

Contents

1	Introduction	1
1.1	What Is Biological Invasion?.....	1
1.1.1	Invasion of Rats and Cats in Ocean Islands.....	2
1.1.2	Muskrat in Eastern Europe	4
1.1.3	Japanese Beetle in North America	6
1.1.4	Gray Squirrel in the UK	7
1.1.5	<i>Mnemiopsis Leidy</i> in the Black Sea	10
1.1.6	More Examples	12
1.2	Issues and Questions Arising.....	15
1.3	Why Mathematical Modeling?.....	16
1.4	Why Is This Book Timely?.....	17
2	Dynamics of Biological Invasions	19
2.1	Stages of Invasion	19
2.2	Population Dynamics in a Nonspatial System	23
2.2.1	Continuous-Time Models.....	26
2.2.2	Discrete-Time Models	38
2.3	Dynamical Systems Approach to Invasion	46
2.4	Moving Around in Space	53
2.4.1	Growth–Dispersal Models	61
2.5	Conclusion	66
3	Reaction–Diffusion Models: Single Species	69
3.1	Species Establishment	69
3.2	Establishment in Two Dimensions: Effects of Geometry	77
3.3	Population Spread: Traveling Front Propagation.....	82
3.4	Convergence of the Initial Conditions	96
3.5	Remarks on Species Spread in Two Dimensions.....	101
3.6	Conclusion	104

4	Invasion in a Multispecies System	107
4.1	Introduction	107
4.2	Spatial Spread into a Competitor	110
4.3	Invasion by a Predator	113
	4.3.1 Patterns in the Wake of a Predator Invasion	114
4.4	Predator–Prey Spread and Biological Control.....	122
4.5	Biological Control and the Allee Effect	128
	4.5.1 Spatiotemporal Complexity of Invasion	131
	4.5.2 Complexity of the Parameter Space.....	139
4.6	Biological Control and Patchy Spread	141
4.7	Biological Control with Pathogens	146
	4.7.1 Case Study: Invasion of Gypsy Moths in the US	149
4.8	Conclusion	152
5	Long-Distance Dispersal and Spread	155
5.1	Introduction	155
5.2	Dispersal Kernels for Describing Movement.....	157
5.3	Population Spread and Long-Distance Dispersal	169
5.4	Discrete-Time Growth and Dispersal	171
	5.4.1 Spreading Speeds for Thin-Tailed Dispersal Kernels	173
	5.4.2 Spreading Speeds for Fat-Tailed Dispersal Kernels	178
5.5	Continuous-Time Growth and Dispersal	179
5.6	Spatial Contact Models for Disease Spread	183
5.7	A Stratified Diffusion Model for Accelerating Invasions	184
5.8	Including Age Structure in a Renewal Equation	188
5.9	Impact of Allee Dynamics on Spread.....	189
5.10	Conclusion	192
6	A User’s Guide to Integro-difference Models for Invasive Spread	195
6.1	Introduction	195
6.2	Connecting Spread Rate to Long-Distance Dispersal Data.....	196
6.3	A Nonparametric Approach	198
6.4	Spread in Two Dimensions	200
6.5	Monte Carlo Methods	203
6.6	Including Stage Structure	203
6.7	Conclusion	208
7	Stochasticity and Invasion Dynamics	211
7.1	Introduction	211
7.2	A Simple Hierarchical Model for Biological Invasion.....	212
7.3	A Nonlinear Hierarchical Model Including Allee Dynamics.....	217
7.4	Effect of Environmental Stochasticity on Linear Population Growth Models.....	222
	7.4.1 Discrete-Time Population Growth	223
	7.4.2 Continuous-Time Population Growth	225

7.5	A Nonlinear Model with Multiple Sources of Stochasticity	226
7.5.1	Diffusion Processes	226
7.5.2	Establishment and Extinction Levels	228
7.6	Conclusion	232
8	Stochastic Spread	233
8.1	Introduction	233
8.2	Spread in Fluctuating Environments	234
8.2.1	A Stochastic Integrodifference Model	234
8.2.2	Including Environmental Stochasticity in Reaction–Diffusion Models	240
8.3	Effects of Demographic Stochasticity on Spread	241
8.3.1	Experimental Studies	241
8.3.2	A Reaction–Diffusion Model	242
8.3.3	Furthest-Forward Velocity	242
8.3.4	Stochastic Models for Patchy Spread	249
8.4	Conclusion	255
9	Assessing Invasion Risk	257
9.1	Introduction	257
9.2	Risk Associated with the Invasion Process	259
9.2.1	Which Factors Cause Propagule Flow?	259
9.2.2	Which Species Are Likely to Be Invasive?	260
9.2.3	Which Region Is likely to Be Invaded?	260
9.2.4	Intersecting Spheres of Influence	261
9.3	Probabilistic Approaches	261
9.3.1	Gravity Models for Human-Mediated Propagule Pressure	262
9.3.2	Regression Models to Connect Invader Traits and Environmental Attributes	264
9.3.3	Network Models for Combining Human Interactions with Environmental and Species Traits	268
9.3.4	Maximum Entropy Density Estimation (MaxEnt)	271
9.4	Binary Methods	273
9.4.1	Decision Trees	273
9.4.2	Boosted Decision Trees and Random Forests	276
9.4.3	The <i>k</i> Nearest Neighbors Approach	277
9.4.4	Support Vector Machines	278
9.4.5	Genetic Algorithms for Rule-Set Prediction (GARP)	279
9.5	Probabilistic Versus Binary	281
9.6	An Economic Quantification of Risk	283
9.6.1	Example: Zebra Mussel Invasion	284
9.7	Conclusion	284

10	Responding to Invasions: Detection, Control, and Adaptation	287
10.1	Introduction	287
10.2	Optimal Detection	289
10.3	Adaptation	293
10.4	Adaptation and Control in a Stochastic Dynamic Setting	295
10.5	Control in a Deterministic Setting	298
	10.5.1 Prevention Control in a Lake Network	299
10.6	Eradication Control Using Linear Programming	302
10.7	Conclusion	304
A	Appendix	307
A.1	The Fourier Transform	307
A.2	The Fourier Series Expansion	307
A.3	The Poisson Distribution	308
A.4	Comparison Theorems for PDEs	309
A.5	The Central Limit Theorem	310
A.6	Jensen's Inequality	310
A.7	The Green's Function for the Diffusion Equation	311
	A.7.1 The Moments of $w(x, t)$	312
A.8	Maximum Likelihood Estimation (MLE) and the Ratio Test	312
A.9	Akaike Information Criterion (AIC)	313
A.10	Bayesian Information Criterion (BIC)	314
A.11	Receiver Operating Characteristic (ROC) Curve	314
A.12	Gini Impurity	315
A.13	Solution to the KISS Model	316
A.14	The KISS Model with Gaussian Initial Conditions	318
A.15	Deriving Spatial Extent from an Integrodifference Equation for Growth and Dispersal	319
A.16	Sensitivity and Elasticity of Spreading Speed to Growth Rate Parameters	321
A.17	Details of the Dispersal Kernel Integration in Sect. 5.2	323
A.18	Details of the Distribution Limits in Sect. 5.2	323
A.19	Probability Generating Function for the Hierarchical Model of Sect. 7.3	325
A.20	Stochastic Dynamical Programming	328
A.21	The Maximum Principle	330
A.22	Linear Programming	333
	References	335
	Index	355