Course Title: Theoretical Biology and Models
Course Number: IB 494
Credit hours: 4
Instructor: James O'Dwyer
Contact: jodwyer@illinois.edu
Class hours/frequency: Lecture-lab (2 hrs) twice per week (MW 10am-11:50pm)
Office hours: Thursday 1pm in 179 Morrill or by appointment on Zoom

Course Description:
To understand how biological systems function and change over space and time, biologists increasingly use math- and computer-based models to complement fieldwork and experimental data. This class will focus on how to encode a biological mechanism into a mathematical model and how to find solutions to these models and relate them to biological data. Discussions of primary literature will bring lectures and labs to research questions, drawn primarily from ecology and evolutionary biology.

Requirements that Course Meets

IB 494 can contribute to the major requirements (under Additional advance courses) for the Integrative Biology major. It is also a valid course for the Computational Science and Engineering Certificate and can be taken in place of MATH 231 as part of the Degree in Honors Integrative Biology.

Prerequisites:
Math 220 or 221 or equivalent Calculus class; Any introductory course in Ecology and/or Evolution

Textbook:
Otto & Day. 2007. A Biologist's Guide to Mathematical Modeling in Ecology and Evolution. Princeton University Press

Journal articles:
Readings from primary literature for discussion sections, and tutorials for computer labs will all be made available online.

Grading:

Mid-term Exam	15 %
Final Exam	25 %
Assignments	15 %
Group project paper	15 %
Group project presentation	10 %
Discussion Participation	20 %

Course Attendance Policy and Expectations: My primary expectation is that students are ready to learn. As part of this expectation, both attendance and punctuality are essential---for you as students and also for me as instructor. If you are unable to attend a class, you should let me know in advance. Assignments submitted late will be graded at the discretion of the instructor, with a maximum grade of 70%.

This commitment to participate and excel also extends to the weekly readings and discussion session, where students will be expected to prepare by reading and (most importantly) thinking about the assigned readings. If you have any questions along the way, please feel free to contact me by email or come to my office hours.

Academic Integrity Policy

All students should follow University of Illinois "Code of Policies and Regulations Applying to All Students." The Code is available online at: http://www.admin.uiuc.edu/policy/code/index.html

Disability Accommodations

To ensure that disability-related concerns are properly addressed from the beginning, students with disabilities who require assistance to participate in this class are asked to see me as soon as possible.

Student Learning Outcomes

1. Students will gain an overarching view of the different kinds of models in biology and the purposes for which they are developed and used
2. Students will develop a facility in translating biological questions into mathematical form, and solving for predictions and solutions where possible
3. Students will develop skills in coding using the R environment, and will be able to solve models numerically and analyze/apply these models to data where possible

Class Format:
The first lecture-lab session each week will combine a short lecture presenting the principles and fundamental knowledge necessary to understand the topic, with hands-on training in simulation and data analysis, using the open source software "R" and "R Studio".

The second lecture-lab session each week will begin with a discussion session based on specific primary literature, chosen to bring out at a research level some of the issues covered in Monday's lecture. The second half of Friday sessions will continue the computer lab started on Monday, and towards the middle and end of the semester will incorporate group project work and presentations.

Computer Requirement
Students are required to have a laptop computer to complete in-class computational assignments in class. If a student cannot bring her/his laptop then he/she must pair up with someone who has a laptop for in-class assignments and discussion. Much of the work in this class will require computer access in and out of class.

Exams:
A midterm and final exam, in total worth 40% of the final grade, will be given on key concepts learned from lecture material. Students with a valid reason for missing an exam will be given an opportunity to take a make-up exam at the discretion of the instructor. Valid reasons include only medical reasons (with a note from McKinley), tragedy in your immediate family, or religious observances and practices.

Assignments:
Four problem sheets applying skills learned in the lectures will be given throughout the term, to be completed independently outside of class. The solutions to these problems are in total worth 15% of the final grade. Times and locations to submit problem solutions will be given during the lectures.

Group project:
Group projects will begin in week five. Students are encouraged to bring their own data, and should discuss the nature of their data with the instructor. Projects can also involve data provided by the instructor, or can be computational or theoretical in nature. Assessment will be in the form of a short written paper written independently by each participant, and a group presentation of around 15 minutes. In total, the paper and presentation are worth 25% of the final grade.

Discussion participation:
Readings will be provided online in advance of Friday's discussion session. Students must prepare questions that arose from reading of the weekly paper, and be prepared to participate in all discussion sessions. In total this participation is worth 20% of the final grade.

Requirements for Graduate vs. Undergraduate Students:
(1) Graduate students must write a 8-10 page paper about their group projects, while undergraduates must write a 4-5 page paper about their projects. (2) Graduate students will be responsible for leading one of the primary literature discussions and participating in all discussions. Undergraduates will be responsible for participating in all discussions.

Weekly Schedule

Unit 1: Deterministic Dynamics and Biological Mechanisms

Week	Class Format	Topic
1	Lecture	Introduction: The role of theory in science
	Lab	Problem Solving in Biology
2	Lecture	Population Growth and Competition
	Lab	Getting to grips with R
	Discussion	Are there general laws in biology?
	Lab	Getting to grips with R
3	Lecture	Nonlinear equations and Equilibria
	Lab	Simulate Growth and Competition
	Discussion	Complex behavior in Simple Ecological Models
	Lab	Logistic Equation and Chaos
4	Lecture	Population Growth and Competition in Continuous time
	Lab	Numerical solution of differential equations
	Discussion	Bistability
	Lab	Numerical solution of differential equations
5	Lecture	Interactions among multiple species
	Lab	Competition and Niche structure
	Discussion	Limiting Similarity
	Lab	Competition and Niche structure
6	Lecture	Predator-Prey
	Lab	Predator Prey dynamics
	Discussion	Epidemiological dynamics and Model Complexity
	Lab	Epidemiological dynamics

Unit 2: Model Complexity

Week	Class Format	Topic
7	Lecture	Matrices and Linear Algebra
	Lab	Reading data and multivariate dynamics
	-	MID
	-	TERM
8	Lecture	Stability for multivariate linear systems
	Lab	Demography and age-structure
	Discussion	Loggerhead sea turtles and implications for conservation
	Lab	Demography and age-structure
9	Lecture	Stability for multivariate, nonlinear, continuous time models
	Lab	Large random matrices
	Discussion	Are large complex systems unstable?
	Lab	Large random matrices and stability

Unit 3: Space and Stochasticity

Week	Class Format	Topic
10	Lecture	Stochastic models
	Lab	Simulating demographic stochasticity
	Discussion	Metastasis dynamics
	Lab	Simulating demographic stochasticity
	Lecture	Steady-state solutions

11	Lab	Simulating more general stochastic models
	Discussion	Neutral theory of biodiversity
	Lab	Biodiversity in Stochastic models
12	Lecture	Maximum Likelihood and parameter inference
	Lab	Maximum Likelihood for real and simulated data
	Discussion	Markov Models and Phylogenetic Reconstruction
	Lab	Markov Processes
13	Lecture	Spatial Dynamics
	Lab	Advection and Diffusion
	Discussion	Rock paper scissors, space, and coexistence
	Lab	Group project work
14	Lecture	More general spatial models
	Lab	Simulating spatial models
	Discussion	Model building strategy
	Presentations	Group project work
15	Lecture	Group project Presentations
	Lab	Group project Presentations
	Presentations	Group project Presentations
	Presentations	Group project Presentations