BIOL 2400: Mathematical Models in Biology

Spring Semester 2007, 3 credits
T/Th 1:35 – 2:55

Instructors Dr. Anne-Marie Hoskinson

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Overview

This is an active-learning class that explores mathematical models from several domains in biology, including epidemiology, ecology, and evolution. The course is built around a series of assignments that introduce students to:

techniques such as rapid prototyping, sensitivity analysis, evaluation of trade-offs, and modeling as a form of communication;

software such as Microsoft Excel, Populus, and potentially Mathematica, to support a thorough understanding of the

concepts and practices of stochastic and dynamic modeling using mathematics as a structural and logical tool.

Prerequisites

One year of calculus (differential and integral) and one year of biology are required for the course. We assume you are comfortable with basic use of Microsoft Excel. Familiarity with simple probability and statistics concepts (probability distributions, t-tests, simple linear regression) is helpful but neither assumed nor required.

This is not a course in probability and statistics, nor does it require extensive mathematics. We will use some differential and integral calculus, simple matrix algebra and linear algebra, and simple statistical analysis as needed. We will teach you the mathematics and software implementation that you need for the course.

Learning Objectives

By the end of the course, you will develop several skills that will serve you as a scientist and responsible citizen, no matter what profession you choose. These skills include:

1. Graphically and verbally representing vague problems.
2. Quantitative representation of hypotheses (equations).
3. Basic model analysis: equilibria, stability, assumptions, sensitivity analysis, validation.
4. Modeling stochastic processes.
4. Communicating model experiment results targeted to your audience, in the most economic and efficient ways possible.

Instructional format

Three hours each week are scheduled for the class. Class time will be approximately equally divided among short "mini-lectures" and group problem-solving exercises or discussions.

The course is designed around students formulating and solving problems in small cooperative groups of four members. Group members will shuffle for each assignment. The following rules apply to all group work:

1. Everyone is responsible for making sure that all group members contribute.

2. Assist each other in understanding the material and in developing skills such as translating scenarios to equations, using computer software, writing model reports, and designing figures and tables.

3. Each group will prepare a joint (single) report. Each member of the group should sign the report, thereby indicating agreement with the group's conclusions, contribution to the report, and understanding of its contents. If you use any sources other than class notes or your own original ideas, you must cite the source(s). Violation of this policy is a violation of the GT Honor Code.

4. You will work collaboratively with other members of your group, but collaboration between or among groups is not authorized, whether on the conceptualization, development, interpretation, or writeup of the homework. Violation of this policy is a violation of the GT Honor Code.

5. You may not discuss your peer evaluations (described below) with any classmate at any time. Violation of this policy is a violation of the GT Honor Code and will result in a failing grade for that assignment.

Some class days will be devoted to in-class modeling exercises. These days are noted on the schedule, below. You are invited and encouraged to bring laptop computers to class to work on these problems.

Course policies

Because of the heavy emphasis on group work, it is important that you attend each and every class, that you be on time, and that you stay for the entire class period. Each student in a group will earn the same grade for the group's work.

Part of your project grade will be determined by anonymous peer evaluation, which will be completed after each assignment. The instructors will address any deficiencies noted by your peers individually and confidentially with you, to help you in acting as a more effective group member.

While much of your work will be in collaborative groups, insights and the take-home portion of the midterm examination are individual assignments; you may not collaborate with anyone inside or outside of the class on these. Any violations of the GT Honor Code will result in referral to the Office of Student Integrity and penalty ranging from no credit for the assignment in question, to a grade of "F" for the class. We don't want to see you fail, and we will be glad to answer questions about class activities and the Honor Code.

Evaluation

Regular assignments (insights, modeling exercises)	50%
Mid-semester examination (Thursday, 3/15/2006)	20%
Final (group) project	30%

Text and Software

Haefner, James W. 2005. Modeling Biological Systems: Principles and Applications. Springer: New York. ISBN: 0387250115. (Available in the bookstore.)

Other short papers, as assigned.

Microsoft Excel (Windows 2000/Windows XP/Mac OS X) and Populus (free download for Windows 2000/Windows XP/Mac OS X/Linux), available at http://www.cbs.umn.edu/populus/Download/download.html. These software packages are also installed on the Biology Computer Lab computers.

Schedule of Topics and Assignments (subject to modification)

Week	Topic	Readings	Assignments
1	The nature of modeling and the modeling of nature. **1/11: Laptop day**	Haefner ch. 1 & 2 May, R. M. 2004. Uses and abuses of mathematics in biology. Science 303: 700-793. (distributed in class)	• Download Populus software. • Populus problem set assigned (1/11).
2	Population models. **1/18: Laptop day**	Haefner ch. 3 (pp. 32-41, 45-49)	• Insight 1 due (1/18). • Populus problem set 1 due (1/18). • First modeling homework assignment given (1/18).
3	Population models, continued. **1/25: Laptop day**	Haefner ch. 4 (pp. 58-63) & ch. 13 (272-281)	• Insight 2 due (1/25). • In-class problem given 1/25, due 2/1.
4	System and model stochasticity. Disease models.	Haefner ch. 5 (pp. 81-104) & ch. 10 (215-219, 228-231)	• Insight 3 due (1/30). • First modeling homework assignment due (1/30). • In-class problem from 1/25 due. • Second modeling homework assignment given (1/30), due 2/13.
5	Disease models. **2/8: Laptop day**	Haefner ch 15 (307-309)	Insight 4 due (2/8)
6	Spatial models and scaling. Cellular automata. **2/15: Laptop day**	Haefner ch. 16 & 17; ch. 19 (390-406) Rupp, T. S., A. M. Starfield, and F. S. Chapin, III. 2000. A frame-based spatially explicit model of subarctic vegetation response to climate change: Comparison with a point model. Landscape Ecology 15: 383-400. Haefner ch. 18 (pp. 356-367, 383-38 Scheffer, M., S. R. Carpenter, J. A. Foley, C. Folke and B. Walker (2001). Catastrophic shifts in ecosystems. Nature 413: 591-596. (both papers available from the GT library website eJournals link)	• Second modeling homework assignment due (2/13). • Insight 5 due (2/15). • In-class problem-solving exercise given

7	Games and evolution.	Required: Maynard-Smith (1982), Evolution and the Theory of Games. ch 1 & 2. Supplemental: Krebs & Davies (1993) An Introduction to Behavioural Ecology. ch 7. (both distributed in class)	Insight 6 due (2/22).
8	Models from evolution.	Wade, M. J. 1978. Review of models of group selection. Quarterly Review of Biology 53: 101-114. (distributed in class)	Insight 7 due (3/1).
9	Dynamic programming.	Mangel & Clark (1988) Dynamic Modeling in Behavioral Ecology. ch. 2 (distributed in class)	• Final project proposal due (3/6). • Insight 8 due (3/8).
10	Genetic algorithms. Midterm exam.	TBA – from Dawkins The Blind Watchmaker	• Revisions to final project proposal due (if required, 3/13). • Take-home portion of midterm exam given 3/13, due in class 3/15. • Self-assessment due in class 3/15. • In-class portion of midterm exam 3/15. • Insight 9 due (3/15).

Spring break 3/19-3/23 – No class. Enjoy!

11	3/27: Genetic algorithms. 3/29: Final project work day.		• Final project rapid prototype due (3/27). • Insight 10 due (3/29).
12	Optimization and Decision Analysis. **4/3: Laptop day**	Starfield, A. M., J. D. Roth, and K. Ralls. 1995. "Mobbing" in Hawaiian monk seals: The value of simulation modeling in the absence of apparently crucial data. Conservation Biology 9: 166-174. Ralls, K. and A. M. Starfield. 1995. Choosing a management strategy: Two structured decision-making methods for evaluating the predictions of stochastic simulation models. Conservation Biology 9: 175-181. (both distributed in class)	• In-class optimization exercise given 4/3, due 4/10. • Insight 11 due (4/5).

13	4/10: Guest speaker or special topic (TBA). 4/12: Dr. Joshua Weitz	TBA	• Optimization exercise due (4/10). • Insight 12 due (4/12).
14	4/17: Final project work day. 4/19: You're the Experts: Final Project Presentations (in class)	–	Insight 13 and comprehensive collection of insights due (4/19).
15	You're the Experts: Final Project Presentations (in class)	–	**Final project write-up due Tuesday, May 1, 5:00 pm**