BZ/M348 and BZ548 Theory of Population and Evolutionary Ecology

Contact information:
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Office hours:
TTh 10:00-11:00 a.m., E334A Anatomy/Zoology

Lecture: MWF 1:00 – 1:50 a.m. 206 Yates Hall
Required computer lab: R 3-6 p.m. 212 Yates Hall

Prerequisites: M155 or M160 or 1 semester of calculus.

Objectives: The principal objective of this course is to familiarize students with the theory of population and evolutionary ecology. Students will gain enough background to read theoretical population and evolutionary ecology literature, do simple modeling, and springboard to more complex theory if desired. Students will gain hands on experience through homeworks and computer labs. Students will learn Matlab and use it to program their own models and simulations during lab.

Course web site: http://ramct.colostate.edu/

Optional text: There is no perfect text for this course. I will make written lecture notes available on RamCT prior to each lecture. The text we will use is:

Otto, S.P. and T. Day. 2007. A Biologist's Guide to Mathematical Modeling in Ecology and Evolution. Princeton University Press, Princeton, New Jersey.

I posted pdfs of all recommended readings that are not in the Otto and Day textbook on the course web site to give you references for the lecture material. Copies of the Otto and Day, Hastings and Murray books are on 24 hour reserve at the library also.

Other texts that may be useful:
Bulmer, M. 1994. Theoretical Evolutionary Ecology. Sinauer Associates, Sunderland, Massachusettes.
Case, T.J. 2000. An Illustrated Guide to Theoretical Ecology. Oxford University Press, New York.
Edelstein-Keshet, L. 2005. Mathematical Models in Biology. SIAM, Philadelphia.
Gotelli, N.J. 2001. A Primer of Ecology, 3rd Edition. Sinauer Associates, Sunderland, Massachusettes.
Hastings, A. 1997. Population Biology: Concepts and Models. Springer-Verlag, New York.
Murray, J.D. 2002. Mathematical Biology I, 3rd Edition. Springer-Verlag, New York.

Grading: I will be using the plus/minus system when assigning final grades.

I will drop your lowest 2 homework grades and lowest 2 lab write ups in calculating your final grade. The lab code and write ups are graded check, check +/-. If you receive all checks, you will get all of the points for the code or write ups. Check plus is given for doing something additional in terms of coding or exploration of the biological problem.

BZ/M348	
Homeworks from lecture (11)	30%
In-class mid-term exams (2)	30%
Final exam	20%
Lab participation (4 labs without write up)	5%
Matlab code assignments (8)	5%
Lab write ups (11)	10%

M548

Homeworks from lecture (11)	22%
In-class mid-term exams (2)	22%
Final exam	15%
Lab participation (4 labs without write up)	3%
Matlab code assignments (8)	4%
Lab write ups (11)	9%
Additional graduate lab components (5) (code and write up combined)	5%
Thesis or dissertation module	20%

There will be no opportunities for "make ups" that are not well justified. If you have questions regarding the grading of problem sets or tests, you must resolve the issue within two weeks. For tests, please provide written justification for why you believe your answer was correct. Some "extra credit" questions will be asked on exams, but otherwise extra credit is not available.

Workload: This is a 4 credit course, so you should anticipate spending 8-12 hours per week outside of class time on this course. Students taking all versions of the course report spending a similar amount of time on the course. Students report averaging 4-5 hours per homework (range 2-10 hours depending on student and which homework), 1-2 hours on lab write ups (range 1-4 hours), and 0-2 hours on reading and reviewing lecture material. Students who spent more time reviewing spent less time on homeworks. Students report the workload as heavy, but manageable. More importantly, students also report that they are satisfied with the amount that they learn in the course given the workload. We will work hard, cover a lot of material, and most students learn A LOT!

Lecture/Reading Schedule:

August 20: *Introduction to modeling – why use quantitative approaches*

Ecological properties of populations

I. Single, unstructured populations

August 22: *Density-independent growth in continuous time I: forced, non-autonomous systems*
    Terminology for dynamical systems, forced changes, main theorem of calculus, integration and rescaling
August 24: *Density-independent growth in continuous time II: autonomous systems (exponential growth)*
    Recommended reading: Otto and Day sections 3.2.1, 5.3.1 (Hastings section 2.1)
August 27: *Density-dependent growth in continuous time I (logistic growth)*
    Explicit solutions of autonomous equations, equilibria, linearization, stability, and qualitatively different dynamics
    Recommended reading: Otto and Day section 3.2.2 (Hastings sections 4.1 and 4.2)
August 29: *Density-dependent growth in continuous time II (logistic growth continued)*
August 31: *Density-dependent growth in continuous time III (Allee effects)*
    Bifurcation
September 5: *Density-dependent growth in continuous time IV*
    In-class activity: harvesting problem
    Homework 1 due
    Recommended reading: Murray section 1.6 on harvesting
September 7: *Density-independent growth in discrete time (geometric growth)*
    Rescaling, equilibria, and stability in discrete time
    Recommended reading: Murray sections 2.1 and 2.2
September 10: *Density-dependent growth in discrete time I (discrete logistic model)*
    Period-doubling and chaos
    Recommended reading: Murray section 2.2 and 2.3
September 12: *Density-dependent growth in discrete time II*
    Recommended reading: Strogatz sections 10.2-10.7

II. Single, structured populations

September 14: *2 state populations*

Multiple, non-interacting variables, linear homogeneous systems, vectors, matrices, eigenvalues, and eigenvectors in a 2-dimensional case

Recommended reading: Strogatz sections 5.1-5.2

Homework 2 due

September 17: *2 state populations II*

September 19: *Migration and multistate populations*

Multiple, non-interacting variables, linear systems in discrete time, k-dimensional systems

September 21: *Age structure I*

Life tables, Leslie matrices, estimating population growth rate, sensitivity analysis

Recommended reading: Gotelli chapt. 3

September 24: *Age structure II*

III. Interacting populations

September 26: *Introduction to interacting populations I*

Isoclines, equilibria, linearization, stability in 2 dimensions

Recommended reading: Otto and Day sections 8.2.1 and 8.2.2 (Hastings chapt. 6)

Homework 3 due

September 28: *Introduction to interacting populations II*

October 1: *Lotka-Volterra competition*

Recommended reading: Otto and Day sections 3.4.1, 4.2.4 (Hastings sections 7.1-7.3)

October 3: *Lotka-Volterra competition II*

Homework 4 due

October 5: ***In-class mid-term exam***

October 8: *Competition models of Tilman*

Recommended reading: Tilman 1982, chapt. 3

October 10: *Lotka-Volterra predator-prey*

Structural instability

In-class activity: analyzing predator-prey models

Recommended reading: Otto and Day sections 3.4.2, pp. 307-308

October 12: *Predator-prey models with stability* Hastings sections 8.3-8.6

Homework 5 due

October 15: *Review of predator-prey models*

Classification of stabilizing and destabilizing factors, limit cycles, Andronov-Hopf bifurcations

Recommended reading: Bazykin section 3.3

October 17: *Review of predator-prey models II*

October 19: *Multipopulation and disease models*

Analysis concepts in 3 dimensions

Recommended reading: Otto and Day section 3.5

Homework 6 due

Evolving populations

V. Mechanisms of evolution

October 22: *Factors of microevolution*

Space of genotypes, mutation, selection, sex, migration, and drift: history as initial conditions

Recommended reading: Hastings sections 3.1 and 3.2

October 24: *Selection and genetic load*

Changes in allele frequencies, haploid selection model, relation to logistic model, multiplicative and additive fitness, Lyapunov function, fitness and stability surfaces

In-class activity: lecture notes discussion

October 26: *Selection and segregation*
Panmixia of zygotes and gametes, diploid selection model
Recommended reading: Otto and Day section 3.3. 4.2.3, 4.4.1 (Hastings chapt. 3.4 pp. 48-64)
Homework 7 due
October 29: *Mutation and mutation-selection balance*
Recommended reading: Otto and Day pp. 181-183 (Hastings chapt. 3.4 pp. 64-68)
October 31: *Fisher's Fundamental Theorem and Wright's gradient equation*
Recommended reading: Hastings chapt. 3.5
November 2: *Evolution of quantitative traits*
The gradient equation, Malthusian fitness
Recommended reading: Lande 1976 pp. 314-317 only
Homework 8 due
November 5: ***In-class mid-term exam***

VI. Evolution of an isolated population
November 7: *Hawk-dove game*
Basics of game theory and ESS models, optimization, invasion theory
Recommended reading: Maynard Smith chapt. 2
November 9: *Mixed strategies and generalized 2 player games*
November 12: *Evolutionary conflicts: Foraging theory*
Dynamic programming
Recommended reading: Mangel and Clark chapt. 2
Homework 9 due
November 14: *Evolutionary conflicts: Foraging theory II*
November 16: *Evolutionary conflicts: Parental allocation*
Recommended reading: Mangel and Clark chapt. 6
November 26: *Age structure dynamics*
Iteroparity and semelparity and return to the Leslie matrix
November 28: *Selection in variable environments*
Arithmetic and geometric means
Recommended reading: Bulmer chapt. 5 pp. 89-93
Homework 10 due
November 30: *Evolution of dispersal*
In-class Activity: paper discussion
Required reading: Hamilton and May 1977

VII. Advanced topics
December 3: *Adaptive dynamics and coevolution*
Fast-slow dynamical systems
Recommended reading: Khibnik and Kondrashov 1997
December 5: *Applications to real systems*
In-class Activity: paper discussion
Required reading: Webb et al. 2006
December 7: Wrap-up review
Homework 11 due

FINAL EXAM: Take home exam due by 5 p.m., on the Thursday of finals week (December 13).

Computer labs: In the past, most students were able to finish the entire lab and some of the write up in the time provided. The goal of these labs is for you to explore the models and to learn how to program in Matlab. As much as I want all of you to learn Matlab programming, I also do not want it to get in the way of exploring the models. So, I will release a working version of the Matlab code for the week in the last half hour of the lab. Part of your lab write-up grade is based on having a working code of your own, but students who use my code will receive credit for the rest of the write-up.

You should bring a memory stick to lab in order to save your programs for write ups and use in later labs or you can e-mail them to yourself. If you need extra lab time to finish or for homeworks, Matlab is available on the computers in the Weber computer lab (Weber 205/206). Weber 205/206 is usually open from 8am to 10pm, Monday through Thursday and 8am to 4:45pm on Friday. During the day, the lab is often reserved for classes; there is usually a schedule outside the door denoting the free hours during the day. Yates 212 is usually locked when not in use, but it may be possible for me to open it for additional time if there is demand for it.

Computer Lab Schedule:

August 23: *Introduction to Matlab*

No Assignment

August 301: *Exploring growth in single populations with continuous time I (exponential growth and logistic growth)*

Graphics and special applications in Matlab

Code and Write up Assignment (Grad component available)

September 6: *Exploring the Allee effect and harvesting models*

Code and Write up Assignment (Grad component available)

September 13: *Chaos in the discrete time logistic model*

Control statements and subroutines in Matlab

Code and Write up Assignment

September 20: *Manipulation of Leslie matrices*

More on matrices in Matlab

Code and Write up Assignment (Grad component available)

September 27: *Review of Matlab and special projects*

No Assignment (Grad component available)

October 4: *Dynamics of a competition model*

Code and Write up Assignment (Grad component available)

October 11: *Analysis of the Lotka-Volterra predator-prey model and modifications*

The symbolic toolbox in Matlab

Write up Assignment Only (Grad component available)

October 18: *Biological interpretation of bifurcating systems*

No Assignment

October 25: *Simulation of allele frequency changes and genetic load*

Code and Write up Assignment

November 1: *Evolution of a quantitative trait*

Code and Write up Assignment

November 8: *Simulation of 2 and 3 player games*

Code and Write up Assignment (Grad component available)

November 15: *Investigation of a dynamic state-variable model, patch selection*

Write up Assignment Only (Grad component available)

November 29: *Investigation of the Hamilton and May model*

Required reading: Hamilton and May 1977

Write up Assignment Only (Grad component available)

December 6: *Investigation of Red Queen models*

Required reading: Khibnik and Kondrashov 1997 sections 3 and 4c

No Assignment