

## Research Interests

How will ecosystems respond to human-induced changes? To answer this question we must first understand what structures ecological communities and determines their dynamics. The central goal of my research is to uncover the principles by which ecological communities are organized.

### Thesis Research: The Role of Spatial Heterogeneity

My dissertation was devoted to investigating two aspects of spatial heterogeneity: how populations respond to extrinsic heterogeneity in their environment and how species themselves create heterogeneity through their interactions. Particular problems I looked at are the effect of habitat loss on species persistence, pattern formation in semiarid vegetation, and the vertical distribution of phytoplankton.

### Current and Future Research: Theoretical Plankton Ecology

Plankton are an excellent system for developing and testing ecological theory. 1) Plankton are small, relatively simple, and fast growing: if any populations behave like differential equations, plankton are among the best contenders. 2) Plankton are important: they play major roles in biogeochemical cycles and serve as the base of aquatic food webs. 3) Plankton communities show distinct patterns in space, time, and organization. As a theoretician, I am interested in both freshwater and marine communities. Below, I describe four overlapping foci of my current and future research.

**Vertical structure.** Recently, we took a game theoretical approach to study the vertical distribution of phytoplankton competing for light and nutrients in stratified water columns (Klausmeier and Litchman 2001). When phytoplankton can effectively regulate their depth, our model predicts a benthic layer, a deep chlorophyll maximum, or a surface scum depending on the physical parameters such as nutrient level. We plan on extending this theoretical work to include multiple competing species, more realistic physical structure of the water column, and zooplankton grazers. We have also performed preliminary experimental tests of the theory using 1.5 m laboratory water columns.

**Seasonal succession.** Plankton show broadly repeatable patterns of seasonal succession. We have recently developed a novel approach to the study of periodically forced competition models (Litchman and Klausmeier 2001) that we plan to extend to more complex food webs and test with laboratory microcosms and long term data from our Swiss collaborators.

**Ecological stoichiometry.** As a postdoc at Princeton, I investigated the determinants of phytoplankton N:P stoichiometry. Overall stoichiometry (structure plus stores) varies widely with growth conditions (Klausmeier et al. 2004a), but structural stoichiometry is more constrained. In an attempt to derive the Redfield N:P ratio of 16:1 for structural stoichiometry, we developed a model that links allocation to different cellular components with measures of competitive ability. We found that the Redfield ratio is not a universal optimum, but that the optimum N:P ratio varies with the ecological conditions under which species grow and compete (Klausmeier et al. 2004b).

**Community assembly.** Traditional models in community ecology determine the outcome of the interaction of a few fixed species. They cannot fully address the question of how a community will be structured given its abiotic environment, because the community structure is imposed by modeller. Using a new approach inspired by evolutionary game theory, community structure emerges as the long-term outcome of community self-organization. Species are

defined by their phenotype along a continuous axis corresponding to a physiological trade-off between ecological traits. This approach will let me address several key questions: How do the diversity and composition of communities change along environmental gradients? How does self-organization affect aggregate ecosystem properties such as primary productivity? How will communities reorganize in the face of human-induced changes?

### **Modeling philosophy**

These examples illustrate two elements of my modeling philosophy. First, for the questions I ask I prefer simple models that are at least partially analytically tractable because they often yield general insights. Second, I use mechanistic models in which parameters and variables have clear ecological meanings and can be experimentally measured. This increases the relevance of my work for empiricists because the processes they study are directly accounted for. Parameterization permits quantitative tests of the models' predictions.

### **Teaching Interests and Experience**

In my teaching I aim to show students the importance of quantitative thinking in understanding the complexity of ecological systems. Theory provides both a stock of metaphors and a theoretical framework to organize quantitative findings.

At Georgia Tech, I have taught a senior-level class in Mathematical Biology to math, biology and other majors and a senior/graduate-level class in Theoretical Ecology. I would enjoy teaching the following classes:

**Introduction to Ecology (undergraduates)** — I would cover classic concepts at levels of organization from the individual to the ecosystem and introduce applied areas such as conservation and the role of humans in global biogeochemical cycles. Mathematics would be verbally explained and students would explore models using computer simulations.

**Theoretical Ecology (advanced undergraduates, graduate students)** — This class would provide a solid theoretical foundation in ecology. Topics would include a theoretical treatment of single-species growth, resource- and other forms of competition, predator-prey and disease dynamics, food web theory, age- and spatial-structure, and ecosystem dynamics. Readings would come from the primary literature, supplemented with a text such as *Ecological Dynamics*, W. S. C. Gurney and R. M. Nisbet. Students would use computer simulations to explore topics covered in lecture further and would complete an independent modeling project to be presented in the final weeks of class.

**Mathematical Biology (advanced undergraduates, graduate students)** — This class would provide introduce math and biology majors to dynamical modeling in biology. Topics would include some population biology, biological oscillators, epidemiology, within-host disease dynamics, pattern formation, and game theory. Readings would come from the primary literature, supplemented with a text such as *Essential Mathematical Biology*, N. Britton. Students would use computer simulations to explore topics covered in lecture further.