Entomology/Zoology 540: Theoretical Ecology

Syllabus 2010

Tony Ives

This course will introduce you to a range of ecological problems through the use of simple mathematical models. Mathematical models are useful in ecology for two reasons. First, they provide an avenue to investigate ideas in their simplest form. Hypotheses in ecology are often first generated by verbal arguments – speculations about how things work in nature. Mathematical models allow hypotheses to be formulated with more precision and detail. There are numerous examples in which theoretical models have lead to hypotheses that are later confirmed through experimentation. Second, mathematical models can be used to simulate experiments that are impossible in nature. Nature is sufficiently complex that many important experiments cannot be done. Examples include experiments on the effect of introducing exotic species into new habitats, and the effect of global climate change on the world's biota. Mathematical models can be used as surrogate ecosystems to mimic impossible experiments.

This course is centered around problem sets. I will introduce a problem in class, giving some biological background and a short theoretical discussion. The problem set will then lead you through a more detailed investigation of the problem. The problem sets should be done in groups of 2-3 students. I will assign groups and mix you up for each of the 5 problem sets.

In advance of each class, I will tell you which questions in the problem set you should have prepared. I will then pick groups at random to do problems in front of the class. I will provide help when needed, and also additional questions to keep you on your toes. I will ask the entire class to grade your performances. Course grades will be based solely on your class participation; there is no written work or final exam.

For each problem set, I will also have papers from the primary literature that I expect you to read. I will ask a group to answer questions about them, but then we will also discuss them in a journal-club-like format. This is perhaps the best way of getting exposure to the breadth of theoretical modeling approaches available. The problem sets are somewhat idiosyncratic to me, so the papers will serve as a counterweight. Some of these papers might be hard, but you should be able to get at least the general message from them. Learning how to get the message even if you don't understand the details is a critical skill to do theory.

This course is interactive, and I expect you to participate in helping to design it. I suspect that there will be some students with extensive mathematical experience, and some with very little. I want this course to accommodate both. My ability to do this depends on you; I need as much feedback as possible. Therefore, I will ask you to evaluate each problem set so I can better tailor the course for you. You should also feel free to make suggestions at any time.

Course Credits: This course is 3 credits.

Readings: Most of the readings for the course are from the primary literature. I will post these on Mywebspace and send you tickets. Two recommended readings are:

Outline and Goals of Problem Sets

PS1: Single-species models

Conceptual

1. Density-dependence as a stabilizing and destabilizing force
2. Simple deterministic models can give complex dynamics
3. Variability of stochastic systems depends on environmental variability and amplification by endogenous factors

Methodological

1. Finding the equilibrium and using linear approximations
2. Random variables
3. Geometric means
4. Fitting models to data

PS2: Structured single-species models

Conceptual

1. (St)age-structure and multi-dimensional systems
2. Demographic parameters and population growth rates
3. Density independence and density dependence
4. Reproducing early in growing populations is good

Methodological

1. Leslie matrices and eigenvalues
2. Multi-dimensional stability analyses (eigenvalues and eigenvectors)

**PS3: Competition**

Conceptual

1. Competitive coexistence, $\alpha_{12} \alpha_{21} < 1$
2. Resource partitioning
3. Aggregation
4. Coexistence through environmental stochasticity, lottery model
5. Evolutionarily stable strategies

Methodological

1. Mutual invasibility
2. Models with estimated parameters

**PS4: Predation**

Conceptual

1. Stable limit cycles
2. Stability through intraspecific competition of prey or predator
3. Behavior and population dynamics

Methodological

1. In comparing models, need to decide what to keep the same

**PS5: Community dynamics**

Conceptual

1. Trophic cascades up and down food webs
2. Dynamical patterns with long period
3. Species number and stability

Methodological

1. Stability analyses for complex systems
Questions for first class

In small groups (2-3 people), discuss the following questions for 20 minutes total. Then as an entire class (organize yourselves), come up with your best answers. Next class I will call on random people to answer the questions.

1. What proportion of species experience density-dependent population regulation?

2. Suppose there are populations of a predator and a prey spread among 10 isolated islands. You plan to do a census of the islands to obtain estimates of the predator and prey population sizes on all 10 of them. Would you predict that predator density is positively or negatively correlated with prey density among the islands?

3. Suppose you conduct an experiment using two similar species of flour beetles. First, you place each species separately in Petri dishes and place the Petri dishes in environmental chambers ranging in temperature from 15C to 25C in 2C intervals for 6 months (many beetle generations); over this time, you continuously replace flour so the beetles have a constant food supply. Your goal is to determine how sensitive the final population size of the each species is to temperature. You then repeat the experiment but using Petri dishes containing both species together (at the same initial densities). Do you expect the final population densities of beetles to be more or less sensitive to temperature when species are together rather than separate?