs Szathmáry	
7.1	Introduction	116
7.2	Metabolic Replication: A Cellular Automaton Model	119
7.3	The Phenomenology of Coexistence	123
7.4	Spatial Pattern and the “Advantage of the Rare” Effect	127
7.5	Resistance to Parasites and the Evolution of Community Size	129
7.6	Toward a Dynamical Theory of Surface Metabolism	133
8	Games on Grids	135
	Martin A. Nowak and Karl Sigmund	
8.1	Introduction	135
8.2	One-round Games	137
8.3	Repeated Games	145
8.4	Extensions and Related Work	149
8.5	Concluding Comments	150

9	The Interplay between Reaction and Diffusion	151
	Mikael B. Cronhjort	
9.1	Introduction	151
9.2	The Models: Cellular Automata versus Partial Differential Equations	153
9.3	Spiral and Scroll Ring Patterns	159
9.4	Cluster Dynamics	163
9.5	Concluding Comments	169
10	Spirals and Spots: Novel Evolutionary Phenomena through Spatial Self-structuring	171
	Maarten C. Boerlijst	
10.1	Introduction	171
10.2	A Spatial Hypercycle Model	173
10.3	Spirals and Spots	174
10.4	Local versus Global Extinction	175
10.5	Resistance to Parasites	178
10.6	Concluding Comments	180
11	The Role of Space in Reducing Predator–Prey Cycles	183
	Vincent A.A. Jansen and André M. de Roos	
11.1	Introduction	183
11.2	Individual-based Predator–Prey Models	184
11.3	A Deterministic Model of Two Coupled Local Populations	187
11.4	Larger Spatial Domains	193
11.5	The Spatial Rosenzweig–MacArthur Model	196
11.6	Concluding Comments	199
11.A	Stability Analysis of a Multi-patch System	200
C	Simplifying Spatial Complexity: Examples	203
12	Spatial Scales and Low-dimensional Deterministic Dynamics	209
	Howard B. Wilson and Matthew J. Keeling	
12.1	Introduction	209
12.2	Two Models from Evolutionary Ecology	210
12.3	Identifying Spatial Scales	213
12.4	Dynamics, Determinism, and Dimensionality	219
12.5	Concluding Comments	225
12.A	Singular Value Decomposition	225

13 Lattice Models and Pair Approximation in Ecology	227
Yoh Iwasa	
13.1 Introduction	227
13.2 Plants Reproducing by Seed and Clonal Growth	228
13.3 Forest Gaps	236
13.4 Colicin-producing and Colicin-sensitive Bacteria	243
13.5 Limitations, Extensions, and Further Applications	247
14 Moment Approximations of Individual-based Models	252
Richard Law and Ulf Dieckmann	
14.1 Introduction	252
14.2 Spatial Patterns and Spatial Moments	253
14.3 Extracting the Ecological Signal from Stochastic Realizations	256
14.4 Qualitative Dependencies in a Spatial Logistic Equation .	261
14.5 Exploration of Parameter Space	267
14.6 Concluding Comments	269
15 Evolutionary Dynamics in Spatial Host–Parasite Systems	271
Matthew J. Keeling	
15.1 Introduction	271
15.2 Dynamics of the Spatial Host–Parasite Model	272
15.3 A Difference Equation for the Dynamics of Local Configurations	279
15.4 Evolution to Critical Transmissibility	282
15.5 Concluding Comments	288
15.A Mathematical Specification of the PATCH Model	289
16 Foci, Small and Large: A Specific Class of Biological Invasion	292
Jan-Carel Zadoks	
16.1 Introduction	292
16.2 Epidemic Orders	293
16.3 A Theory of Foci	298
16.4 Generalizations	312
16.5 Concluding Comments	315
16.A Quantitative Applications of Models for Spatial Population Expansion (by Johan A.J. Metz)	315

17 Wave Patterns in Spatial Games and the Evolution of Cooperation	318
Régis Ferrière and Richard E. Michod	
17.1 Introduction	318
17.2 Invasion in Time- and Space-continuous Games	319
17.3 Invasion of <i>Tit For Tat</i> in Games with Time-limited Memory	323
17.4 Invasion of <i>Tit For Tat</i> in Games with Space-limited Memory	329
17.5 Concluding Comments	332
D Simplifying Spatial Complexity: Techniques	337
18 Pair Approximations for Lattice-based Ecological Models	341
Kazunori Satō and Yoh Iwasa	
18.1 Introduction	341
18.2 Pair Approximation	344
18.3 Improved Pair Approximation	349
18.4 Improved Pair Approximation with Variable Discounting	355
18.5 Concluding Comments	357
19 Pair Approximations for Different Spatial Geometries	359
Minus van Baalen	
19.1 Introduction	359
19.2 The Dynamics of Pair Events	364
19.3 Average Event Rates	368
19.4 Pair Approximations for Special Geometries	372
19.5 Pair Approximations versus Explicit Simulations	379
19.6 Invasion Dynamics	382
19.7 Concluding Comments	385
20 Moment Methods for Ecological Processes in Continuous Space	388
Benjamin M. Bolker, Stephen W. Pacala, and Simon A. Levin	
20.1 Introduction	388
20.2 Moment Methods	389
20.3 A Spatial Logistic Model	391
20.4 A Spatial Competition Model	400
20.5 Extensions and Related Work	403
20.6 Concluding Comments	405

20.A	Mean Equation	406
20.B	Covariance Equation	408
20.C	Analyzing the One-species System	409
20.D	Analyzing the Two-species System	410
21	Relaxation Projections and the Method of Moments	412
Ulf Dieckmann and Richard Law		
21.1	Introduction	412
21.2	Individual-based Dynamics in Continuous Space	418
21.3	Dynamics of Correlation Densities	425
21.4	Moment Closures and their Performance	438
21.5	Further Developments and Extensions	447
21.A	Derivation of Pair Dynamics	452
22	Methods for Reaction-Diffusion Models	456
Vivian Hutson and Glenn T. Vickers		
22.1	Introduction	456
22.2	Continuous Models	459
22.3	Linearized Stability and the Turing Bifurcation	466
22.4	Comparison Methods	471
22.5	Traveling Waves	475
22.6	The Evolution of Diffusion	479
22.7	Concluding Comments	481
23	The Dynamics of Invasion Waves	482
Johan A.J. Metz, Denis Mollison, and Frank van den Bosch		
23.1	Introduction	482
23.2	Relative Scales of the Process Components	483
23.3	Independent Spread in Homogeneous Space: A Natural Gauging Point	485
23.4	Complications	497
23.5	The Link with Reaction-Diffusion Models	504
23.6	Dispersal on Different Scales	507
23.7	Concluding Comments	512
24	Epilogue	513
Johan A.J. Metz, Ulf Dieckmann, and Richard Law		
References		
Index		