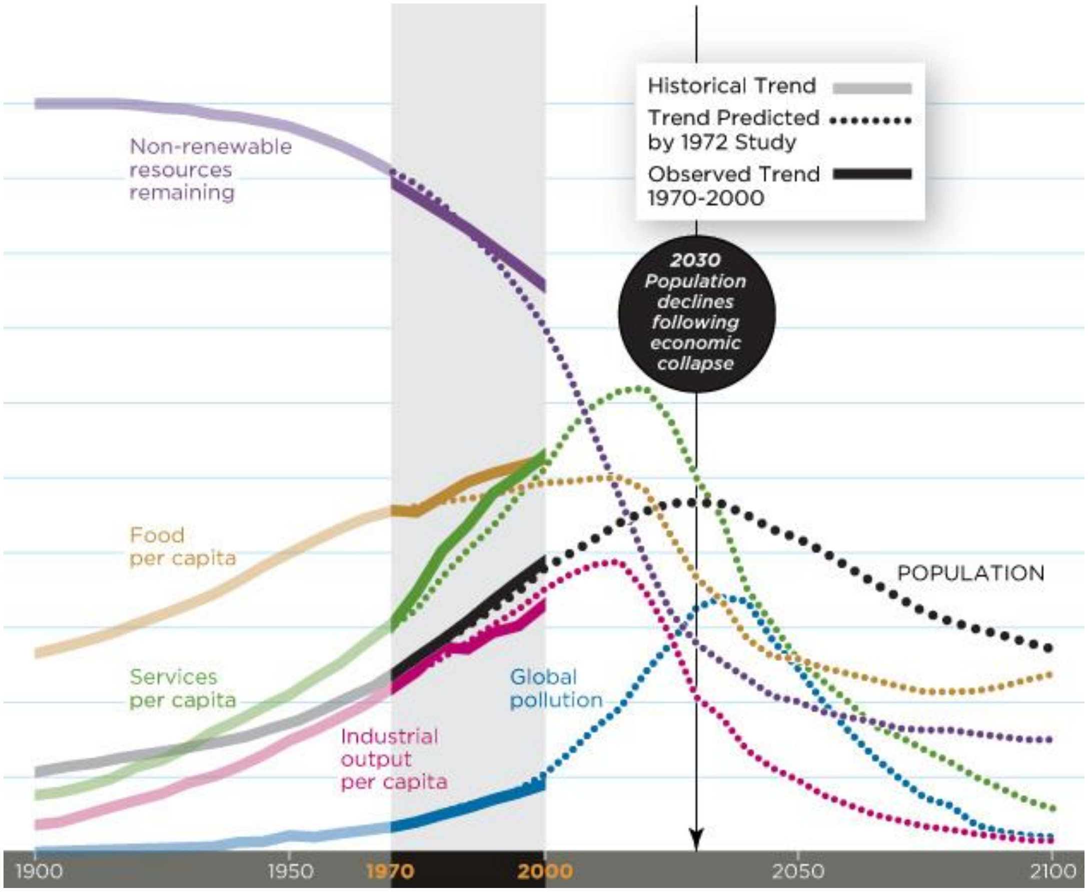
Syllabus: Modeling Natural Resource Systems



Trend lines depicting one of the output scenarios from the famous ‘Limits to Growth’ study. From thwink.org.

Course Description

Every day, we interact with systems that have natural resource components—from deciding how to commute, to what to eat for dinner. Some of us—wildlife managers, farmers, engineers, and many others—must make strategic interventions in natural resource systems in order to fulfill personal, societal, or institutional goals. As we navigate natural resource systems, we use models to predict their behavior and plan interventions, although we may not be aware that we are doing so. Most of the time, the structure of these models stays hidden inside our heads. These mental models are powerful tools which help us to navigate the complex and dynamic systems in which we are embedded, and for some purposes they function quite well. On the other hand, recent research has demonstrated that human beings are not very good at predicting the behavior of complex systems. We as a species are quite bad at intuitively grasping exponential growth, stocks and flows, delayed feedback, and many other common characteristics of systems. Understanding how to effectively use models of natural resource systems, and how to construct and evaluate these models, is valuable for anyone working with the complexities of natural resource systems, which is just about all of us.

There are many approaches to modeling systems. This course is developed around a quantitative, dynamic modeling approach called ‘system dynamics’ modeling (after Jay Forrester). ‘Quantitative’ means we’ll be using numbers and mathematical relations to describe systems; ‘dynamic’ means that these relations may change over time, or be influenced by other variables. We will also provide an introduction to participatory modeling approaches.

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Course Objectives

This course is intended to introduce quantitative modeling approaches as tools for students interested in addressing real-world problems in complex environmental systems. By the end of this course, you should be able to:

1. Identify the characteristics and behavior of complex systems, and be able to define a problem in a systems context;
2. Explain why we use models to understand systems and what makes a 'good' model;
3. Know the steps involved in formulating a research or management question and building a model to address it;
4. Build and use models of real-world systems (using Stella) that display exponential growth; equilibrium-seeking; S-curve growth; oscillatory; and maximum power behavior
5. Construct quantitative, dynamic models with appropriate, data-derived relations between variables;
6. Understand why, when and how we might use participatory modeling to address a natural resource problem
7. Build your own model (individually, or as a team) to address a research or management question

Instructor

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Class Schedule

Classes will take place on Mondays from 11:30 to 2:20 p.m., in Natural Resources Building 218. The first third of class (11:30 to approximately 12:30.) will usually consist of a lecture/readings discussion, while the second two-thirds of class (from 12:30 to 2:20 p.m.) will involve computer lab work.

Prerequisites

This course is designed with upper-level undergraduates and graduate students in mind. There are no prerequisites, but calculus and some familiarity with ecological principles will be an advantage. If you already have some experience with modeling, you will be able to create more advanced versions of the models we'll be using in class. You do not need to know a programming language, but if you do, you should feel free to program your models in the language in which you feel most comfortable.

Course Expectations

There will be both a lab component and a coursework component to this class. The labwork will consist of an individual or team project, and a series of labs I've designed to help you practice modeling and systems analysis skills. The project will involve working individually or as a member of a team to build a model of a system you are interested in. For graduate students, you might want to use a model to address a research question related to your thesis or to a project you are working on for your advisor. I will consult with you or your team to ensure that your modeling question is appropriately formulated, and that your research plan is reasonable given the time limitations of the course. Although we will devote some lab time to working on your team projects, you will need to work outside of class to complete the project.

This course is reading-intensive. We lean heavily on the readings to provide you with (1) The theory behind what we do in class and in the lab, and (2) Some of the 'how-to' nuts and bolts of building models, so it is essential that you keep up with the readings. Each student will have the opportunity to choose an article on modeling and lead a discussion of that article. This will count as one half of your participation grade.

Regarding the programming skills you will be learning in Stella, this course takes a 'learn by doing' approach. Most of your modeling skills will be developed as you work on the labs and on your projects. We will start out by modifying and running models that will be provided for you, but by the end of the course you will be designing, building, running and de-bugging your own models for a given lab topic. You will need to take advantage of the lab time to try out your new skills, ask questions, and get help on designing and de-bugging your programs. This is another reason to keep up with the reading assignments, so that you will always be prepared for the lab work!

All assignments must be completed by the due date for full credit unless there are legitimate extenuating circumstances. **You must speak to me before the assignment is due** if these are to be taken into account. Otherwise, ten percentage points per day will be taken off for a late assignment.

Grading and Assignments

Lab writeups	40% (5% each for 8 labs)
Midterm exam	20 %
Final report and presentation	30 %
Participation and effort	10 %
Total	100 %

Each assignment is graded on a 100-percentage point scale, and weighted according to the course percentage points assigned above. The final course grade is converted to a 4-point scale as follows:

MSU grade points	Composite class points
4.0	93.0 - 100.0
3.5	88.0 - 92.9
3.0	80.0 - 87.9
2.5	75.0 - 79.9
2.0	68.0 - 74.9
1.5	60.0 – 67.9
1.0	50.0 – 59.9
0.0	0 – 49.9

Required Reading

1. Donella Meadows. 2008. *Thinking in Systems: A Primer*. White River Junction, VT: Chelsea Green Publishing.
2. Andrew Ford. 2009. *Modeling the Environment, Second Edition*. Washington, DC: Island Press
3. Marjan Van den Belt. 2004. *Mediated Modeling: A System Dynamics Approach to Environmental Consensus Building.* Washington DC: Island Press.

Optional: Peter Hovmand. 2014. *Community Based System Dynamics.* New York: Springer.

I will also post some readings on Desire2Learn, and some readings will be chosen by your classmates.

Course Policies

Academic Integrity:
From the Office of the Ombudsman at Michigan State (https://www.msu.edu/unit/ombud/RegsOrdsPolicies.html, accessed 7/29/09):
"The principles of truth and honesty are fundamental to the educational process and the academic integrity of the University; therefore, no student shall:

- claim or submit the academic work of another as one's own.
- procure, provide, accept or use any materials containing questions or answers to any examination or assignment without proper authorization.
- complete or attempt to complete any assignment or examination for another individual without proper authorization.
- allow any examination or assignment to be completed for oneself, in part or in total, by another without proper authorization.
- alter, tamper with, appropriate, destroy or otherwise interfere with the research, resources, or other academic work of another person.
- fabricate or falsify data or results."

If an academic integrity violation has taken place, you may receive a failing grade for the course or be referred to appropriate campus authority. Ignorance of the rules is NOT an excuse for an academic integrity violation. Please see Prof. Schmitt Olabisi if you have any questions about this policy.

Accommodation of Disability
If you feel you may need special accommodation based on a disability, please speak with Prof. Schmitt Olabisi as soon as possible so that arrangements may be made.

COURSE SCHEDULE

WEEK	TEACHING FOCUS	ASSIGNMENTS	LAB WORK
1/12	**Introduction to Systems Theory** Course overview What are systems? What does 'systems thinking' mean? How is 'systems thinking' important in addressing natural resource issues? Why do we use models to represent systems?	Daniels & Walker 2012	Characteristics of complex systems; feedback loops and delays; introduction to causal loop diagrams *(Lab 1)*
1/19	**NO CLASS—MLK DAY**		
1/26	**System Dynamics Modeling: the Basics** How to build a model; how to think about modeling	Meadows ch. 1 Ford ch. 1-2 **Lab 1 due**	Introduction to Stella: How is the atmosphere like a bathtub?
2/2	**Water Systems** Stocks and flows: the building blocks of systems	Meadows ch. 2 Ford ch. 3-4	Stock and flow modeling; exploring equilibrium *(Lab 2)*
2/9	**Water Systems** Integrating multiple flows; testing policies	Meadows ch. 4-6 **Lab 2 due**	Pollutant modeling *(Lab 3)*
2/16	**The Mathematics of System Dynamics** Calculus refresh: differential equations	Ford ch. 13 Van den Belt ch. 3 **Lab 3 due**	Writing equations for Stella *(In-class exercise).*
2/23	**Population Dynamics and Limits to Growth** Exponential growth: are there limits?	Ford ch. 7 Meadows et al. authors' preface, ch. 2 **Project Proposal Due**	Population growth modeling, S-curve growth, overshoot and collapse. *(Lab 4)*
3/2	**Predator-Prey Dynamics** ***(Guest lecturer: Dr. Phil Grabowski)*** System oscillation	Ford ch. 18, 20-21 **Lab 4 Due**	Modeling predator-prey dynamics *(Lab 5)* ***Take-home midterm assigned***
3/9	**NO CLASS—SPRING BREAK**		
3/16	**Renewable Resource Use** Managing a resource for human consumption while (hopefully) avoiding collapse and resource degradation	Ford ch. 15 **Midterm due**	Modeling fish harvest *(Lab 6)*
3/23	**Energy and Nonrenewable Resources** Nonrenewable resources; energy return on investment	Hall et al. ch. 5 **Lab 5 due**	Modeling peak oil *(Lab 7)*

WEEK	TEACHING FOCUS	ASSIGNMENTS	LAB WORK
3/30	**Participatory Modeling** ***Guest: TBA*** Examples and challenges	Van den Belt ch. 1, 5 **Lab 6 due**	Participatory modeling exercise
4/6	**Participatory Modeling Part 2**	 **Lab 7 due**	Participatory modeling exercise, continued
4/13	**Modeling Human Behavior** ***Guest lecturer: Dr. Ralph Levine*** How can variables like 'trust' and 'learning' be represented in models?	Readings TBA	Project work and data search
4/20	**Introduction to Spatial Modeling** ***Guest Lecturer: Dr. Arika Ligmann-Zielinska*** Including spatial variables in a model	Ford Appendix G	Spatial modeling exercise
4/27	**Analyzing Model Results** Statistical and scenario methods to better understand model output	Readings TBA	Course Summary & evaluations; final project work Model analysis exercise *(Lab 8)*
5/7 (Thur)	**Final Presentations: 10 a.m.-12 p.m.**	**Lab 8 due** **Final project write-ups due**	