Arizona State University, Polytechnic
Department of Applied Sciences and Mathematics

ABS 560 Ecological Modeling

Instructor information

Instructor: Yun Kang Office: Wanner 340C
Email: yun.kang@asu.edu Tel: 7-5004
Office Hours: Tuesday/Thursday 9:00am-11:30am, 3:00pm-:6:00pm or by appointment.

Course credits: 3

Class time: Two meetings per week, 75 minutes for each meeting

Course description

Ecological modeling is a key methodological skill in modern environmental research. Ecological models are very useful for simulating and analyzing the long-term dynamics and stability properties of complex ecological systems. They allow integrating information from different disciplines as well as analyzing, interpreting and understanding field observations.

This **course** gives a systematic introduction to the development and analysis of ecological models and provides an overview of important approaches and model types. It gives a variety of examples for the use of models in order to understand and predict ecological processes and to support the development of management strategies and policy options in fields such as: biodiversity conservation, sustainable use of natural resources, regulations on invasive species, disease control, the adaptations to the impacts of climate change, etc. The course is a mixture of lectures, computer labs and discussions about modeling projects carried out by students.

Class learning outcomes: Students will be able to

- Describe a modeling project using written and oral communication.
- Outline the concepts and steps involved in constructing and applying models.
- Identify the underlying assumptions in any model and discuss their implications.
- Prescribe an appropriate model to address a particular question about a particular ecological system.
- Classify ecological models, e.g., into categories such as:
  - dynamic vs. static
  - continuous vs. discrete
  - spatial vs. point
  - deterministic vs. stochastic

Prerequisites: Brief Calculus and 6 hours in ecological studies; or equivalent or permission of the instructor.

Textbook: *A Primer of Ecology with R* by M. Henry H. Stevens. Supplemental material on lecture notes and readings (see weekly schedule) will be provided during the semester.

Computing resources and software: Students will need computer lab access for programing and simulations. Students are expected to participate in interactive simulations of the mathematical models presented.

Homework: There are 8 sets of homework assignments based on lectures and labs (see weekly schedule).

Projects: Each student will choose topics from her/his interests and is expected to finish two projects during the whole semester (one is the midterm project and the other one is the Final project). For each project, students need to submit a written report and give an oral presentation in class. The written project report will describe the modeling project, which should have five components: abstract, introduction, model formulation, simulations and conclusion. Students are expected to quantify and simulate the model with techniques learned in class. The simulations should be dynamic, that is, they will include time as an independent variable. The purpose of an oral presentation is to stimulate general class discussion and to promote a wider sharing of experience. The time frame of an oral presentation is 10 minutes with additional 3 minutes for questions for the midterm project and 15 minutes with additional 5 minutes for questions for the final project. More detailed information on the reports and presentations will be given in class.

Grading

Homework assignments	30%
Mid-term group project report + presentation	15% + 15% = 30%
Final project report+presentation:	20% + 20% = 40%
Total	100%

A+ >90% A 85-90% B 75%-84% C 60%-74% D < 59%

Tentative list of topics

Week	Topics, programming concepts and assignments	
1	Lecture:Introductions-General view of ecological models. Simple density-independent growth models Reading: Lecture notes. Ch. 1 from textbook	Discussion: The purpose of mathematical models in ecology. Reading: Hall C.A.S., 1988
2	Lecture: Density-independent demography Reading: Lecture notes. Ch. 2 from textbook Lab activities: Introduction to R. Lab notes and handout 1.	Discussion: How do simple mathematical models teach us? Reading: Stone & Ezrati 1996 Optional: May & Oster 1976 Homework 1: Computer simulations (see handouts)
3	Lecture: Density-dependent growth models Reading: Lecture notes. Ch. 3 from textbook Lab activities: Data structure (vectors, matrices, etc.) Lab notes and handout 2.	Discussion: Model modifications and variants. Reading: Jensen 1996 Homework 2: Sustainable whale harvest.
4	Lecture: Population in space. Reading: Lecture notes. Ch. 4 from textbook Lab activities: Functions and Lab notes and handout 3	Discussion: How do species coexist in space Reading: Nee&May 1992 Homework 3: Island models

5	Lecture: Introduction to differential equations. Lotka-Volterra competition models Reading: Lecture notes. Ch. 5 from textbook Lab activities: Numerical Structures Lab notes and handout 4	Discussions: Better life through theory Reading: Smith et al. 1998 Homework 4: Lotka-Volterra competition
6	Lecture: Predator-prey /Consumer-resource models Reading: Lecture notes. Ch. 6 from textbook Lab activities: Iterated actions. Lab notes and lab handouts 5	Discussion: How can we construct ecological models through simple mathematics? Reading: Borrett et al. 2007 No Homework: Pick a topic on your midterm projects.
7	Guess Lectures from the faculties in Applied Biology department (Topics can be population genetics, Biofuel, environment analysis, Plant-fungus interactions, Riparian ecology, GIS modeling, etc.) Lab activities: The practice of analyzing a model.	Discussion 1: Steps to analyze a model Discussion 2: Homework and Midterm projects Homework 5: Report on guess lectures.
8	Lecture: Food webs models Reading: Lecture notes. Ch. 7 from textbook Lab activities: Presentation of midterm projects	Discussion: The complexity of food webs Reading: McCann, Hastings & Huxel 1998 Homework 6: Intraguild predations
9	Lecture: Multiple basins of attraction Reading: Lecture notes and Ch. 8 from textbook Lab activities: Numerical integration of ODEs. Lab notes and handout 5	Discussion: Allee effects and Allee-like effects Reading: Kang & Lanchier 2010 Kang et al 2010 No Homework: But you need to start thinking about your final projects
10	Lecture: Ecosystem models Reading: Ecological Dynamics, Ch. 7. Lecture notes Lab activities: Numerical optimization. Lab notes and handout 6.	Discussion: Population dynamics models and stoichiometric ecological models Reading: Daufreshne & Hedin 2005 Homework 7: see lab handouts
11	Lecture: Fluctuated environments and storage effects. Reading: *Mechanisms of maintenance of species diversity* by P. Chesson. Lecture notes. Lab activities: The lottery model of competition. Lab notes and handout 7	Discussion: A framework for invasion ecology Reading: Shea & Chesson 2005 Homework 8: on lab handout
12	Lecture: Dynamics of invasive species Reading: Lecture notes. Ch. 9 from textbook Lab activities: Simulations on Plant-herbivore models	Discussion: What leads to the outbreak of pest? Reading: Kang et al. 2008 Liebhold et al 2000 No Homework: Final Project
13	Lecture: Spreading of invasive species Reading: Lecture notes. Ch. 10 from textbook Lab activities: Individual project.	Discussion: How can we manage the spreading of invasive species? Reading: Liebhold and Tobin 2008 Kang et al 2010

14	Lecture: Applications of game theory in ecology Reading: Theoretical Evolutionary Ecology, Ch.8 Lecture notes Lab activities: Discussion on final projects	Discussion: What do you think about ecological modeling now? Draft presentation of final projects
15	Presentations	

The following is the list of books and articles that will be used for the lecture and discussion readings.

Books:

1. Textbook: *A Primer of Ecology with R* by M. Henry H. Stevens, Springer, 2009.
2. *Ecological dynamics* by W.S.C. Gurney and R.M. Nisbet, Oxford University Press, USA, 1998.
3. *Theoretical Evolutionary Ecology* by Michael Bulmer, Sunderland, Mass. : Sinauer Associates, 1994.

Papers:

Borrett S.R., Bridewell W., Langley P. and Arrigo K.R., 2007. *A method for representing and developing process models*, Ecological Complexity, 4, 1-12.

Chesson P., 2000. *Mechanisms of maintenance of species diversity,* Annual Review of Ecology and Systematics, 31, 343-366.

Daufreshne T. and Hedin L.O., 2005. *Plant coexistence depends on ecosystem nutrient cycles: Extension of the resource–ratio theory*, PNAS, 102, 9212-9217.

Hall C.A.S., 1988. *An assessment of several of the historically most influential theoretical models used in ecology and of the data provided in their support.* Ecological Modeling*,* 43, 5-31.

Jensen A.L.,1996. *Density-dependent matrix yield equation for optimal harvest of age-structured wildlife populations,*Ecological Modelling, 88,125-132.

Kang Y., Ambruster D. and Kuang Y., 2008. *Dynamics of a plant-herbivore model*. Journal of Biological Dynamics, 2, 89-101.

Kang Y., Ambruster D. and Kuang Y., 2010. *Dispersal effects on a two-patch discrete model for plant-herbivore interactions.* (Preprint, submitted)

Kang Y. and Lanchier N., 2010. Expansion or extinction:*Dispersal effect on deterministic and stochastic two-patch model with Allee effect.* (Preprint, submitted)

Liebhold A., Elkinton J. Williams D. and Muzika R.-M., 2000. *What causes outbreaks of the gypsy moth in North America?* Population Ecology, 42, 257-266.

Liebhold A. and Tobin P.C., 2008. *Population ecology of insect invasions and their management,* Annual Review of Entomology, 53, 387-408.

May R.M. and Oster G.F., 1976. *Bifurcations and dynamic complexity in simple ecological models*, The American Naturalisty, 110, 573-599.

McAllister R.R.J., Gordon I.J., Janssen M.A. And Abel N., 2006. *Pastoralists' responses to variation of rangeland resources in time and space*, Ecological Applications, 16, 572-583.

McCann K., Hastings A. and Huxel G.R., 1998. *Weak tropic interactions and the balance of nature*, Nature, 395, 794-799.

Nee S. and May R.M., 1992. *Dynamics of metapopulations: habitat destruction and competitive coexistence*, Journal of Animal Ecology, 61,37-40.

Shea K. and Chesson P., 2005. *Community ecology theory as a framework for biological invasions*, Trends in Ecology & Evolution, 17, 170-177.

Smith V.H., Graham D.W. and Cleland D.D., 1998. *Application of resource-ration theory to hydrocarbon biodegradation*, Environmental Science & Technology, 32, 3386-3395.

Stone L. and Ezrati S., 1996. *Chaos, cycles and spatiotemporal dynamics in plant ecology*, Journal of Ecology, 84, 279-291.