

Contents

1	Introduction	1
1.1	Linking individuals, traits, and population dynamics	1
1.2	Survey of research applications	2
1.3	About this book	3
1.3.1	Mathematical prerequisites	4
1.3.2	Statistical prerequisites and data requirements	5
1.3.3	Programming prerequisites	5
1.4	Notation and nomenclature	6
2	Simple Deterministic IPM	9
2.1	The individual-level state variable	9
2.2	Key assumptions and model structure	10
2.3	From life cycle to model: specifying a simple IPM	12
2.3.1	Changes	15
2.4	Numerical implementation	17
2.5	Case study 1A: A monocarpic perennial	19
2.5.1	Summary of the demography	19
2.5.2	Individual-based model (IBM)	21
2.5.3	Demographic analysis using <code>lm</code> and <code>glm</code>	22
2.5.4	Implementing the IPM	24
2.5.5	Basic analysis: projection and asymptotic behavior	26
2.5.6	Always quantify your uncertainty!	30
2.6	Case study 2A: Ungulate	32
2.6.1	Summary of the demography	33
2.6.2	Individual-based model	34
2.6.3	Demographic analysis	35
2.6.4	Implementing the IPM	36
2.6.5	Basic analysis	39
2.7	Model diagnostics	41
2.7.1	Model structure	42
2.7.2	Demographic rate models	42

2.7.3	Implementation: choosing the size range	45
2.7.4	Implementation: the number of mesh points	48
2.8	Looking ahead	49
2.9	Appendix: Probability Densities and the Change of Variables Formula	49
2.10	Appendix: Constructing IPMs when more than one census per time year is available	52
3	Basic Analyses 1: Demographic Measures and Events in the Life Cycle	57
3.1	Demographic quantities	57
3.1.1	Population growth	58
3.1.2	Age-specific vital rates	62
3.1.3	Generation time	63
3.2	Life cycle properties and events	65
3.2.1	Mortality: age and size at death	66
3.2.2	Reproduction: who, when, and how much?	70
3.2.3	And next...	73
3.3	Case study 1B: Monocarp life cycle properties and events	74
3.3.1	Population growth	74
3.3.2	Mortality: age and size at death calculations	75
3.3.3	Reproduction: who, when, and how much?	78
3.4	Appendix: Derivations	82
4	Basic Analyses 2: Prospective Perturbation Analysis	87
4.1	Introduction	87
4.2	Sensitivity and elasticities	88
4.3	Sensitivity analysis of population growth rate	88
4.3.1	Kernel-level perturbations	89
4.3.2	Vital rate functions	93
4.3.3	Parameters and lower-level functions	94
4.4	Case Study 2B: Ungulate population growth rate	96
4.4.1	Kernel-level perturbations	96
4.4.2	Vital rate functions	98
4.4.3	Parameters and lower-level functions	103
4.5	Sensitivity analysis of life cycle properties and events	106
4.6	Case Study 2B (continued): Ungulate life cycle	108
5	Density Dependence	111
5.1	Introduction	111
5.2	Modeling density dependence: recruitment limitation	112
5.3	Modeling density dependence: Idaho steppe	115
5.4	Theory	121
5.4.1	Persistence or extinction?	122
5.4.2	Local stability of equilibria	126

5.4.3	Equilibrium perturbation analysis	127
5.4.4	Density dependence and environmental stochasticity	128
5.5	Case study 2C: ungulate competition	128
5.6	Coda	136
5.7	Appendix: Mean field approximations for neighborhood competition	136
6	General Deterministic IPM	139
6.1	Overview	139
6.2	Case study 2D: ungulate age-size structure	140
6.2.1	Structure of an age-size IPM	141
6.2.2	Individual-based model and demographic analysis	142
6.2.3	Implementing the model	144
6.3	Specifying a general IPM	148
6.4	Examples	150
6.4.1	Seeds and plants	150
6.4.2	Susceptible and Infected	151
6.4.3	Time delays	152
6.4.4	Individual quality and size	152
6.4.5	Stage structure with variable stage durations	154
6.5	Stable population growth	155
6.5.1	Assumptions for stable population growth	156
6.5.2	Alternate stable states	159
6.5.3	Time delay models	159
6.6	Numerical implementation	160
6.6.1	Computing eigenvalues and eigenvectors	160
6.6.2	Implementing a size-quality model	162
6.7	Case Study 2D: Age-size structured ungulate, further calculations	167
6.7.1	Population growth rate	167
6.7.2	Other demographic measures	169
6.7.3	Consequences of age-structure	170
6.8	Other ways to compute integrals	171
6.9	Appendix: the details	180
6.9.1	Derivations	183
7	Environmental Stochasticity	187
7.1	Why environmental stochasticity matters	187
7.1.1	Kernel selection versus parameter selection	188
7.2	Case Study 1C: Another monocarpic perennial	189
7.2.1	Building an IPM	191
7.2.2	Basic analyses by projection	193
7.3	Modeling temporal variation	195
7.3.1	Fixed versus random effects	195
7.4	Long-run growth rate	201
7.4.1	Implementation	204

7.5	Sensitivity and elasticity analysis	206
7.5.1	Kernel perturbations	209
7.5.2	Function perturbations	211
7.5.3	Parameter perturbations	214
7.6	Life Table Response Experiment (LTRE) Analysis	218
7.7	Events in the life cycle	221
7.8	Appendix: the details	223
7.8.1	Derivations	227
8	Spatial Models	229
8.1	Overview of spatial IPMs	229
8.2	Building a dispersal kernel	231
8.2.1	Descriptive movement modeling	232
8.2.2	Mechanistic movement models	236
8.3	Theory: bounded spatial domain	237
8.4	Theory: unbounded spatial domain	239
8.5	Some applications of purely spatial IPMs	243
8.6	Combining space and demography: invasive species	244
8.7	Invasion speed in fluctuating environments	251
9	Evolutionary Demography	255
9.1	Introduction	255
9.2	Motivation	257
9.3	Evolution: Dynamics	257
9.3.1	Approximating Evolutionary Dynamics	259
9.4	Evolution: Statics	260
9.4.1	Evolutionary Endpoints	261
9.4.2	Finding ESSs using an optimization principle	263
9.5	Evolution: Stochastic Environments	265
9.6	Function-valued traits	272
9.6.1	Solving the ESS conditions for function-valued strategies	277
9.7	Prospective evolutionary models	280
9.8	Appendix: Approximating evolutionary change	281
10	Future Directions and Advanced Topics	283
10.1	More flexible kernels	283
10.1.1	Transforming variables	284
10.1.2	Nonconstant variance	284
10.1.3	Nonlinear growth: modeling the mean	286
10.1.4	Nonlinear growth: parametric variance models	287
10.1.5	Nonparametric models for growth variation	288
10.2	High-dimensional kernels	291
10.3	Demographic stochasticity	293
10.3.1	Population growth rate	297
10.3.2	Extinction	301

Contents	xiii
10.4 IPM meets DEB: deterministic trait dynamics or constraints . . .	304
10.5 Different kinds of data	306
10.5.1 Mark-recapture-recovery data	306
10.5.2 Count data	310
10.6 Coda	312
10.7 Appendix: Covariance with demographic stochasticity	312
References	315
Index	327

Data-driven Modelling of Structured Populations
A Practical Guide to the Integral Projection Model

Ellner, S.P.; Childs, D.Z.; Rees, M.

2016, XIII, 329 p. 67 illus., 29 illus. in color., Softcover

ISBN: 978-3-319-28891-8