Ecology in theory and in data

Instructor: Vadim Karatayev

Course objectives and style: The goals of this class are twofold. The first is to overview foundational concepts in population and community ecology. The second is to become comfortable with implementing your own ecological ideas as models in R and confront them with real ecological data. The first half of lectures will be primarily chalkboard talks, the second half will focus on data analysis and group work. The labs will focus on introducing R and group work.

Skills and concepts you will learn in this course:

1. Fundamental concepts in population and community ecology
2. Construct, program, and analyze simple population models in R
3. Fundamentals of working with large-scale ecological data
4. Read and discuss research papers that involve modeling
5. Understand and apply a variety of quantitative tools (equilibrium and stability analysis, phase plane analysis, maximum likelihood, etc.)
6. Working in small, collaborative research groups

Prerequisites: calculus

Class schedule:

Lectures: 2 per week, 90min each

Computer labs: 1 per week, 120min each

Homeworks: Four problem sets, Two ½-page reviews of a modeling paper that you choose, and group work

Study hall: 1 per week, 120min. This is a period available to you to work on homeworks with peers and both the professor and TA available for asking questions. It is entirely optional and serves as both an extended office hour and a group learning opportunity.

Course outline (approximate, 2 lectures, 1 lab, and 1 homework per week):

Lecture #, topic	Sub-concepts	Readings
1. From biology to a model, exponential growth	Continuous vs. discrete time	Fretwell 1991; Hastings 1-16 Kareiva
2. Density dependence and stability analysis		Hastings 81-95; Algebra & calculus review sheet
HW1: math, modeling, or annotate lab code		
Lab 1: introduction to R - objects, functions, and loops		
3. Complex model dynamics	Allee effects and density dependence in discrete time	Hastings 96-101; May 1974
4. Age structure		Hastings 16-40, Crouse 1987
HW2: problem set 1 – logistic growth variations (life histories, metapopulations; finding equilibria)		

Lab 2: Simulating and numerically analyzing models - chaos and regime shifts		
5. Competition I: Lotka-Volterra	Phase plane analysis	Gause 1934
6. Competition II: Space	Competition-colonization trade-offs and extinction debt	Tilman 1994
HW3: problem set 2 – direct + apparent competition (metapopulations, coral reefs; phase planes)		
Lab 3: Age-structured models		
7. Predation		Hastings 151-178
8. Epidemic models		Hastings 189-200; Keeling 2005; Lloyd-Smith 2005; Keeling and Grenfell 1997
HW4: problem set 3 – predator-prey, herbivore outbreaks (stability and alternative stable states)		
Lab 4: Predation – doing differential equations and phase planes numerically		
9. Exam review		
10. Midterm exam		
HW5: Paper review 1		
Lab 5: practice exam Q&A		
11. Competition III: Niches in time	Storage effects	Chesson 2002
12. Limits of deterministic models	Stochasticity-induced instability, neutral theory	Encyclopedia of Theoretical Ecology entry
HW6: problem set 4 – statistics review; choose time series for group project		
Lab 6: adding stochasticity to competition and epidemic models		
13. Maximum likelihood	Model complexity; model selection	Bolker; Ellner et al.
14. Observation and process error		
HW7: Paper review 2		
Lab 7: fitting dynamical models to data		
15. Data analysis I: Time	Diagnostics and transient dynamics	Bolker
16. Data analysis II: Space	Bifurcations and substituting space for time	
HW: group work		
Lab 8: Importing and diagnosing data for group project		
17. Population genetics I	Selection, evolutionary rescue	
18. Population genetics II	Disease coevolution or gene drives	
HW: complete lab 9, group work		
Lab 9: Size-structured populations – data-driven integral projection models		
19. Group presentations II		
20. Group presentations III		
Lab 10: Disease coevolution or gene drives through candy		

Grading: 25% labs, 20% homework, 30% Midterm exam, 25% group project

Midterm is open-notes and will involve analyzing variations of models seen on homeworks and on the practice exam. Electronic resources not allowed.

Homeworks and Labs are due 1 week after they are assigned; assignments accepted up to 1 week past due date with 10% penalty. Working together in groups is highly beneficial and encouraged, but please note that you cannot copy each other's work. For additional guidelines, see the SJA Collaboration handout under course resources

Group project: You will work with 2-3 of your classmates to chose a time series from the Global Population Dynamics database, statistically analyzing patterns in the time series, and coding up and fitting several dynamical models to the observed patterns. Your task will involve (1) turning in a term paper that summarizes your work and compares your models with published papers and (2) a 15-minute presentation of your group's work to the class. You will receive a separate handout with a description of the project.