Introduction to Theoretical Ecology: Populations and Species Interactions

Instructor

Chad E. Brassil, University of Nebraska-Lincoln, cbrassil@unl.edu, 402-419-0076.

Dates and Location

Monday July 9 to Friday July 13 at the W.K. Kellogg Biological Station, Michigan State University

Table of Contents

Short Description

This course will provide an introduction to the theoretical side of ecology. In other words, how does mathematics provide insights into our understanding of ecological processes? Mathematically, the course will introduce skill sets such as model construction, solving for equilibria, and analyzing the stability of those equilibria. We will examine systems of continuous-time differential equations, as well as discrete-time difference equations and structured populations via Leslie matrices. Ecologically, the course will provide a framework to think about single-species population dynamics and multi-species interactions such as competition and predation.

Inclusion Statement

All students are welcome in this course. All students shall exhibit respect for each other so that we can foster an engaged learning environment. I will strive to remove barriers to learning, and I ask you to communicate with me any ways in which barriers can be removed. Our differences make us a stronger learning team as long we all participate, which is facilitated by listening and communicating. Let us foster in inclusive learning environment.

In this class, those differences include differences in math background and comfort level. However, we will all learn more by asking questions about what we don't understand, and by teaching each other when we do understand.

Daily Outline

8:30 am – 10:30 am	New material will be presented and discussed
10:30 am – 11:30 am	Work on problem set
1:00 pm – 3:00 pm	New material will be presented and discussed
3:00 pm – 4:00 pm	Work on problem set

Topical Outline

01 Monday AM: Single-species population models

Parameters, state variables, units, model change (differential equations or difference equations)

Single species, density-independent model, continuous time (Exponential)

Equilibrium and stability

Mathematica notebook

Single-species, density-independent, discrete time (Geometric); equilibrium and stability;

Mathematica: NestList

[Problem set: find doubling time]

02 Monday PM: Density-dependence

Single species, density-dependent model (Logistic)

Derive, compare graphs, examine in Mathematica

Alternative continuous-time models (Smith; Theta-logistic)

Non-dimensionalized models

Discrete-time models (Discrete Logistic; Ricker; Beverton-Holt)

Stability; cob-web plots; overcompensatory

[Problem set: negative density-dependence]

Texts: Hastings Ch 2 and 4. Gotelli Ch 1and 2.

03 Tuesday AM: Structured Populations

Leslie matrix

Stable age distribution

Projection matrix, Eigenvalues, Eigenvectors

Lifetime reproductive success

[Problem set: extend to stage-distribution]

04 Tuesday PM: Structured population analysis

Reproductive value

Sensitivity analysis

Integral projection matrix

Merow et al. 2104. Advancing population ecology with integral projection models: a practical guide. Methods in Ecology and Evolution. 5, 99-110.

05 Wednesday AM: Competition

Lotka-Voltera

Two-species stability. Phase plane and analytical

[Problem set: extend to 3rd species]

06 Wednesday PM: Consumer-Resource and R* Competition

Chemostat

Consumer-resource model

Monod

R*

[Problem set: ?]

Texts: Hastings Ch 6 and 7. Gotelli Ch 5

07 Thursday AM: Functional responses

Classical Predator-prey

Derive type II functional response

Handling Time Simulation

Type II functional response

[Problem set: ?]

08 Thursday PM: Enemy-victim variants

Stability of Rosenzweig-Macarthur and variants

Parasitoid Host: Nicholson-Bailey

Texts: Hastings Ch 8 and 9. Gotelli Ch 6

[Problem set: dd in predator death]

09 Friday AM: Disease and evolution (Alternatively, food chain chains)

SI, SIR, SEIR

[Problem set: make more modifications]

10 Friday PM: Evolution

SIR disease evolution in face of trade-offs

Cole's paradox

[Problem set:]

Text: Hastings Ch 10 and 5

Course Learning Goals

- Be able to construct a mathematical representation of a population process
- List the assumptions of a given model population model
- Analyze stability of a single-species and two-species models graphically and analytically
- Relate the biology, mathematical expressions, and graphical representations to each other

Materials

Mathematica will be a useful tool in the course, in part, because it can do some basic calculus for you in areas in which you might be rusty.

Michigan State students can download and install Mathematica at no cost. See instructions at: https://techstore.msu.edu/mathematica-installation-and-use-information

If you are not a Michigan State student, your home institution may have an equivalent site license of students. Alternatively, anyone can download and install a 15-day trial version: https://www.wolfram.com/mathematica/trial/

These are not required, but here are some approachable texts that introduce topics in theoretical ecology at a similar level to this course. At times, I will pull from these as sources material for the course.

Gotelli, NJ. 2008. A Primer of Ecology. 4th Edition. Sinauer Associates. Sunderland, MA.

Gurney, WSC, and RM Nisbet. 1998. Ecological Dynamics. Oxford University Press. Oxford.

Hastings, A. 1997. Populatiobn Biology: concepts and models. Springer. New York.

Otto, SP, and T Day. 2007. A Biologist's Guide to Mathematical Modeling in Ecology and Evolution. Princeton University Press. Princeton, NJ.

Assignments and Grades

Problem Sets. Half of your grade will be based on the completion of periodic problem sets during the course. Each problem set will reinforce the concepts we've discussed in class, and challenge you to understand the material at a deeper level.

Participation. Half of your grade will be based by attendance and participation in lectures and in groups while working on problem sets.

Course grades will be determined via the cut-offs of A (93.0%), A- (90.0%), B+ (87.0%), B (83.0%), B- (80.0%), C+ (77.0%), C (73.0%), C- (70.0%), D+ (67.0%), D (63.0%), D- (60.0%), F (<60.0%).