CAMBRIDGE

Cambridge University Press
978-1-108-47782-6 — River Networks as Ecological Corridors
Andrea Rinaldo , Marino Gatto , Ignacio Rodriguez-Iturbe
Table of Contents
More Information

Contents

List of Boxes *page* xi
Preface xiii
Acknowledgments xviii

1 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

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-108-47782-6 — River Networks as Ecological Corridors
Andrea Rinaldo , Marino Gatto , Ignacio Rodriguez-Iturbe
Table of Contents
More Information

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

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE
Cambridge University Press
978-1-108-47782-6 — River Networks as Ecological Corridors
Andrea Rinaldo , Marino Gatto , Ignacio Rodriguez-Iturbe
Table of Contents
More Information

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

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-108-47782-6 — River Networks as Ecological Corridors
Andrea Rinaldo , Marino Gatto , Ignacio Rodriguez-Iturbe
Table of Contents
More Information

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

© in this web service Cambridge University Press www.cambridge.org