A Summary of Graduate Theoretical Ecology, Winter 2015

Basic information

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Office hours for Profs. Cobey and Dwyer are by appointment. Feel free to email too. We'll try to get back to you within 24 hours.

Philosophy

The overall philosophy of the course is that, in theoretical ecology and indeed in much of theoretical biology, there is no clear dividing line between biological problems and mathematical problems. Accordingly, the course covers both conceptual issues and methodological issues. The overall goal is to understand how a given set of assumptions leads to a particular model, and what each model predicts. Examples are drawn from basic models in ecology. There is a slight bias towards stochastic models, because such models have often been neglected in the ecological literature.

Conceptual Issues

- Simple models of a single species can generate complex dynamics. The clearest example of this behavior is the discrete-logistic model. In this model, as the reproductive rate increases, the population dynamics change from a point equilibrium successively to a two-point cycle, a four-point cycle, and on to chaos by period doubling.
- The way in which time is modeled (discrete v. continuous) can dramatically affect expected outcomes. In contrast to the discrete logistic model, chaos will not arise in a continuous-time, deterministic model of a single species without external variables, such as competitors, weather, or population structure.
- Simple models of consumer-resource interactions can lead to population cycles. In the Rosenzweig-MacArthur model, increasing the prey's carrying capacity makes cycles more likely. This occurs essentially because a higher carrying capacity means the constraint imposed by direct density-dependence is less severe, which in turn means that the delayed density-dependence imposed by the predator can drive cycles. Cycles may also arise transiently if systems are perturbed from equilibrium. Analyzing the equations lets us predict the existence of these oscillations without having to simulate.
- Environmental stochasticity, which is due to random fluctuations in parameter values, can have strong effects on population growth irrespective of the number of individuals in the population. In the simplest models, a large enough time series of population sizes can be represented on a log scale using a normal distribution.
- Demographic stochasticity is due to the chance events that befall individuals. If only births occur, population sizes will follow a negative binomial distribution, whereas if only

deaths occur, population sizes will follow a binomial distribution. Pure birth is probably not a very useful model, but pure death provides a good description of the dynamics of cohorts in the absence of reproduction. The distribution of population sizes for birth-death models is quite a bit more complicated, but the most interesting result for birth-death is that the long term variance is largest when the birth rate is close to the death rate. A basic feature of any kind of demographic stochasticity is that the effects go away as the population size increases. One of the consequences of this effect is that, for models and/or parameter values for which population is increasing, virtually all the stochasticity occurs early in the population trajectory. For the pure-death model, population size only ever decreases, so of course the opposite is true.

Syllabus

We start by modeling deterministic systems of few species, emphasizing analytic solutions and confirmation by numerical simulation. The second half of the course introduces stochasticity, model fitting, and model selection. Prof. Cobey will teach the first four lectures, Prof. Dwyer the next four, and both will lead discussions of the presentations.

Week 1. Single-species dynamics
Week 2. Two competing species
Week 3. Predators, prey, and food webs
Week 4. Infectious diseases
Week 5. Environmental stochasticity
Week 6. Demographic stochasticity
Week 7. Likelihood
Week 8. Model selection
Weeks 9 and 10. Presentations

Assignments

The assignments include occasional reading, weekly problem sets, and a final presentation.

The weekly problem sets are due on Chalk at the end of the week. These assignments will involve short answers, derivations, and modest programming in R. All of the assignments have to be completed to receive a passing grade in the course.

The aim of the presentations is to work with the instructors to identify an interesting problem in theoretical ecology and one or two modeling papers that address it. A list of potential questions follows, but you are encouraged to develop your own. Final selections for topics and papers are due by the seventh week of class.

Guidelines for presentations

The purpose of these talks is for you, as a presenter, to think deeply about research in an area that interests you, and as an audience member, to learn about the kinds of questions and approaches that are being used in theoretical ecology.

The presentations should be 20 min total, which includes a 15-min talk and 5 min for questions.

Please cut unnecessary fluff and focus on the theoretical components of the paper. (You may discuss two or more papers if you think you have enough time to delve into each.) What hypotheses were the authors trying to test? Did they test it satisfactorily? What are the key assumptions of their model(s)? What are the shortcomings? Can you think of alternative approaches? Provide a critical description of their analytical/computational methods. Read at least one other article in the subfield to provide some context for their work. What had been done before and what has been done since?

If you think it would help, we (the instructors) can give brief introductions to your topic to get the class up to speed. Please identify several questions on the paper for class discussion.

You may use the whiteboard and/or a projector. Well assume youll bring your own laptop. If you need to borrow one, please let us know in advance.

Youre welcome to meet with us to discuss your paper or presentation. Please give us at least 48 hours of notice.

Readings

- Demographic versus environmental stochasticity: Lande, R., Engen, S. and Saether, B.-E. 2003. Stochastic Population Dynamics in Ecology and Conservation (Oxford Series in Ecology & Evolution), pp. 1-17.

- Environmental stochasticity: Caswell, H. 2006. Matrix population models, second edition, pages 387-392.

- Demographic stochasticity: Kot, M. 2001. Elements of mathematical ecology, pages 25-42 and Renshaw, E. 1993. Modelling Biological Populations in Space and Time (Cambridge Studies in Mathematical Biology) pp. 15-45 and 62-67.

- Likelihood and model-fitting: Mood, A. F., and Graybill, F. A., and Boes, D. C. 1973. Introduction to the theory of statistics pp. 482-491 and Pawitan, Y. 2001. In all likelihood: statistical modelling and inference using likelihood, pp. 21-52.

- Simple dynamical models: Edelstein-Keshet, L. 1988. Mathematical models in biology, pp. 39-61.

- Predator-prey models: Edelstein-Keshet, pp. 130-142.