Primer of Ecology using R

Hank Stevens

2023-02-06

Contents

Pı	Preface			
1	The	Theory in Ecology		
	1.1	Examples of theories	9	
	1.2	An example: Metabolic Theory of Ecology	9	
	1.3	Power law scaling implies constant relative differences	9	
	1.4	Meet METE: Maximum Entropy Theory of Ecology	9	
	1.5	In fine	9	
2	Opt	Optimal Foraging 1		
	$2.\overline{1}$	A prey model	11	
	2.2	The patch model	11	
	2.3	A simulation of a prey model	11	
3	Sim	Simple density-independent growth		
	3.1	Discrete growth rates of fruit flies in my kitchen	14	
	3.2	Fruit flies with continuous overlapping generations	14	
	3.3	Properties of geometric and exponential growth	14	
	3.4	Modeling with Data: Simulated Dynamics	14	
	3.5	1/f environmental noise	14	
	3.6	In fine	14	
4	Den	sity-independent Demography	15	
	4.1	A two stage matrix model	16	
	4.2	A brief primer on matrices	16	
	4.3	Decomposing $A \dots \dots \dots \dots \dots$	16	
	4.4	A three stage model	16	
	4.5	Projection	16	
	4.6	Analyzing the transition matrix	16	
	4.7	Matrix models can be challenging	16	
	4.8	Integral projection	16	
	4.9	R packges for demography	16	
	4.10	Loggerhead Sea Turtle: a classic example	16	

4 CONTENTS

5	Density-dependent growth				
	5.1	Continuous logistic growth			
	5.2	Dynamics around the equilibria			
	5.3	Discrete Density-dependent Growth			
	5.4	Nonlinear Discrete Density-dependence in Single-species Popula-			
		tions of Plants			
	5.5	Maximum Sustainable Yield			
6	Pop	ulations in Space			
	6.1	Source-sink Dynamics			
	6.2	Metapopulations			
	6.3	Hanski's incidence function			
7	Dire	Direct competition and mutualism 2			
	7.1	Interspecific competition			
	7.2	Interspecific mutualism			
	7.3	Generalized Lotka-Volterra models			
	7.4	Nonlinear direct competition			
	7.5	In fine			
8	Consumer-resource Interactions 23				
	8.1	Ratio dependence			
	8.2	Prey dependence			
	8.3	Interlude: Functional response - what an individual predator does 2			
	8.4	Stability analysis for the prey-dependent Lotka–Volterra model . 2			
	8.5	Resource growth functions			
	8.6	Paradox of enrichment			
	8.7	Consumption of two resources			
	8.8	In fine			
9	Hos	t-parasitoid relations 2			
	9.1	Independent and random attacks			
	9.2	Aggregation leads to coexistence			
	9.3	Dynamics of the May host–parasitoid model			
	9.4	<i>In Fine</i>			
10	Dise	ease 2			
	10.1	Closed epidemics			
	10.2	Open epidemics			
		Modeling data from Bombay $\dots \dots \dots$			
11	Con	sumer-resource Competition and Mutualisms 29			
		Competition for one resource			
		Competition for Substitutable resources			
		Tilman's resource ratio with essential resources			
		Consumer-resource mutualism			
		Plant-soil feedbacks			

CONTENTS	5
----------	---

	11.6 Simulations for learning	30
12	Food webs and other networks	31
	12.1 Food Web Characteristics	32
	12.2 Does omnivory destablize food chains?	32
	12.3 Perhaps mutualism stabilizes bipartite networks	32
	12.4 Exploring Pandora, right here at home	32
13	Diversity	33
	13.1 Background	34
	13.2 Species Composition	34
	13.3 Diversity	34
	13.4 Species diversity	34
	13.5 Rarefaction and total species richness	34
	13.6 Distributions	34
	13.7 Neutral Theory of Biodiversity and Biogeography	34
	13.8 Species—area relations	34
	13.9 Diversity Partitioning	34
	13.10In fine	34
14	References	35

6 CONTENTS

Preface

8 CONTENTS

Theory in Ecology

- 1.1 Examples of theories
- 1.1.1 Hierarchy theory
- 1.1.2 A general theory of ecology
- 1.1.3 Efficient theory
- 1.2 An example: Metabolic Theory of Ecology
- 1.2.1 Body-size dependence
- 1.2.2 Temperature dependence
- 1.3 Power law scaling implies constant relative differences
- 1.4 Meet METE: Maximum Entropy Theory of Ecology
- 1.5 In fine

Optimal Foraging

- 2.1 A prey model
- 2.1.1 Our intuition
- ${\bf 2.1.2} \quad {\bf Mathematical \ support}$
- 2.2 The patch model
- 2.3 A simulation of a prey model
- 2.3.1 Lab exercise

Simple density-independent growth

- 3.1 Discrete growth rates of fruit flies in my kitchen
- 3.2 Fruit flies with continuous overlapping generations
- 3.3 Properties of geometric and exponential growth
- 3.3.1 Average growth rate
- 3.4 Modeling with Data: Simulated Dynamics
- 3.4.1 Data-based approaches
- 3.4.2 Creating and visualizing the data
- 3.4.3 One simulation
- 3.4.4 Multiple simulations
- 3.4.5 A distribution of possible futures
- 3.4.6 Analyzing results
- 3.4.7 Extinction probability: expectation and uncertainty
- 3.4.8 Inferring processes underlying growth rate
- $3.5 ext{ } 1/f$ environmental noise
- 3.5.1 Reddened Song Sparrow growth
- 3.6 In fine

Density-independent Demography

- 4.1 A two stage matrix model
- 4.2 A brief primer on matrices
- 4.3 Decomposing A
- 4.4 A three stage model
- 4.5 Projection
- 4.6 Analyzing the transition matrix
- 4.6.1 Eigenanalysis
- 4.6.2 Finite rate of increase
- 4.6.3 Stable stage distribution
- 4.6.4 Calculating the stable stage distribution
- 4.6.5 Reproductive value
- 4.6.6 Sensitivity and elasticity
- 4.7 Matrix models can be challenging
- 4.8 Integral projection
- 4.8.1 On probability density
- 4.8.2 A size-based IPM of smooth coneflower
- 4.8.2.1 Graphing size-dependent transitions
- 4.8.3 Statistical modeling of size-dependent transitions
- 4.8.4 Generating the projection kernel
- 4.8.5 Population summaries
- 4.9 R packges for demography
- 4.10 Loggerhead Sea Turtle: a classic example

Density-dependent growth

- 5.1 Continuous logistic growth
- 5.2 Dynamics around the equilibria
- 5.2.1 A marble and a wok
- 5.2.2 Analytical linear stability analysis
- 5.2.3 Projection with numerical integration
- 5.2.4 Effects of N on birth and death rates
- 5.2.5 Theta-logistic growth
- 5.2.6 Allee effect
- 5.2.7 The integral of logistic growth
- 5.3 Discrete Density-dependent Growth
- 5.3.1 Effects of r_d
- 5.3.2 Bifurcations
- 5.3.2.1 Sensitivity to initial conditions
- 5.3.2.2 Boundedness, and other descriptors
- 5.3.3 The Ricker model
- 5.4 Nonlinear Discrete Density-dependence in Single-species Populations of Plants
- 5.5 Maximum Sustainable Yield

Populations in Space

Placeholder

6.3

6.1	Source-sink Dynamics
6.1.1	Complications and cases
6.2	Metapopulations
6.2.1	The classic Levins model
6.2.2	Propagule rain
6.2.3	The rescue effect and the core-satellite model
6.2.4	Parallels with Logistic Growth
6.2.5	Levins $vs.$ Hanski
6.2.6	Habitat Destruction
6.2.7	Illustrating the effects of habitat destruction
6.2.8	Different assumptions lead to different predictions about rates of extinction

Hanski's incidence function

Direct competition and mutualism

7.1 Interspecific competition

- 7.1.1 Equilbria
- 7.1.1.1 Isoclines
- 7.1.1.2 Finding equilibria
- 7.1.1.3 Coexistence the invasion criterion
- 7.1.1.4 Other equilibria
- 7.1.2 Dynamics at the Equilibria
- 7.1.2.1 Determine the equilibria
- 7.1.2.2 Create the Jacobian matrix
- 7.1.2.3 Solve the Jacobian at an equilibrium
- 7.1.2.4 Use the Jacobian matrix
- 7.1.2.5 Three interesting equilbria
- 7.1.3 Return Time and the Effect of r
- 7.2 Interspecific mutualism
- 7.3 Generalized Lotka-Volterra models
- 7.4 Nonlinear direct competition
- 7.4.1 Investigate stability criteria
- 7.5 In fine

Consumer-resource Interactions

- 8.1 Ratio dependence
- 8.1.1 Dynamics of ratio dependent predation
- 8.2 Prey dependence
- 8.2.1 Dyanmics of prey-dependent predation
- 8.3 Interlude: Functional response what an individual predator does
- 8.4 Stability analysis for the prey-dependent Lotka–Volterra model
- 8.5 Resource growth functions
- 8.5.1 Consumption of a renewable resource
- 8.5.2 Prey carrying capacity and type II functional response
- 8.6 Paradox of enrichment
- 8.7 Consumption of two resources
- 8.7.1 Interpreting consumption and assimilation
- 8.8 In fine

Host-parasitoid relations

- 9.1 Independent and random attacks
- 9.1.1 Simulating simple host-parasitoid dynamics
- 9.1.1.1 Simulating Random Attacks
- 9.2 Aggregation leads to coexistence
- 9.2.1 Equilibria for a discrete-time model
- 9.3 Dynamics of the May host-parasitoid model
- 9.4 In Fine

Disease

10.1	Closed epidemics
10.1.1	Density-dependent transmission
10.1.2	Frequency-dependent transmission
10.2	Open epidemics
10.3	Modeling data from Bombay
10.3.1	Optimization

Consumer-resource Competition and Mutualisms

- 11.1 Competition for one resource
- 11.2 Competition for Substitutable resources
- 11.3 Tilman's resource ratio with essential resources
- 11.4 Consumer-resource mutualism
- 11.4.1 A model of uni-directional mutualism
- 11.5 Plant-soil feedbacks
- 11.6 Simulations for learning
- 11.6.1 lvg()
- 11.6.2 Systematic simulations
- 11.6.3 Checking simulation results
- 11.6.4 Comparing simulation results to analytical solutions
- 11.6.5 One last thing: using the Jacobian matrix
- 11.6.6 In Fine

Food webs and other networks

- 12.1 Food Web Characteristics
- 12.2 Does omnivory destablize food chains?
- 12.2.1 Multi-species Lotka-Volterra notation
- 12.2.2 Background
- 12.2.3 Implementing Pimm and Lawton's Methods
- 12.2.4 Shortening the Chain
- 12.2.5 Adding Omnivory
- 12.2.6 Comparing Chain A versus B
- 12.2.7 Re-evaluating Take-Home Messages
- 12.3 Perhaps mutualism stabilizes bipartite networks
- 12.3.1 Creating bipartite webs
- 12.3.2 Testing effects of nestedness and modularity on network resilience.
- 12.3.3 Modeling causal networks
- 12.4 Exploring Pandora, right here at home
- 12.4.1 Properties assessed

Diversity

13.1	Backgroun	d
------	-----------	--------------

- 13.2 Species Composition
- 13.2.1 Measures of abundance
- 13.2.2 Dissimilarities and Distances
- 13.2.3 Displaying multidimensional distances
- 13.3 Diversity
- 13.4 Species diversity
- 13.5 Rarefaction and total species richness
- 13.5.1 An example of rarefaction and total species richness
- 13.6 Distributions
- 13.6.1 Log-normal distribution
- 13.6.2 Other distributions
- 13.6.3 Pattern vs. process
- 13.7 Neutral Theory of Biodiversity and Biogeography
- 13.7.1 Different flavors of neutral communities
- 13.7.2 Investigating neutral communities
- 13.8 Species—area relations
- 13.8.1 Island biogeography
- 13.9 Diversity Partitioning
- 13.9.1 Partitioning species—area relations
- 13.10 In fine

References