Syllabus
ENVS 22/EEES 181 Coupled human-natural systems: theory and practice
Spring 2024 / Dartmouth – 10A
T/R 10:10a-12p

Instructor: Professor Theresa Wei Ying Ong, PhD.
theresa.w.ong@dartmouth.edu

Office hours: TBD

Pre-requisites

MATH 3 or MATH 10, an equivalent statistics course or permission from instructor

Description of course

This course is an introduction to coupled human-natural systems, exploring how social, ecological, and environmental systems are linked and feedback to influence each other. Increasing human demand for Earth's limited resources has resulted in a plethora of hazards to the natural world; problems which are unlikely to be solved without understanding the links between human and natural systems. Here, we will explore some of the complex, sometimes non-intuitive behavior that results from coupling these systems. The primary objective is to introduce students to the tools and techniques of complex systems science used for researching coupled human-natural systems. In a series of lectures and computer laboratory modules, students will be introduced to significant areas of research in the field and learn how to analyze and leverage basic continuous and discrete time differential models to address socio-ecological problems. The course will provide basic coding instruction, as necessary. No prior experience in coding is needed, although students should have a basic understanding of calculus as a prerequisite. In a final project, students will work to develop or adapt an existing socio-ecological model, gather and analyze existing data, as well as interpret the implications of their results for human management.

Major themes covered

1. Collapse and resilience: socio-ecological systems on edge (Obj 1, 5)
2. Dynamical systems concepts: qualitative and quantitative models, feedback, equilibria, stability, continuous and discrete systems (Obj 2-3)
3. Examining uncertainties: deterministic and non-deterministic systems (Obj 4)
4. Hysteresis: a manifestation of path dependency (Obj 2-3)
5. Spatial complexity. (Obj 2-3)

Learning outcomes/objectives

At the end of this course, students should be able to:

1. Have an understanding of today's main socio-ecological challenges;
2. Develop basic coding and analytical skills for socio-ecological systems;
3. Apply theoretical knowledge and skills to address a CNH question of interest;
4. Analyze socio-ecological data and models, present and defend results;
5. Identify links between human and natural systems and describe them as complex adaptive systems.

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Grading

Homework (6 total, lowest dropped)	55%
Final Presentation	20%
Final Paper	20%
Q&A Participation/Readings/Discussions	5%

Grading Policies:

Homework assignments are graded on a 0-2 scale. 0= Assignment not turned in on time, 1=incomplete tasks and/or misunderstanding of core concepts or assignment is late, 2= all tasks executed, core concepts adequately mastered i.e., 1-2 issues max. Lowest score is automatically dropped. Late assignments are accepted up to 1-week past deadline. Any assignments beyond 1 week late will not be accepted. However, if you have an extenuating circumstance that require exceptions, I am happy to work with you. To start the process, please contact SAS and me to discuss options and create a plan for finishing the term as soon as possible.

Participation grades (0-5) are based on: discussion participation, in class share-out participation, total attendance, and lab engagement (asking questions, answering questions, working with partners). 0= absent more than 3 times in the term (unless required, e.g. sick), 1-3= absent 3 times or less and voluntarily speaks in class average of 1-3 times per class, rarely to minimally engaged in partner-work discussions, 4-5= absent 1 time or fewer, speaks in class consistently and clearly prepared for discussions and class work, actively engaged in partner work.

Pop quizzes will be distributed throughout the term and are meant to test your knowledge of core-course concepts/skills as the term progresses. They are not graded and are just meant to reinforce core concepts along the way. The number of pop quizzes and when they will happen are a surprise!

Attendance Policies:

This course works best when you are present in class and can benefit from group work and assistance from in-class demonstrations, discussions, and troubleshooting, which is reflected in the participation grade. **However, you are not expected to come to class when you have an illness and that will be excused in your participation grade.** We follow current CDC guidelines for COVID-19 exposure, which you can use to determine when and how to return to class. In cases where you are advised to stay home, please contact me and we will create a plan for any missed assignments. All make-up assignments will be remote and independent. No classes will be streamed or recorded, but any class material will be posted and available on canvas. You are expected to reach out to classmates for notes and arrange office hour meetings (which can be virtual) as necessary to support your make up learning.

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Dartmouth Policies

Academic Honors Principle

The faculty, administration, and students of Dartmouth College recognize the Academic Honor Principle as fundamental to the education process. Any instance of academic dishonesty is considered a violation of the Academic Honor Principle.

Fundamental to the principle of independent learning are the requirements of honesty and integrity in the performance of academic assignments, both in and out of the classroom. Dartmouth operates on the principle of academic honor, without proctoring of examinations. Any student who submits work which is not his or her own, or commits other acts of academic dishonesty, violates the purposes of the college and is subject to disciplinary actions, up to and including suspension or separation.

The Academic Honor Principle depends on the willingness of students, individually and collectively, to maintain and perpetuate standards of academic honesty. Each Dartmouth student accepts the responsibility to be honorable in the student's own academic affairs, as well as to support the Principle as it applies to others.

Any student who becomes aware of a violation of the Academic Honor Principle is bound by honor to take some action. The student may report the violation, speak personally to the student observed in violation of the Principle, exercise some form of social sanction, or do whatever the student feels is appropriate under the circumstances. If Dartmouth students stand by and do nothing, both the spirit and operation of the Academic Honor Principle are severely threatened.

A number of actions are specifically prohibited by the Academic Honor Principle. These focus on plagiarism and on academic dishonesty in the taking of examinations, the writing of papers, the use of the same work in more than one course, and unauthorized collaboration.

More information can be found at https://students.dartmouth.edu/judicial-affairs/policy/academic-honor-principle.

Disabilities and Special Circumstances

Please feel free to discuss with me questions relating to disabilities (including hidden ones such as chronic illness and learning disabilities) at the earliest possible moment. I will make every effort to ensure an appropriate learning environment. In addition, I realize that some students may wish to take part in religious observances that occur during this academic term. Should you have a religious observance that conflicts with your participation in the course, please come speak with me before the end of the second week of the term to discuss appropriate accommodations.
Dartmouth is committed to providing equal opportunities for students, faculty, staff, and visitors with disabilities to access and participate in our academic, social, cultural, and

recreational programs. This commitment is grounded not only in disability law, including Section 504 of the Rehabilitation Act of 1973 (Sections 504 and 508), the Americans with Disabilities Act of 1990 (ADA) and the ADA Amendments of 2008, but also in Dartmouth's commitment to diversity, equity, inclusion and belonging for all members of the academic community. Dartmouth's ADA/504 Coordinator (ADAC) in the The Equal Opportunity, Accessibility, and Title IX office serves as the first point of contact for information about Dartmouth's Disability-Based Accommodation Appeals Procedure

If you find yourself in need of academic or other kinds of support, please do not hesitate to reach out to me and or your Dean's office and Dicks house, as appropriate.

You can schedule a Zoom or phone appointment with your dean by using your dean's Calendly link, calling the office at 603-646-2243 or emailing undergraduate.deans.office@dartmouth.edu. Nursing advice is available 24/7 through Dick's House at 603-646-9440. A complete list of health-related phone numbers and services can be accessed at https://students.dartmouth.edu/health-service/about/get-help-now.

Mental Health and Wellness
The academic environment at Dartmouth is challenging, our terms are intensive, and classes are not the only demanding part of your life. There are a number of resources available to you on campus to support your wellness, including your undergraduate dean (http://www.dartmouth.edu/~upperde/), Counseling and Human Development (http://www.dartmouth.edu/~chd/), and the Student Wellness Center (http://www.dartmouth.edu/~healthed/). encourage you to use these resources to take care of yourself throughout the term, and to come speak to me if you experience any difficulties

Diversity and Inclusivity at Dartmouth
Dartmouth's capacity to advance its dual mission of education and research depends upon the full diversity and inclusivity of this community. We must increase diversity, particularly among our faculty and staff. As we do so, we must also create a community in which every individual, regardless of gender, gender identity, sexual orientation, race, ethnicity, socio-economic status, disability, nationality, political or religious views, or position within the institution, is respected. On this close-knit and intimate campus, we must ensure that every person knows that he, she, or they is a valued member of our community.

Diversity and inclusivity are necessary partners. Without inclusivity, the benefits of diversity—an increase in understanding, improvement in performance, enhanced innovation, and heightened levels of satisfaction—will not be realized. - President Philip Hanlon '77 - Excerpt from May 2016 Letter to the Dartmouth community

Land Acknowledgement
We recognize that Dartmouth College is built on the unceded ancestral lands of the

Abenaki people. Dartmouth College was founded in 1776 with the explicit charge to support Native American education, a mission that was largely unfulfilled with only 19 Native American students graduated in Dartmouth's first 200 years. As part of the necessary reparations to the Abenaki people, we have since built one of the strongest Native American and Indigenous Peoples Departments in higher education and host 2% of students hailing from American Indian, Alaskan Native, Native Hawaiian and Other Pacific Islander backgrounds. We promise to continue to repair our relationship with the Abenaki people through the cultivation of knowledge and food in this course that honors indigenous histories, perspectives and people.

Course Structure and Access

This course will be held in person, no components will be recorded for virtual attendance. Students who have absences will be required to make up work on their own time and are encouraged to schedule 1-1meetings and attend office hours to ensure concepts are understood. This class requires access to a laptop or desktop computer, which we provide through access to the RAHR lab. Please let me know as soon as possible if you will have trouble accessing a laptop or desktop or using the RAHR lab.

Tentative Schedule:

Week 1 - Overview: the era of ecological collapse

Course objectives 1

T Coupled Human-Natural Systems Introduction
Qualitative/conceptual models
Variables vs. Parameters
Modeling tradeoffs: Realism, Precision, Generality
Causal loop diagram introduction aka signed digraphs

Lab exercise IA: Produce causal loop diagrams for classic CNH questions in pairs

Read ***Chapters 1-2: Qualitative Modeling of Complex Systems***

Course objectives 2

R Feedback loops: positive (reinforcing) and negative (balancing)
Introduction to Loop Analysis, Lab walkthrough

Optional additional information:
Chapter 3: Qualitative Modeling of Complex Systems
Handout 1: An Introduction to the Loop Analysis of Qualitatively Specified Complex Causal Systems

Lab exercise IB: Develop community matrix, conduct loop analysis to detect and determine feedback sign and impact on stability for qualitative models in pairs

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Week 2 – There be dragons: the unknown in the known

Course objectives 3

HW1 **Create and analyze a causal loop diagram to address your own CNH question that you will develop and expand throughout the course.**

Read ***An Introduction to the Practice of Ecological Modeling (from beginning to "Computational issues associated with equations" inc. Box: "Decisions about model implementation")***
Bolker: Chapter 3- Deterministic Functions

T Walkthrough process from qualitative to quantitative model
Deterministic models
Choosing equations/functional forms (linear/nonlinear systems)- looking under the hood of loop analysis
Checking units, simplifying model
Deciding on time: discrete time models- recurrence equations
Stability/equilibrium concepts (+ relationship to feedback)

Lab Exercise IIA: Work with partner to take your conceptual models and turn them into equations with linear functions, assess model's tradeoffs, share out with class, look for areas of improvement

Watch "Secret Life of Chaos" (https://www.youtube.com/watch?v=mEHbdrpy_Lg)

Read ***and practice R Markdown Cookbook Sections 2-5:***
https://bookdown.org/yihui/rmarkdown-cookbook/

R Introduction to R/Markdown basics, Lab walkthrough
Nonlinear model example: logistic growth
Producing plots: time series, Poincare plots, bifurcations (sensitivity analysis)
Chaos/sensitivity to initial conditions
Overshooting/undershooting with thermometers

Lab exercise IIB: Work in pairs on logistic maps: cobwebbing pen and practice and in R!

Week 3 – Complicating matters: complexity

Course objectives 3

HW2 **Modify and analyze quantitative discrete time model to include 1 nonlinear function, calculate equilibria/produce plots to assess stability that addresses your own CNH question**

Read ***Handout 2: Discrete and continuous models; Linear and exponential growth***

***Nykamp DQ*, "From discrete dynamical systems to continuous dynamical systems." From Math Insight.** http://mathinsight.org/from_discrete_to_continuous_dynamical_systems
Noy-Meir: An Application of Predator-Prey Graphs

T Moving from discrete to continuous time models- ordinary differential equations
Parameter units
Dimensionality: Stability outcomes for 1 vs 2D vs 3D in continuous time
Phase diagrams: Zero-growth isoclines
Example 2-D continuous time model walkthrough: Noy-Meir's grazing model

Lab exercise IIIA: Work with partner to graph equilibrium densities of grass as a function of management intensity

R **Lab exercise IIIB:** Work with partner to rewrite your discrete time models in continuous time, re-calculate equilibria and assess stability and describe differences in results if any. Troubleshoot in class with Professor. Are results robust to model structures?

Week 4 - Path dependencies

Course objectives 3

HW3 Write up summary of your continuous time model specifications, methods of analysis, results, and discussion

Read ***Chapter 2, 10, 12 from Critical Transitions and Society***

T Monotonic and non-monotonic systems
History of *bacalhau*
Cod-fisheries collapse
Feedback between markets and ecological systems
Irreversibility. Hysteresis: tipping points
Example systems: fires and precipitation, forest and savanna, and others
Interpreting bifurcation plots for management implications

Lab exercise IVA: Work with partner to hand-draw bifurcation graph for non-monotonic model (Carpenter model), Reproduce in R

R Methods for increasing model realism

Lab exercise IVB: Work with partner to adjust continuous time models to increase complexity where appropriate (think: dimensionality, nonlinearity, monotonicity)
Troubleshoot in class with Professor
Share out

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Week 5 – Space: the final frontier

Course objectives 3

HW4: Create bifurcation plots to assess whether hysteresis occurs in more complex model. What adjustments to your model would create hysteresis? Are they realistic? Describe implications for management of coupled human-natural system

Read Nature of Code- Cellular Automata

T Space in 1D
Space in 2D: Cellular Automata, neighborhood rules
Migration, Dispersal, Dispersion

Lab exercise VA: Effects of decision making on spatial and temporal dynamics- Schelling's model of segregation

R Space practice
Lab exercise VB: With your partner, add 1-D space to your model

Week 6 – Non-deterministic systems

Course objectives 4

HW 5: Create a simple cellular automata version of your model by editing the lab script from class, what is the effect of space on your conclusions?

Read ***An Introduction to the Practice of Ecological Modeling (from "Deterministic or stochastic?" to end)***
Bolker- Bestiary of Distributions (Ch. 4.5) & Ch. 5: Stochastic Simulation

T Non-deterministic systems: Role of noise and stochasticity
How to add noise to a model: Lab walkthrough- exogenous forcing, parameter variation (realistic bounds, error distributions)
Sensitivity analyses

Lab exercise VIA: Field trip to the green! Data collection on leaf out in managed trees

R Simulating data and comparing to real data, Walkthrough model validation process using class data collection
Simple correlation tests
Confidence bands on model predictions (if time available)

Lab exercise VIB: With partners, add noise to your non-spatial continuous time models. Describe what data you would need to test one of your model predictions? Is temporal or spatial scale important? Units? Is observational or experimental data necessary?

Week 7 – Modeling review

Course objectives 1-5

HW 6: Review literature or open-source datasets to assess state of data available to test your model predictions. Is it available? If so, where? Does the model have to be modified to use this data to test predictions? Future research directions?

T Recap of modeling toolkit available to you (All the places you can go!)
Final presentation and paper overview

Lab exercise VIIA: Work with partners to look through homework thus far, finding open questions for further investigation and what methods you would need to address them, game plan for model extension/development for next 3 weeks
Pitch your project at the end of class -1 min per student, Q/A at end for all

R Work on final projects I- Open lab for guided independent project work
Extend your model/model analysis to further address your CNH question.

Week 8 - Wrap up, concluding thoughts

Course objectives 1-5

Read ***Fragile Dominion Ch. 9***

T Discussion: Realistic, general and/or useful models
Policy/management and science in a complex CNH world
Share preliminary results with partner - Q&A and feedback/suggestions
Class share-out. What's working, what's not, what's next

R Work on final projects II

Week 9 - Project presentations

Course objectives 1-5

T Work on final projects III
R Final Presentations

Week 10 - Finals Week

Course objectives 1-5

T NO CLASS, work independently: lab open if desired

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**Final Paper due May 31, 11:59p