

# Contents

	<i>page</i>
<b>Contributing Authors</b>	xiii
<b>1 Introduction</b>	1
Richard Law, Ulf Dieckmann, and Johan A.J. Metz	
<b>A Empirical and Statistical Background: A Plant Ecological Perspective</b>	7
<b>2 A Neighborhood View of Interactions among Individual Plants</b>	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
<b>3 Spatial Interactions among Grassland Plant Populations</b>	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
<b>4 Spatio-temporal Patterns in Grassland Communities</b>	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

<b>5</b>	<b>Statistical Modeling and Analysis of Spatial Patterns</b>	<b>65</b>
	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>B</b>	<b>When the Mean-field Approximation Breaks Down</b>	<b>89</b>
<b>6</b>	<b>Grid-based Models as Tools for Ecological Research</b>	<b>94</b>
	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
<b>7</b>	<b>Coexistence of Replicators in Prebiotic Evolution</b>	<b>116</b>
	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
<b>8</b>	<b>Games on Grids</b>	<b>135</b>
	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

Cambridge University Press

0521642949 - The Geometry of Ecological Interactions: Simplifying Spatial Complexity

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

Table of Contents

[More information](#)

	ix
<b>9 The Interplay between Reaction and Diffusion</b>	<b>151</b>
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
<b>10 Spirals and Spots: Novel Evolutionary Phenomena through Spatial Self-structuring</b>	<b>171</b>
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
<b>11 The Role of Space in Reducing Predator–Prey Cycles</b>	<b>183</b>
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
<b>C Simplifying Spatial Complexity: Examples</b>	<b>203</b>
<b>12 Spatial Scales and Low-dimensional Deterministic Dynamics</b>	<b>209</b>
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

<b>13 Lattice Models and Pair Approximation in Ecology</b>	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
<b>14 Moment Approximations of Individual-based Models</b>	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
<b>15 Evolutionary Dynamics in Spatial Host–Parasite Systems</b>	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
<b>16 Foci, Small and Large: A Specific Class of Biological Invasion</b>	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

<b>17 Wave Patterns in Spatial Games and the Evolution of Cooperation</b>	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
<b>D Simplifying Spatial Complexity: Techniques</b>	337
<b>18 Pair Approximations for Lattice-based Ecological Models</b>	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
<b>19 Pair Approximations for Different Spatial Geometries</b>	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
<b>20 Moment Methods for Ecological Processes in Continuous Space</b>	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

Cambridge University Press

0521642949 - The Geometry of Ecological Interactions: Simplifying Spatial Complexity

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

Table of Contents

[More information](#)

xii

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
<b>21</b>	<b>Relaxation Projections and the Method of Moments</b>	<b>412</b>
	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
<b>22</b>	<b>Methods for Reaction–Diffusion Models</b>	<b>456</b>
	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
<b>23</b>	<b>The Dynamics of Invasion Waves</b>	<b>482</b>
	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
<b>24</b>	<b>Epilogue</b>	<b>513</b>
	Johan A.J. Metz, Ulf Dieckmann, and Richard Law	
	<b>References</b>	<b>517</b>
	<b>Index</b>	<b>553</b>