Special Session 38: Evolution Dynamics in Ecology and Epidemiology

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Dispersal Behavior of Insects around Boundary between Two Habitat Types

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We modeled the landscape dispersal process as a diffusion equation system, which describes the movements of insects around an interior boundary between two habitat types.

For quantifying the diffusion parameters, the model with discontinuous diffusion rates within the composite medium, and with the absorbing exterior boundaries need to be solved. Two cases were studied:

1) Rectangular filed.
2) Circular field.

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The Impact of Vaccination and Multiple HPV Strains on Cervical Cancer

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The impact of vaccination and multiple HPV strains on cervical cancer

Understanding the relationship between multiple strains of human papillomavirus and cervical cancer may play a key role in vaccination strategies for the virus. In this talk we present a model with two strains of infection, and vaccination for one of the strains, in order to investigate how multiple strains of HPV and vaccination may affect the number of cervical cancer cases and deaths due to infections with both types of HPV. We calculate the basic and invasion reproductive numbers for each strain, which determine equilibrium stability, and present numerical results to estimate the impact of vaccination on a scenario in which infection with the vaccine strain predisposes women to infection with the non-vaccine strain.

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Removal of Vaccine-induced Backward Bifurcations in Epidemic Models

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Epidemic models, formulated using standard incidence function, typically exhibit the phenomenon of backward bifurcation, where a stable disease-free equilibrium co-exists with a stable endemic equilibrium when the associated reproduction number is less than unity. The epidemiological consequence of this fact is that the classical requirement of having such epidemiological threshold to be less than unity is necessary but not sufficient for disease elimination. The talk will describe this mechanism in some detail and will show that such phenomenon is dependent on the type of incidence function used to formulate the epidemic model.

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Models with explicit resource quality dynamics and their implications

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In almost all existing population growth models, authors have adopted the physical science's single-currency (energy) approach to understanding population dynamics. However, biomass production requires more than just energy. It is crucially dependent on the chemical compositions of both the consumer species and food resources. In this talk, we explore how depicting organisms as built of more than one thing (for example, carbon and an important nutrient, such as phosphorous) in stoichiometrically explicit models results in qualitatively different and realistic predictions about the resulting dynamics. Stoichiometric models incorporate both food quantity and food quality effects in a single framework, appear to stabilize predator-prey systems while simultaneously producing rich dynamics with alternative domains of attraction and occasionally counterintuitive outcomes, such as coexistence of

more than one predator species on a single-prey item and decreased herbivore performance in response to increased plant growth rate.

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Coupling SI Epidemic and Virus Dynamics: Pathogen Evolution

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Zhilan Feng and Jorge Velasco-Hernandez

We proposes a theoretical approach for the study of coupled ecological processes exemplified by the study and analysis of a mathematical model for the linkage of an epidemic SI disease and the virus-cell dynamics corresponding to the onset of disease at the individual level. By linking two simple mathematical models the combined dynamical system provide insights into the interactions and emergent phenomena that arise in the coupled biological processes. Our main results indicate 1) the existing of bi-stability at the epidemic level (dependency on initial conditions) taking the place of the usual threshold associated with the basic reproductive number, and 2) the bi-stability threshold mentioned above depends on the basic reproductive number of the within-host dynamical system.

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Modeling the glucose-insulin regulation system: towards to artificial pancreas

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Yang Kuang, Clint Mason and Haiyan Wang

Diabetes has been classified as an epidemic recently. More than 7% population of American people suffers diabetes. Both number of diabetics and health expense grow fast. Thus more efficient and effective treatments to help diabetics are in demand. In this talk, we will present a few mathematical models in modeling the system of glucose-insulin regulations. These models can be candidates for the design of artificial pancreas.

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Heteroclinic bifucation in the Michaelis-Menten type ratio-dependent predator-prey system

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We discuss the existence of a heteroclinic bifucation for the Michaelis-Menten type ratio-dependent predator-prey system. We show that the heteroclinic bifurcation is characterized by the collision of a stable limit cycle with the origin, and the bifucation triggers a catastrophic shift from the state of large oscillations of predator and prey populations to the state of extinction of both populations. We also show that limit cycles related to the heteroclinic bifurcation originally bifurcate from the Hopf bifurcation.

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Plant-herbivore interactions mediated by plant toxicity

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Z. Feng, D. DeAngelis and H. Zhu

We explore the impact of plant toxicity on the dynamics of a plant-herbivore interaction, such as that of a mammalian browser and its plant forage species, by studying a mathematical model that includes a toxin-determined functional response. In this functional response, the traditional Holling Type 2 response is modified to include the negative effect of toxin on herbivore growth, which can overwhelm the positive effect of biomass ingestion at sufficiently high plant toxicant concentrations. Two types of consumption decisions of the herbivore are considered.

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Two-Sex, Age-Structured, Logistic Population Models

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We formulate a new model for population dynamics that is both age- and sex-structured and has logistic mortality, combining the classical model of Gurtin and MacCamy and the two-sex Frederickson-Hoopensteadt model. We introduce a new type of

birth boundary condition that consists of two integral terms, one modeling births from couples and another one modeling births from single mothers. We establish the well-posedness of the model and do extensive numerical simulations with real-life data from US census and vital statistics for several time periods. The model consists of three first-order partial differential equations of hyperbolic type, one each to model the age density evolution of females and of males, and a third one describing the age density evolution of couples. Births are modeled by integral terms that give boundary conditions at age zero for the densities of females and males.

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An application of diffusion models to insects inhabiting a complex landscape.

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Insects commonly move through a variety of landscape elements and boundaries in search of food, mates, reproductive sites and refuge from predators. We developed and parameterized a diffusion model of movement for an insect herbivore (a prairie planthopper) that inhabits a landscape composed of patches of its host plant embedded in a matrix of non-host plants and mudflat. The model incorporates varying diffusion rates for different landscape elements, boundary behavior between elements, and two classes of planthopper dispersal behavior (mobile vs. sessile). Maximum likelihood was used to estimate the model parameters with data from marked insects released at various positions within experiment arenas. We then combined the diffusion model for movement with a discrete-time model of population dynamics, to predict the long-term behavior of host plant patches surrounded by matrix. Persistence of the planthopper population was highly dependent on patch size, the surrounding matrix type, and the behavior at the host plant-matrix boundary.

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Variable decay kinetics of HIV-1 latent reservoir and intermittent viral blips in HIV-infected individuals on HAART

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When HAART is administered to HIV-infected patients, most achieve viral loads that are below the limit of detection of current standard assays after a few months. Despite this, virus eradication from the host has not been achieved. Latent, replication-competent HIV-1 can generally be identified in resting memory CD4+ T cells in patients with “undetectable" viral loads. Turnover of these cells is extremely slow but virus can be released from the reservoir quickly upon cessation of therapy. In addition, a number of patients experience transient episodes of viremia (viral blips), even with suppression of the viral load to below the limit of detection for many years. In this talk, I will present a mathematical model that examines the mechanisms underlying the slow decay of the latent reservoir and occurrence of intermittent viral blips, as well as the relationship between them. The model can robustly generate intermittent viral blips in HIV patients during potent therapy, and more interestingly, reconcile the differences between the divergent estimates of the half-life of the latent reservoir in the literature.

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