CONFERENCE ON MATHEMATICAL ECOLOGY
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Talk Abstracts

Priyanga Amarasekare
University of California Los Angeles

Towards a mechanistic understanding of temperature effects on population viability

Climate warming is predicted to cause large-scale extinctions, particularly of ectothermic species. A striking difference between tropical and temperate ectotherms is that tropical species experience an upper temperature limit for survival that is very close to the optimal temperature at which fitness is maximized, and a mean habitat temperature that is quite close to this optimum. In temperate species, the upper temperature limit is farther away from the optimum, and the mean habitat temperature is much lower than the optimum. Thus, even a small increase in environmental temperature could put tropical ectotherms at high risk of extinction, whereas temperate ectotherms have a wider temperature cushion. Although this pattern is widely observed, the mechanisms that produce it are not well-understood. I use age-structured population dynamics to derive an analytical expression for the temperature response of fitness in terms of the temperature responses of fitness components (fecundity, development, survivorship). This expression provides exact calculations of the lower and upper temperature limits for viability and the optimal temperature for fitness. It also predicts the life history attributes that have the greatest effect on fitness: temperature sensitivity of development and the width of the temperature response of reproduction. Tests of these predictions with data from tropical and temperate insects provide strong support for the model. Because it can predict the thermal limits to viability based on temperature data for fecundity, development and survivorship for any multicellular ectotherm species, this framework provides for a rigorous, and general, method for quantifying extinction risk due to climate warming.

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Stephen Cantrell
University of Miami

Evolutionary stability of ideal free strategies in patchy environments

A central question in the study of the evolution of dispersal is what kind of dispersal strategies are evolutionarily stable. Hastings (Theor. Pop. Biol. 1983) showed that among unconditional dispersal strategies in a spatially heterogeneous but temporally constant environment, the dispersal strategy with no movement is convergent stable. The work of McPeek and Holt (Am. Nat. 1992) suggested that among conditional dispersal strategies in a spatially heterogeneous but temporally constant environment, an ideal free strategy, which results in the ideal free distribution for a single species at equilibrium, is evolutionarily stable. We use continuous-time and discrete-time models to determine when the dispersal strategy with no movement is evolutionarily stable and when an ideal free dispersal strategy is evolutionarily stable, both in a spatially heterogeneous but temporally constant environment.

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Kim Cuddington
University of Waterloo

Invasion risk and the birthday problem

The existence of a strong Allee effect caused by a low probability of mate-finding may imply that some small populations of non-native species are unlikely to invade. However, for populations that use a restricted number of mating-finding sites, successful mating may be highly probable. I model mate-finding using a 2 object class variant of the birthday problem. The birthday problem describes the probability that any two people in a group of a given size share the same birthday Contrary to the intuition of many, this probability is greater than 50 percent for a relatively small group of people (n=23). This problem is of import when calculating quantities in widely various applications such as the probability that airplanes will collide, or that there are matches between random length clone fragments in DNA mapping. The birthday problem is related to, but not exactly the same problem as calculating the probability that a male and female will meet at the same location when density is low. For species that use specific mate-finding locations rather than random encounter, we can describe the probability of mating as the probability that two different kinds of objects would collide in the same bin. Using Asian carp as our example, we find that only a small population density is required to have a very high probability of successful mating in the limited number of spawning rivers available. Researchers may find it counterintuitive that a limited number of mate-finding locations could increase the probability of mating. I explore some of the conditions which are required for this result to hold. In addition, I demonstrate that when the number of possible mate-finding locations is small, the demographic Allee effect may be very small as well, and invasion may be likely at small density. This finding is also of more general interest since many species make use of a restricted number of mating-finding locations that are not selected for habitat reasons (e.g., hill-topping in butterflies).

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Stephen P. Ellner
Cornell University

Temporally variable dispersal and demography can accelerate the spread of invading species

We analyze how temporal variability in local demography and dispersal combine to affect the long-term spread rate of an invading species. The model combines state-structured local emography (a matrix or integral projection model), general dispersal distributions that may depend on the state of the individual or its parent, and general patterns of random variation in local demography and dispersal. Using general expressions for the asymptotic spread rate and its sensitivity to perturbations, we show that that random variability in dispersal can accelerate population spread. Demographic variability on its own always slows population spread. But if demographic variation is positively correlated with dispersal variation, it can instead increase the spread rate. These properties relate to the fact that rare chances for especially long-range dispersal dominate the long-term spread rate, even if they are very rare. A simple model for the invasive plant Lepidium latifolium illustrates the effects of dispersal variation and shows that they can have substantial impacts on the predicted spread rate. This is joint work with Sebastian Schreiber.

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Bill Fagan
University of Maryland

Linking Individual Movements and Population Patterns in Dynamic Landscapes

Real landscapes are dynamic in space and time, and the scale over which such variation occurs can determine the success of different strategies of population growth and movement. Real species rely on a variety of individual-level behaviors to move in and navigate through their landscapes. Such behaviors include (1) non-oriented movements based on diffusion and kinesis in response to proximate stimuli, (2) oriented movements utilizing perceptual cues, and (3) memory mechanisms that assume prior knowledge of movement targets. Species' use of these mechanisms depends on life-history traits and resource dynamics, which together shape population-level patterns such as range residency, migration, and nomadism. This talk will draw upon empirical data, remote sensing imagery, and a variety of mathematical models to demonstrate the connections among individual movements, landscape dynamics, and population-level patterns.

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Mark Lewis
University of Alberta

First passage time in complex environments: Connecting random walks to functional responses

Abstract: In this talk I will outline first passage time analysis for animals undertaking complex movement patterns while searching for prey. I will extend the analysis to complex heterogeneous environments to assess the effects of man-made linear landscape features on functional responses in wolves searching for elk. (This work is joint with Hannah McKenzie, Evelyn Merrill and Ray Spiteri)

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Judith Miller
Georgetown University

Quantitative genetics and species' ranges

A fundamental problem in spatial ecology is to understand the determinants of a species' geographical range, including the reasons for range expansions or invasions. Genetic factors including adaptive evolution can play a crucial role in determining the location and dynamics of species' range limits, but have received far less attention than demographic and environmental factors. Here we reanalyze two influential models of range limits, due to Kirkpatrick and Barton, to show how lag times followed by explosive, difficult-to-reverse range expansions (hysteresis) can arise from interactions between environment, demography and genetics, even in the absence of an Allee effect. We also consider whether patterns of genetic variance can characterize adaptive evolution in a spatially varying environment.

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Michael Neubert
Woods Hole Oceanographic Institution

Strategic Models for the Spatial Management of Fisheries and their Bioeconomic Implications for Marine Reserves

Marine reserves can be established for conservation or fisheries management purposes. As is appropriate, the mathematical models that are currently used to understand the economic costs and benefits of marine reserves make a number of simplifying assumptions. In my lecture, I will provide a brief review of recent progress in the bioeconomic theory of marine reserves. I will then talk, in slightly more detail, about the consequences of one common assumption: that the stock is either under the exclusive control of a single owner, or that it can be exploited by anyone. In reality, the distributions of actual stocks often straddle the exclusive economic zones of a small number of states as well as the high seas. In this talk, I will demonstrate how to construct spatially-explicit bioeconomic models for such "transboundary" or "straddling" stocks. Using a two-state model, I will show the ecological and economic conditions under which closed areas are optimal, and show how the economic and conservation costs of noncooperation between states depend on biological and economic conditions.

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Roger Nisbet
University of California – Santa Barbara

Modeling population level impacts of engineered namomaterials in the environment

The use of engineered nanomaterials (ENMs) (particles smaller than 100nm in at least one dimension) is growting rapidly. Release of ENMs into soil and water is inevitable, and the ecological consequences are uncertain. There is a near limitless combination of ENMs, organisms,and environments of potential importance, but there are limited resources for ecological studies which are commonly expensive and time consuming. Progress in understanding ecological implications of ENMs in the environment thus requires models that relate readily obtainable laboratory data on suborganismal processes to population and ecosystem dynamics. I shall describe an approach based on Dynamic Energy Budget (DEB) theory. At its core is a dynamic model of the physiological performance of an individual organism, with a low-dimensional system of ordinary differential equations describing the rates at which an organism assimilates and utilizes energy and elemental matter for maintenance, growth, reproduction, development, and reducing the risk of mortality. Ecotoxicological applications of DEB theory require additional toxicokinetic and toxic effect submodels. Toxicokinetic submodels describe contaminant exchange with the environment and chemical transformations within an organism. Toxic effect submodels specify how the basic DEB model parameters change. The connection to population dynamics is made through “structured” or “individual-based” modeling techniques. A brief outline of DEB theory will preceed an overview of some recent applications to nanotoxicology. The examples cover the response of phytoplankton populations to metal and metal oxide ENMs, the response of marine mussels to metal oxide ENMs, and the response of bacteria to Cd-Se quantum dots.

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Tim Reluga
University of Pennsylvania

Discrete Random Variable Algebras and the Representations of Stochastic Population Models

Abstract: Discrete random variable algebras are composed of non-negative integer-valued random variables with a product defined in terms of a sum of a random number of other IID discrete random variables. The simplest examples of discrete random variables are density-independent branching processes, but they can also be extended to describe stochastic populations dynamics when vitality rates are density-dependent. In this talk, I'll present the basic mathematical properties of discrete random variable algebras, and explore their application as an alternative description of stochastic population models.

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Sebastian Schreiber
University of California - Davis

Should I stay or should I go? An SDE perspective on the ecology and evolution of movement

All populations, whether they be plants, animals, or viruses, live in spatially and temporally variable environments. Understanding how this variability influences population persistence and the evolution of movement is a fundamental issue of practical and theoretical importance in population biology. Prior work has shown that spatial variability, in and of itself, enhances persistence and selects against random movement as well as movement into sink habitats (places unable to harbor a self-sustaining population). Alternatively, temporal variability, in and of itself, inhibits persistence and exerts no selective pressures on movement. The combined effects, however, of spatial and temporal variability are remarkably complex. This combined variability can select for movement into sink habitats and allow for populations to persist in landscapes comprised solely of sink habitats. In this talk, I will discuss recent analytic results in which populations living in patchy environments are modeled with stochastic differential equations (SDEs). These results provide a diversity of new insights into population persistence and the evolution of movement. Much of this work was done in collaboration with Steve Evans (Berkeley), Peter Ralph (Davis), and Arnab Sen (Cambridge).

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Stuart Townley
University of Exeter

Diffusion, density dependence and linearised transients: A triumverate of destabilising effects

In this talk we consider (possibly coupled) density dependent population dynamics and the interplay between three competing effects: Spatial diffusion, density dependence and transients of linearised dynamics. Turing patterns are a result of diffusion driven instability; turbulence is caused by interactions between transients in linearised fluid flows and neglected nonlinearities. Using ideas from control engineering: we develop new necessary conditions for Turing instability based on linear matrix inequalities; and discuss how increasing population momentum (a measure of transients) can trigger biological invasion. We illustrate our results by revisiting a number of classical models from the literature, including host-parasite-hyperparasite models and a Gierer-Meinhardt system modeling regenerative properties of Hydra.

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Shripad Tuljapurkar
Stanford University

Stage-Plus-Age Dynamics: Measures of Reproductive Timing that predict Growth Rate

In classical demography, the timing of reproduction (as measured by cohort generation time and demographic dispersion) has a precise relationship to stable growth rate. Uli Steiner and I have found corresponding measures for stage-plus-age models that uniquely define a generation time and dispersion that predict growth rate. I present these and discuss implications for ecology and life history evolution.

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Pauline van den Driessche
University of Victoria

Models for the Spread of Cholera

Compartmental models for the spread of cholera are formulated that include direct transmission by person-to-person contact and indirect transmission to humans via contaminated water. For a model with spatial homogeneity it is shown that the basic reproduction number R0 gives a sharp threshold: if $R0 < 1$, then cholera dies out; whereas if $R0 > 1$, then the disease tends to an endemic level. Motivated by data from the recent cholera outbreak in Haiti, ideas for incorporating spatial heterogeneity are introduced.

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Hao Wang
University of Alberta

Risk Assessment of Oil Sands Pollution on Fish Population Dynamics

Abstract: The oil sands in northern Alberta, Canada, represent one of the largest oil deposits in the world. Rapid expansion of oil sands industry presents several challenges with respect to the protection of local freshwater resources such as the Athabasca River basin. It is necessary and urgent to assess the risk of the fish population exposed to toxins, and to find important factors that determine the persistence and extinction of a fish species. In this talk, I will introduce a basic toxin-dependent population model, and briefly show positive invariant region and stability of boundary and interior steady states. The model is connected to experimental data via model parametrization. Based on the results of model parametrization, the numerical solution of the model are then used to make the risk assessment of oil sands on fish population. In particular, I will discuss the effect of mercury, one of 13 considered priority pollutants released by oil sands industry, on the persistence and likelihood of extinction of rainbow trout (Oncorhynchus mykiss) population.*This work is mainly carried out by the postdoc, Qihua Huang, and in collaboration with Mark Lewis and Caroline Bampfylde (Alberta Environment).