

Contents

List of Boxes	<i>page xi</i>
Preface	xiii
Acknowledgments	xviii
I Introduction	1
1.1 The Context	1
1.1.1 Neutral Theory of Biodiversity in a Nutshell	3
1.2 Neutral Individual-Based Models on Networks (and Beyond)	8
1.3 Species' Persistence Times and Their Landscape	17
1.3.1 Network Topology and Persistence Times	18
1.3.2 Observational Distributions of Empirical Persistence Times	22
1.3.3 Scaling of Persistence Times and Species–Area Relations	24
1.4 Testing Directional Connectivity in the Laboratory	25
1.4.1 Design of the Experiments	25
1.4.2 Experimental Studies on the Role of Directional Dispersal and Habitat Size	30
1.5 Invasion Wave Fronts along Fractal Networks and Population Dynamics	32
1.5.1 River Networks and Ecological Corridors: Migration Fronts, Hydrochory, Transport on Fractals	32
1.5.2 Modeling Human Range Expansions: Western Colonization in the Nineteenth-Century United States	44
2 Species	47
2.1 Fish Diversity, Hydrologic Controls, and Riverine Habitat Suitability	47
2.1.1 A Hierarchical Metacommunity Model of the MMRS Network	48
2.1.2 Geomorphic Processes, the Frequency Concept, and Riverine Habitat Suitability	53
2.2 Metapopulation Persistence and Species Spread in River Networks	64
2.2.1 A Metapopulation Approach	66

2.2.2	Connectivity Structures and Dispersal Mechanisms	66
2.2.3	Derivation of Species' Persistence Conditions	67
2.2.4	Spatial Patterns of Species Spread and a Spatially Explicit Persistence Criterion	71
2.2.5	The Role of Network Structure and Dispersal Pathways	71
2.2.6	A Paradigmatic Example: The Persistence of an Amphibian Metapopulation in a River System	73
2.2.7	Spatial Patterns of Species Spread	79
2.3	Elevational Gradients of Biodiversity in Fluvial Landscapes	84
2.3.1	Fluvial versus Idealized Landscapes	84
2.3.2	Of Altitude-Specific Environmental Drivers	88
2.3.3	Fluvial Landforms and Biodiversity	91
2.4	Metapopulation Capacity of Evolving Fluvial Landscapes	96
2.4.1	Optimality of Total Energy Dissipation and Species Viability	100
2.5	A Minimalist Model of Range Dynamics in Fluvial Landscapes	103
2.5.1	Landscape Effects on Metapopulation Extinction Dynamics	106
2.5.2	Computational Experiments with SPOM	111
3	Populations	114
3.1	Biological Invasions	114
3.1.1	Movement and Demographic Increase: Resulting Patterns	125
3.1.2	Traveling Waves and Invasion Fronts	135
3.2	Modeling Biological Invasions via Interacting Particle Systems (IPS)	139
3.2.1	Branching Random Walks	140
3.2.2	Properties of Local and Global Survival	140
3.2.3	Contact Processes	143
3.3	Zebra Mussel Invasion of the Mississippi–Missouri River System	148
3.3.1	An Iconic Biological Invasion	148
3.3.2	Fluvial Transport and the Demography of the Invader	149
3.4	Demographic Stochasticity, Fluctuating Resource Supply, Substrate Heterogeneity	156
3.4.1	Population Fluctuations and Different Kinds of Stochasticity	157
3.4.2	Demographic Stochasticity and the Fisher–Kolmogorov Deterministic Model of Invasions	160
3.4.3	Slowing Invasion Speed by Heterogeneous Environments	164
3.4.4	Biased Reaction–Diffusion Wave Fronts along Fractal Networks	164
3.4.5	Biased Random Walks on Fractals	164
3.4.6	Reaction Random Walks on Oriented Graphs	165
3.4.7	Heterogeneous Invasions: The Role of Spatial Resource Variability	176
3.5	Mixing and Dispersion in River Networks	183
3.5.1	Fickian Diffusion	184
3.5.2	Turbulent Diffusion	188
3.5.3	Shear Flow Dispersion	194
3.5.4	Geomorphological Dispersion	196
3.6	Estimating Species Distribution and Abundance in River Networks Using Environmental DNA	213
3.6.1	Of eDNA and Rivers	213
3.6.2	eDNA-Derived Spatial Distribution of the Source Biomass	216
3.6.3	Maps of eDNA Production in the Wigger River (CH)	222

4	Waterborne Disease	225
4.1	Introduction to the Ecology of Waterborne Disease	225
4.1.1	Epidemiological Models of Microparasitic Diseases: A First Assessment	229
4.1.2	Models of Macroparasitic Diseases	236
4.1.3	Early Models of WB Disease Spread	241
4.1.4	Generalized Reproduction Numbers for Spatially Explicit Models of WB Disease Epidemics	242
4.1.5	The Geography of Disease Spread	248
4.1.6	Disease Spread in Theoretical Networks	249
4.2	Seasonal Environmental Forcings and Epidemicity of Spatially Explicit Waterborne Epidemics	252
4.2.1	Floquet Theory for River Network Models	257
4.2.2	Geography of Periodic Disease Spread	259
4.2.3	The Transient Spread of Epidemics	261
4.3	Epidemic Cholera	265
4.3.1	A First Assessment of the Haiti Cholera Outbreak	266
4.3.2	A Second Assessment of the Haiti Cholera Outbreak	270
4.3.3	On the Probability of Extinction of the Haiti Cholera Epidemic	283
4.3.4	Mobile Phone Data, Tracking of Human Mobility, and the Spread of Infection	290
4.4	Endemic Schistosomiasis	293
4.4.1	Spatially Explicit Models of Schistosomiasis	295
4.4.2	A Spatially Explicit Model of Schistosomiasis in Burkina Faso	296
4.4.3	An Integrated Study of Endemic Schistosomiasis in Senegal	309
4.5	Proliferative Kidney Disease (PKD) in Salmonid Fish	316
4.5.1	Hierarchy of Models	316
4.5.2	Spread of PKD in Idealized River Networks	318
4.5.3	Integrated Field, Laboratory, and Theoretical Studies of PKD Spread in a Swiss Prealpine River	322
4.6	Of Hydrologic Drivers and Controls of WR Disease	331
4.6.1	Rainfall and Cholera	332
4.6.2	Rainfall and Schistosomiasis	335
5	Afterthoughts and Outlook	340
5.1	The Book's Design	340
5.2	Outlook on Spatially Explicit Epidemiology of WR Disease	342
5.3	Streamflow Ephemerality and Schistosomiasis (and Other WR Diseases) Control	348
5.4	Hydrologic Controls on Microbial Diversity and Beyond	351
5.5	Scaling of Carbon Sequestration and Fluvial Corridors: Global Issues	354
5.6	eDNA, Species Dispersal and River Networks – What's Up?	358
6	Appendices	362
6.1	Stability of Dynamical Systems and Bifurcation Analysis	363
6.1.1	Stability of Linear Systems	363
6.1.2	Linear Time-Invariant Systems	363
6.1.3	Positive Systems and Perron–Frobenius Theory	366
6.1.4	Time-Varying Periodic Systems	366
6.1.5	Stability of Nonlinear Systems	367
6.1.6	Stability of Equilibria of Nonlinear Systems	367
6.1.7	Stability of Cycles in Nonlinear Systems	368
6.1.8	Bifurcations in Nonlinear Systems	370

6.2	Optimal Channel Networks and Geomorphological Statistical Mechanics	374
6.2.1	Formulation of the Mathematical Problem	375
6.2.2	Comparative Geomorphological Studies	376
6.2.3	Feasible Optimality	379
6.2.4	Examples of OCNs and Their Landscapes	382
6.2.5	Exact Results	384
6.3	Computational Tools for Waterborne Disease Spread	386
6.3.1	A Solver for a Spatially Implicit SIRB Model	386
6.3.2	Computing Conditions for Transient Epidemics in Spatially Explicit Systems	386
	References	401
	Index	432