Last update: 8-20-2015

GES 591-006
Integrated Socioecological Systems Modeling of Emerging Biotechnologies
Fall 2015

10:15 to 11:30 a.m.
Tuesdays and Thursdays
Entomology Conference Room

Instructors

Prof. Zack Brown (course coordinator)
Nelson Hall 4310; zack_brown@ncsu.edu; office hours by appointment
Prof. Alun Lloyd
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Prof. Jennifer Kuzma
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Scope

This course will help the students identify open research questions in understanding the interaction between biological and social systems related to genetically engineered organisms (GEOs) in environment. Different modeling approaches used in the biological and social sciences will be presented for example cases. The course will emphasize an ecological perspective, investigating how emerging biotechnologies might fit into broad coupled human-natural systems. The students, guided by the instructors, will learn existing modeling approaches, and be tasked with applying these tools to emerging social issues in the governance of biotechnologies. The Fall 2015 iteration of this course will focus on systems modeling in the adoption and diffusion of agricultural biotechnology, particularly transgenic pesticidal crops (an area with an already rich research literature) and genetic pest management (an emerging set of technologies posing new questions for governance and regulation).

Students will learn

- The basics of common modeling techniques (e.g. system dynamics, agent-based modeling, optimization, risk analysis, and mind-mapping) in the biological, economic and social sciences.
- How to assess the validity of different modeling techniques across disciplines.
- How to identify suitable modeling techniques for different research questions, and based on different types of available data.
- How reduce complex systems to key processes of interest (to you).
- How to integrate and apply modeling techniques to analyze social and economic issues related to emerging (agricultural) biotechnologies.

Assignments and grading

Your grade for course will be comprised of three parts: a group assignment that will be completed in stages over the course of the semester, periodic take-home exercises to reinforce concepts from class, and participation. Your final letter grade will be determined based on your total points earned from each component, with the standard, grading scale:

>98 = A+	92-98 = A	90-92 = A-	
88-90 = B+	82-88 = B	80-82 = B-	
78-80 = C+	72-78 = C	70-72 = C-	
68-70 = D+	62-68 = D	60-62 = D-	<60 = F

Group assignment (60 points)

In this course, students will organize into groups of 4-5 members, and will develop a framework for the model-based, socioecological risk assessment of genetic pest management, with specific applications to be selected by the groups themselves. The deliverables will consist of a final report, associated model software and a final presentation. There will be a single report for each group, with all students expected to contribute equally. The assignment will be completed in stages, with consecutive portions due throughout the course. At each stage of the assignment, the group will include a short statement of how each individual contributed to the assignment. The 'final' will consist of the final draft of the proposed framework, and should be (a) publication-worthy (with some revision) and (b) could possibly inform the NCSU gene drive workshop to be held in the spring.

Periodic small-scale, take-home assignments (20 points)

To reinforce the techniques learned in class, faculty will assign take-home modeling exercises. These exercises will assessed on a 'check' (90%, turned in) / 'check+' (100%, turned in and exceptional) basis. There will be between one and two of these assignments each month.

Participation (20 points)

Engaging in the discussion, in-class exercises, and good teamwork in pairs--with such a small class, we can tell if you've done the readings. Do them before class. If you miss a class for a non-excused absence, you will get a zero for that session. For excused absences, see the instructor to make up the participation grade for that session.

Software

In choosing the software packages that best facilitate learning in the course, a balance is necessary between an omnibus package that does everything but requires a steep learning curve and dedicated packages that are more limited in their scope but quicker to learn. To try and strike that balance, we will use three different software packages in this course. The first is Excel, which is a much more powerful modeling tool that you might initially suspect. The second is @Risk, which is a proprietary Excel plugin dedicated to analyzing model uncertainty. The third is AnyLogic, which is a dedicated software package for both systems dynamics and agent-based modeling. All of these packages are widely used in academia and industry.

@Risk will be distributed to students via a class license. We will provide instructions on how to install the software in class. A free, 'personal learning edition' of AnyLogic can be acquired at the following link: http://www.anylogic.com/downloads. Note that there is often a delay between when you request a free copy of the software, and when you receive approval from the company. So it would be wise to install this software well in advance of when we start using it in the course.

POLICIES

Attendance

Students are expected to attend all classes. Please review NC State's policies on attendance, (excused and unexcused) absences, and scheduling makeup work available at Attendance Regulation (REG02.20.3), available at http://www.ncsu.edu/policies/academic_affairs/courses_undergrad/REG02.20.3.php. We will use this attendance policy to govern student behavior and will rely on it for university definitions of excused absences.

Code of student conduct

All students are bound by the Code of Student Conduct which governs academic integrity at North Carolina State University. Therefore, students are required to review the definitions of academic dishonesty to avoid behaviors which are in violation of this code. In submitting an assignment, students consent that he/she neither gave nor received unauthorized aid. Students who violate the code of student conduct will receive zero points for that assignment only. Please see the website for a full explanation of the University Code of Student Conduct
http://www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php

Unexcused assignments submitted late may be graded on a reduced criteria, at the discretion of the instructor.

University policy on incompletes

The NCSU policy on incompletes can be found in the *Graduate Handbook.* Please review this policy – incompletes will be given only when a student makes a formal request and when appropriate documentation accompanies the written request for an incomplete. Please see the university's policy, available at http://www.ncsu.edu/grad/handbook/sections/3.18-grades.html#I.

University non-discrimination policies

It is the policy of the State of North Carolina to provide equality of opportunity in education and employment for all students and employees. Accordingly, the university does not practice nor condone unlawful discrimination in any form against students, employees or applicants on the grounds of race, color, religion, creed, sex, national origin, age, disability, or veteran status. North Carolina State University regards discrimination on the basis of sexual orientation to be inconsistent with its goal of providing a welcoming environment in which all its students, faculty, and staff may learn and work up to their full potential. The University values the benefits of cultural diversity and pluralism in the academic community and welcomes all men and women of good will without regard to sexual orientation.

Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, (919) 515-7653. For additional information, see http://www.ncsu.edu/provost/offices/affirm_action/dss/. For more information on NC State's policy on working with students with disabilities, please see: http://www.ncsu.edu/policieis/academic_affairs/courses_undergrad/REG02.20.1.php

Mid-semester and end-of-semester Evaluations

We may ask you to complete a short, anonymous mid-semester evaluation of how the course is going, so that we actually have a chance to adjust things!

End-of-semester online class evaluations will be available for students to complete during the last 2 weeks of each semester. Students will receive an email message directing them to a website where they can login using their Unity ID to complete evaluations. All evaluations are confidential; instructors will not know how any one student responded to any question, and students will not know the ratings for any instructors.

Evaluation website: https://classeval.ncsu.edu/

Student help desk: classeval@ncsu.edu

More information about ClassEval: http://www.ncsu.edu/UPA/classeval/

COURSE SCHEDULE AND READINGS *(subject to revision)*

💣 = Component of group assignment due

Week 0: Thu, 8/20
Outline of the course and introductions.

Week 1: 8/25 & 8/27
Complexity in coupled human-natural systems: the case of pest control in agriculture

Liu, J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., … Taylor, W. W. (2007). Complexity of coupled human and natural systems. *Science (New York, N.Y.), 317*(5844), 1513–1516. doi:10.1126/science.1144004

Kopainsky, B., Huber, R., & Pedercini, M. (2015). Food Provision and Environmental Goals in the Swiss Agri-Food System: System Dynamics and the Social-ecological Systems Framework. *Systems Research and Behavioral Science, 32*(4), 414–432.

Tomich, T. P., Brodt, S., Ferris, H., Galt, R., Horwath, W. R., Kebreab, E., … Yang, L. (2011). Agroecology: A Review from a Global-Change Perspective. *Annual Review of Environment and Resources*, *36*(1), 193–222.

Week 2 (Alun): 9/1 & 9/3
Introduction to dynamic systems modeling in biology and ecology

Lloyd: notes on simple ecological models.

Jackson et al. (2000) An Introduction to the Practice of Ecological Modeling. BioScience, **50**: 694-706

Turchin (2001) Does population ecology have general laws? Oikos **94**: 17-26.

Kendall (2001) Nonlinear dynamics and chaos. *Encylopedia of Life Sciences*

Scheffer et al. (2001) Catastrophic shifts in ecosystems. Nature **413**: 591-596.

Week 3 (Alun): 9/8 & 9/10
Modeling population genetics: modeling the evolution of resistance to Bt crops

Lloyd: notes on population genetic models, including spread of resistance in pest populations.

Week 4 (Alun): 9/15 & 9/17
Modeling population genetics: dominant lethal gene systems

Lloyd: notes on gene drives, including Wolbachia and dominant lethal genetic systems

Burt (2003) Site-specific selfish genes as tools for the control and genetic engineering of natural populations. Proc. R. Soc. Lond B. **270**, 921-928.
Davis et al. (2001) Engineered underdominance allows efficient and economical introgression of traits into pest populations. J. Theor. Biol. **212** 83-98.
Deredec et al. (2008) The population genetics of using homing endonuclease genes in vector and pest management. Genetics **179**, 2013-2026
Phuc et al. (2007) Late-acting dominant lethal genetic systems and mosquito control. BMC Biology **5**:11

Week 5 (Alun): 9/22 & 9/24
Continuation of gene drives and genetic systems

(If time permits: discussion of ecological and population genetic complexities, such as stochasticity and heterogeneity.)

Week 6: 9/29 & 10/1

💣 (9/29) Class meeting on group assignments

DUE (details of assignment to follow)
- **10 min presentation & introductory text** of report: proposed GPM case and key socioecological questions or modeling. Potential biological / ecological risks and social objectives to consider, possible strategies for modeling?
- **Class discussion** of next stage of assignment: ways of assessing costs and benefits, intertemporal tradeoffs, uncertainties.
- **One paragraph statement** of group member contributions.

(10/1) Zack: Introduction to economic analysis and evaluation

[Instructor notes on marginal benefits and costs, efficiency and optimization.]

Week 7 (Zack): 10/6 ** Fall break is 10/8 **
Environmental and Resource Economics

Cost-Benefit Analysis and the Environment, Pearce et al.:
Chapters 1-2, pp. 29-49

Intermediate Microeconomics, Varian:
Chapter 4 (Utility), pp. 54-70
Chapter 33 (Welfare), pp. 631-642

Valuing the Future, Heal:
Chapters 1-2, pp. 1-35

Week 8 (Zack): 10/13 & 10/15

Bioeconomic modeling I: Bt refuge policy & optimal control of gene drive releases

Laxminarayan, R., & Simpson, R. D. (2002). Refuge strategies for managing pest resistance in transgenic agriculture. *Environmental and Resource Economics*, *22*(4), 521–536.

Livingston, M. J., Carlson, G. A., & Fackler, P. L. (2004). Managing Resistance Evolution in Two Pests to Two Toxins with Refugia. *American Journal of Agricultural Economics*, *86*(1), 1–13.

Qiao, F., Wilen, J., & Rozelle, S. (2008). Dynamically optimal strategies for managing resistance to genetically modified crops. *Journal of Economic Entomology*, *101*(3), 915–926.

Policy background:
EPA. (2000). Insect Resistance Management. In *Biopesticides Registration Action Document - Bacillus thuringiensis Plant-Incorporated Protectants* (p. Section II.D). US Environmental Protection Agency, Office of Pesticide Programs, Biopesticides and Pollution Prevention Division.

[Instructor handout on optimization for gene drive releases]

Week 9 (Zack): 10/20 & 10/22

Economic modeling of uncertainty and irreversibilities

(10/20) Economic Foundations and Modeling Methods

Intermediate Microeconomics, Varian:
Chapter 12 (Uncertainty & Expected Utility), pp. 217-233
Cost-Benefit Analysis and the Environment, Pearce et al.:
Chapters 10 (Option Value), pp. 29-49

(10/22) Applications

Finnoff, D., McIntosh, C., Shogren, J. F., Sims, C., & Warziniack, T. (2010). Invasive Species and Endogenous Risk. *Annual Review of Resource Economics*, *2*(1), 77–100.

Sims, C., & Finnoff, D. (2013). When is a "wait and see" approach to invasive species justified? *Resource and Energy Economics*, *35*(3), 235–255.

Week 10 (Zack): 10/27 & 10/29
Bioeconomic modeling II: Externalities, spillovers, individual rationality and coordination

Modeling Approaches and Empirical Examples

Intermediate Microeconomics, Varian:
Chapter 34 (Externalities), pp. 645-665

Brown: Handout on individual heterogeneity and random utility models.

Althouse, B. M., Bergstrom, T. C., & Bergstrom, C. T. (2010). A public choice framework for controlling transmissible and evolving diseases. *Proceedings of the National Academies of Science*, *107*(Suppl 1), 1696–1701.

Hutchison, W. D., Burkness, E. C., Mitchell, P. D., et al. (2010). Areawide suppression of European corn borer with Bt maize reaps savings to non-Bt maize growers. *Science*, *330*(6001), 222–225.

Useche, P., Barham, B. L., & Foltz, J. D. (2009). Integrating Technology Traits and Producer Heterogeneity: A Mixed-Multinomial Model of Genetically Modified Corn Adoption. *American Journal of Agricultural Economics*, *91*(2), 444–461.

[Notes on agent-based modeling (using AnyLogic)]

Milne, A., Bell, J. R., Hutchison, et al. (forthcoming). The Effect of Farmers' Decisions on Pest Control with Bt Crops: a Billion Dollar Game of Strategy.

Atallah, S. S., Gomez, M. I., Conrad, J. M., & Nyrop, J. P. (2014). A Plant-Level, Spatial, Bioeconomic Model of Plant Disease Diffusion and Control: Grapevine Leafroll Disease. *American Journal of Agricultural Economics*, *97*(1), 199–218.

Week 11: 11/3 & 11/5

(11/3) Class meeting on class assignment

DUE (details to follow)

- **10 min presentation and draft model** of biological process: draft model (in AnyLogic) of focal biological process and sketch of social/economic objective function.
- **Class discussion** of next stage of assignment: risks assessment elements, hazards to consider, weighing likelihood and severity of hazards.
- **One paragraph statement** of group member contributions.

(11/5) (Jennifer)

Renn, O. (1992) "Concepts of risk: a classification". Chapter 3, 53-79. *Krimsky, Sheldon (Hrsg.): Social theories of risk. Westport, Conn.: Praeger, 1992*

IRGC (2006). Risk governance: towards an integrative approach. pp. 1-66, skim appendices for useful risk policy approaches and definitions. Lausanne: International Risk Governance Council (IRGC). Available from: www.irgc.org

IRGC (2015). Guidelines for Emerging Risk Governance. Lausanne: International Risk Governance Council (IRGC). Read all Available from: www.irgc.org

Week 12 (Jennifer): 11/10 & 11/12

(11/10) Modeling Decisions

Ezell et al. (2010). Probabilistic Risk Assessment and Terrorism Risk. Risk Analysis 30(4).

Clemen and Reilly (2014). Making Hard Decisions 3rd Edition. Chapters 3 Structuring Decisions, Chapter 4 Making Choices, and Chapter 5 Sensitivity Analysis. (skim cases and exercises—we will do 1 in class)

(11/12) Modeling Uncertainty

Byrd &Cothern (2000) Chapter Two—Functions, Models, and Uncertainties skim over equation derivations. Introduction to Risk Analysis: A Systematic Approach to Science-Based Decision Making. Government Institutes Press: Lanham, MD

Clemen and Reilly (2014). Making Hard Decisions 3rd Edition. Probability Basics & Subjective Probability Chapters 7 & 8, Theoretical Probability Models 9, and Simulation Chapter 11. (skim cases and exercises—we will do 1 in class)

Week 13 (Jennifer): 11/17 & 11/19

(11/17) Examples of Modeling for Risk Related to GPM

Maguire (2004). What Can Decision Analysis Do for Invasive Species Management? *Risk Analysis 24: 859-868.*

APHIS (2008) Use of Genetically Engineered Fruit Fly and Pink Bollworm in APHIS Plant Pest Control Programs. Read Appendix C and D. Skim rest.

Murphy B, Jansen C, Murray J, De Barro P. Australia: CSIRO Report; 2010. Risk analysis of the Australian release of Aedes aegypti (L.) (Diptera: Culicidae) containing Wolbachia..

(11/19) Doing your Own Modeling for Risk Related to GPM

Exercise.

Week 14 (Jennifer): 11/24 [Thanksgiving is 10/26]

Risk Governance and Systems Mapping—Integrating the Social and Natural

Sterman, John D. (2000) Business Dynamics: Systems Thinking and Modeling for a Complex World – Chapters 1,3,4, and 5 (pgs. 3-39, 83-190)

Davies, M. (2011) Concept mapping, mind mapping and argument mapping: what are the differences and do they matter? High Educ 62:279–301

Exercise.

💣Week 15: 12/1 & 12/3 [LAST WEEK OF CLASS]**

Class meeting on group assignments

(12/1) In-class work on group assignments

(12/3) **DUE** (details to follow)

- **10 min presentation and complete draft report + model**: draft model (in AnyLogic) of focal biological process and sketch of social/economic objective function.
- **Class discussion** of next stage of assignment: risks assessment elements, hazards to consider, weighing likelihood and severity of hazards.
- **One paragraph statement** of group member contributions.

💣12/15: Final draft of group assignment due