Workshop on Differential Equations and Mathematical Biology

November 23-25, 2024

Lakeside Village, University of Miami, Coral Gables, FL

A Celebration of Professor Shigui Ruan's 60th Birthday

Live video for Lakeside Auditorium (plenary talks and special session 1) can be found

Scan me!

Organizing Committee

- Robert Stephen Cantrell, University of Miami
- Chris Cosner, University of Miami
- Jing Chen, Nova Southeastern University
- Daozhou Gao, Cleveland State University
- Qimin Huang, The College of Wooster
- Xi Huo, University of Miami
- Jaqueline Mesquita, University of Brasília, Brazil
- Joanna Wares, University of Richmond

Funding Resources

- Simons Foundation
- Institute of the Mathematical Sciences of the Americas (IMSA)
- Department of Mathematics, UM
- College of Arts & Sciences, UM

Daily Schedule and Talk Schedule

Saturday, November 23rd, 2024		
8:00 am - 8:15 am	Breakfast	Lakeside Pavilion
8:15 am - 8:30 am	Opening Remarks	Lakeside Auditorium
8:30 am - 9:30 am	Plenary Talk: Qing Nie	Lakeside Auditorium
9:30 am - 10:30 am	Plenary Talk: Jianhong Wu	Lakeside Auditorium
10:30 am - 10:40 am	Group Photo	Lakeside Village
10:40 am - 11:00 am	Coffee Break	Lakeside Auditorium
11:00 am - 12:00 pm	Invited Talk Sessions	Lakeside Auditorium Lakeside Pavilion Lakeside Village Training Room
12:00 pm - 1:30 pm	Lunch Break	Lakeside Pavilion
1:30 pm - 2:30 pm	Plenary Talk: Simon Levin	Lakeside Auditorium
2:30 pm - 3:00 pm	Coffee Break	Lakeside Auditorium
3:00 pm - 5:00 pm	Invited Talk Sessions	Lakeside Auditorium Lakeside Pavilion Lakeside Village Training Room
6:00 pm - 9:00 pm	Banquet	Lakeside Pavilion
Sunday, November 24th, 2024		
8:00 am - 8:30 am	Breakfast	Lakeside Pavilion
8:30 am - 9:30 am	Plenary Talk: Glenn Webb	Lakeside Auditorium
9:30 am - 10:30 am	Plenary Talk: Maia Martcheva	Lakeside Auditorium
10:30 am - 11:00 am	Coffee Break	Lakeside Auditorium
11:00 am - 12:00 pm	Invited Talk Sessions	Lakeside Auditorium Lakeside Pavilion
12:00 pm - 1:30 pm	Lunch Break	Lakeside Pavilion
1:30 pm - 2:30 pm	Plenary Talk: Alan Hastings	Lakeside Auditorium
2:30 pm - 3:00 pm	Coffee Break	Lakeside Auditorium
3:00 pm - 5:00 pm	Invited Talk Sessions	Lakeside Auditorium Lakeside Pavilion
Monday, November 25th, 2024		
8:00 am - 8:30 am	Breakfast	Lakeside Pavilion
8:30 am - 9:30 am	Plenary Talk: Arnaud Ducrot	Lakeside Auditorium
9:30 am - 10:30 am	Plenary Talk: Dongmei Xiao	Lakeside Auditorium
10:30 am - 11:00 am	Coffee Break	Lakeside Auditorium
11:00 am - 12:00 pm	Invited Talk Sessions	Lakeside Auditorium Lakeside Pavilion
12:00 pm - 1:30 pm	Lunch Break	Lakeside Pavilion
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2:30 pm - 3:00 pm	Coffee Break	Lakeside Auditorium
3:00 pm - 3:30 pm	Invited Talk Sessions	Lakeside Auditorium Lakeside Pavilion
3:30 pm - 4:00 pm	Farewell	Lakeside Auditorium

Saturday, November 23rd, 2024		
Plenary Talks - Lakeside Auditorium		
8:30 am - 9:30 am	Qing Nie[1]	Systems Learning of Single Cells
9:30 am - 10:30 am	Jianhong Wu[2]	The Role of Species Behavioural Utility in Multi-stability and Multi-waves of Infestation and Disease Transmission Dynamics
Special Session 1 - Lakeside Auditorium		
11:00 am - 11:30 am	Gail S. K. Wolkowicz*	Decay Consistent Models of Growth, Competition, and Predation
11:30 am - 12:00 pm	Jaqueline Mesquita*	Neutral FDEs with State-dependent Delays: Linearized Instability Principle
Special Session 2 - Lakeside Pavilion		
11:00 am - 11:30 am	Xueying Wang*	Multiscale and Multi-Strain Modeling Approaches to COVID-19 Dynamics
11:30 am - 12:00 pm	Daihai He*	The Effectiveness of the COVID-19 Vaccination Campaign in 2021: Inconsistency in Key Studies
Special Session 3 - Lakeside Village Training Room		
11:00 am - 11:30 am	Yijun Lou*	Stage-structured Models with Stage Distributions and Intraspecific Competition
11:30 am - 12:00 pm	Xiaoying (Maggie) Han*	Dynamic and Probabilistic Analysis of the Lottery Model in Nonstationary Environments
Plenary Talk - Lakeside Auditorium		
1:30 pm - 2:30 pm	Simon Levin[3] (virtual)	Political Polarization, Social Behavior and the Dynamics of Infectious Diseases
Special Session 1 - Lakeside Auditorium		
3:00 pm - 3:30 pm	Joanna Wares	How Working with Dr. Shigui Ruan Taught Me to Love Population Dynamics (and Collaboration)
3:30 pm - 4:00 pm	Troy Day*	A PDE Model for the Evolution of Epigenetically Inherited Drug Resistance
4:00 pm - 4:30 pm	Cameron Browne	Emergence of Antibiotic Resistance in Stochastic Model of Bacterial Competition and Mutation during Drug Treatment
4:30 pm - 5:00 pm	Ousmane Seydi	Linking Within- and Between-Host Scales for Understanding the Evolutionary Dynamics of Quantitative Antimicrobial Resistance
Special Session 2 - Lakeside Pavilion		
3:00 pm - 3:30 pm	Necibe Tuncer*	Understanding Usutu Virus Dynamics: Effects of Data and Model Structure Across Biological Scales
3:30 pm - 4:00 pm	Wenrui Hao	Data-Driven Modeling of Alzheimer's Disease
4:00 pm - 4:30 pm	Xinfeng Liu	Data-driven Mathematical Modeling, Computation and Experimental Investigation of Dynamical T-Cells with Tumor Growth
4:30 pm - 5:00 pm	Xinyue Zhao	Optimal Control of Free Boundary Models for Tumor Growth
Special Session 3 - Lakeside Village Training Room		
3:00 pm - 3:30 pm	Sebastian Schreiber*	Impacts of the Tempo and Mode of Environmental Fluctuations on Population Growth
3:30 pm - 4:00 pm	Daozhou Gao	Some Recent Progress on Epidemic Patch Models
4:00 pm - 4:30 pm	Rachidi Salako	Dynamics of Classical Solutions to a Diffusive Epidemic Model with Varying Population Demographics
4:30 pm - 5:00 pm	Yixiang Wu	On Degenerate Reaction-diffusion Epidemic Models with Mass Action or Standard Incidence Mechanism

* Session Moderator
[1] Chair: Robert Stephen Cantrell
[2] Chair: Chris Cosner
[3] Chair: Abba Gumel

Sunday, November 24th, 2024		
Plenary Talks - Lakeside Auditorium		
8:30 am - 9:30 am	Glenn Webb[1]	Population Models of Epidemics with Infection Age and Vaccination Age Structure
9:30 am - 10:30 am	Maia Martcheva[2]	Optimal Control of a Multi-scale HIV-Opioid Model
Special Session 1 - Lakeside Auditorium		
11:00 am - 11:30 am	Zhisheng Shuai*	Lyapunov Function(al)s for Large-Scale Dynamical Systems
11:30 am - 12:00 pm	Xiaoqiang Zhao*	Basic Reproduction Numbers for Biological Evolution Systems
Special Session 2 - Lakeside Pavilion A		
11:00 am - 11:30 am	Christopher Kribs*	Impact of ADE and Dengue Vaccination with Screening on the Toll of a Dual Dengue-Zika Outbreak
11:30 am - 12:00 pm	Libin Rong*	Recent Developments in Modeling HIV Infection and Treatment
Special Session 3 - Lakeside Pavilion B		
11:00 am - 11:30 am	Chunhua Shan*	Bifurcations of a Predator-prey System with Holling Type Functional Response and Allee Effects
11:30 am - 12:00 pm	Yuan Yuan*	Dynamics in a General Discrete Predator-prey Model with Fear Effect
Plenary Talk - Lakeside Auditorium		
1:30 pm - 2:30 pm	Alan Hastings[3]	Transient Dynamics and Ecological Systems
Special Session 1 - Lakeside Auditorium		
3:00 pm - 3:30 pm	Gergely Röst*	Asymptotic Stability for Non-autonomous Linear Delay Differential Equations Representing Birth-Death Dynamics
3:30 pm - 4:00 pm	Teresa Faria	Extinction and Periodic Solutions for a Competitive Chemostat Model with Delays
4:00 pm - 4:30 pm	Francesca Scarabel	Numerical Stability and Bifurcation Analysis of Equations with Infinite Delay
4:30 pm - 5:00 pm	Dimitri Breda (virtual)	Sparse Identification of Nonlinear Dynamics for Delay and Stochastic Differential Equations
Special Session 2 - Lakeside Pavilion A		
3:00 pm - 3:30 pm	Xiang-Sheng Wang	Periodic Solutions of Switching Scalar Dynamical Systems
3:30 pm - 4:00 pm	Gonzalo Ricardo Robledo Veloso	Persistence and Extinction Scenarios in an Almost Periodic Metapopulation with Competition and Habitat Destruction
4:00 pm - 4:30 pm	Guangyu Zhao	When Small Fractional Powers Matter: How a Competitive Exclusion Occurs
4:30 pm - 5:00 pm	Thomas Hillen*	Mathematical Modelling of Microtube Driven Invasion of Glioma
Special Session 3 - Lakeside Pavilion B		
3:00 pm - 3:30 pm	Marco Tosato	Impact of Deer Migration on Tick Population Dynamics
3:30 pm - 4:00 pm	Guihong Fan*	One Health Modelling for the Transmission Dynamics of West Nile Virus with Multiple Hosts
4:00 pm - 4:30 pm	Karen R Rios Soto	On the Spread of Ultrafine Particulate Matter: A Mathematical Model for Motor Vehicle Emissions and Their Effects as an Asthma Trigger
4:30 pm - 5:00 pm	Yanyu Xiao	Impact of Pulse Controls on a Network Model

* Session Moderator
[1] Chair: Jing Chen
[2] Chair: Qimin Huang
[3] Chair: Joanna Wares

Monday, November 25th, 2024		
Plenary Talks - Lakeside Auditorium		
8:30 am - 9:30 am	Arnaud Ducrot[1]	Spreading Speeds of Solutions to Predator-Prey Reaction-Diffusion Systems
9:30 am - 10:30 am	Dongmei Xiao[2]	Analytical Study of the Stability of the Ecological Community with an Energy Landscape
Special Session 1 - Lakeside Auditorium		
11:00 am - 11:30 am	Hayriye Gulbudak*	Bistability in a Model of Hepatitis B Virus Dynamics
11:30 am - 12:00 pm	Stanca Ciupe*	Understanding Long-term Virus Dynamics: Lessons from Hepatitis B and HIV Infections
Special Session 2 - Lakeside Pavilion A		
11:00 am - 11:30 am	Sue Ann Campbell*	Dynamics of a Conservative Nutrient-Phytoplankton-Zooplankton Model with Diffusion and Spatio-Temporal delay
11:30 am - 12:00 pm	King-Yeung (Adrian) Lam*	On the Shape of Expansion of a Population in the Presence of a Fast Road
Special Session 3 - Lakeside Pavilion B		
11:00 am - 11:30 am	Yu Jin*	A Time-periodic Parabolic Eigenvalue Problem on Finite Networks and Its Applications
11:30 am - 12:00 pm	Junping Shi*	Seasonal Disease Models of Blue Crab Population in the Chesapeake Bay
Special Session 1 - Lakeside Auditorium		
1:30 pm - 2:00 pm	Christopher Walker*	The Principle of Linearized Stability in Age-Structured Diffusive Populations
2:00 pm - 2:30 pm	Rossana Vermiglio (virtual)	Approximating Reproduction Numbers for Age-Structured Models
2:30 pm - 3:00 pm	Sabrina Streipert	Derivation and Analysis of Discrete Population Models with Distributed Delayed Growth
3:00 pm - 3:30 pm	Antonio Mateus Barreto Gondim	On the Geographic Spread of Chikungunya between Brazil and Florida: A Multi-patch Model with Time-delay
Special Session 2 - Lakeside Pavilion A		
1:30 pm - 2:00 pm	James Watmough*	Multi-scale, Host-based Network Models of Immune Landscapes
2:00 pm - 2:30 pm	Qiuyi Su	A Method to Quantify Immunity Gained from Vaccine by Mathematical Modeling: A Case Study for SARS-CoV-2
2:30 pm - 3:00 pm	Tianyu Cheng	Modelling the Impact of Precaution on Disease Dynamics and Its Evolution
3:00 pm - 3:30 pm	Linhao Xu	Spatial Patterns as Long Transients in Submersed-Floating Plant Competition with Biocontrol
Special Session 3 - Lakeside Pavilion B		
1:30 pm - 2:00 pm	Shangbing Ai	Traveling Wave Solutions for a Keller-Segel System with Nonlinear Chemical Gradient
2:00 pm - 2:30 pm	Quentin Griette	Continuous and Discontinuous Traveling Waves in a Hyperbolic Keller–Segel Equation
2:30 pm - 3:00 pm	Wenxian Shen*	Front Propagation Dynamics in Fisher KPP Equations on Unbounded Metric Graphs
3:00 pm - 3:30 pm	Yulei Cheng	Free Habitat Boundaries Expand, Balance or Shrink for One Species and Two Species

* Session Moderator
[1] Chair: Jaqueline Mesquita
[2] Chair: Daozhou Gao

Plenary Talks (alphabetical order)

Arnaud Ducrot, Department of Mathematics, Université Le Havre Normandie, France

Title: Spreading Speeds of Solutions to Predator-Prey Reaction-Diffusion Systems.
Abstract: In this lecture, we investigate the spreading behaviour of solutions to predator-prey reaction-diffusion systems. We begin by deriving results for certain two-component systems, specifically obtaining sharp estimates for the spreading speeds through suitable comparisons with solutions of the Fisher-KPP equation. We then extend our analysis to systems with more species, demonstrating that these solutions can exhibit complex dynamics with multiple propagating layers. Additionally, we provide estimates for the spreading speeds of these layers and show that nonlinearly determined wave speeds may arise.

Alan Hastings, Department of Environmental Science & Policy, University of California - Davis

Title: Transient Dynamics and Ecological Systems.
Abstract: Analyses of both models and data in ecology are still focused on equilibrium or long-term dynamics, with some notable exceptions. Although recent work on tipping points does include approaches based both on underlying changing environments and dynamics on different time scales, the possible situations where dynamics on different time scales are important are much more general. Using new mathematical ideas one can address questions of dynamics on ecological time scales, rather than longer times, and include other kinds of underlying environmental change. The importance of this way of analyzing ecological systems is clear in consideration of changing environments due to anthropogenic influences. The analyses demonstrate that there are wide ranges of ecological situations where standard analyses based on assuming asymptotic behavior are misleading. Additional cases where explicit time dependence is included in dynamics shows further complications. Different kinds of situations where long transient behavior is expected can be identified. In particular, adding space, which essentially makes systems very high dimensional, is often likely to lead to long transient dynamics. This work also, unfortunately, points out challenges in trying to identify systems where future sudden shifts in system state due to transients are going to occur, since transient behavior of a system with long transients will be asymptotic or long-term behavior of a corresponding system without transients. Examples of ecological systems illustrating the conclusions, including coral-algal-grazer systems will be discussed in light of the general theoretical results.

Simon A. Levin, Department of Ecology & Evolutionary Biology, Princeton University

Title: Political Polarization, Social Behavior and the Dynamics of Infectious Diseases.
Abstract: We live in an increasingly polarized world, both domestically and internationally, and this polarization has consequences for our ability to address global problems, including infectious diseases. In this lecture, I will begin with discussion of trends and causes, explore the consequences for disease management, and conclude with some discussion of possible pathways to reducing polarization.

Maia Martcheva, Department of Mathematics, University of Florida

Title: Optimal Control of a Multi-scale HIV-Opioid Model.
Abstract: We introduce an HIV-opioid multi-scale immuno-epidemiological model. We fit the model to data. We apply optimal control theory to the immuno-epidemiological model by using four controls: treating the opioid use, reducing HIV risk behavior among opioid users, entry inhibiting antiviral therapy, and antiviral therapy which blocks the viral production. Two population level controls are combined with two within-host level controls. Comparing the two population level controls, we find that reducing the HIV risk of opioid users has a stronger impact on the population who is both HIV infected and opioid dependent than treating the opioid disorder. The within-host level antiviral treatment has an effect not only on co-affected population but also on HIV-only infected population. Our findings suggest that the most effective strategy for managing the HIV and opioid epidemics is combining all controls at both within-host and between-host scales.

Qing Nie, Department of Mathematics, Department of Developmental and Cell Biology, NSF-Simons Center for Multiscale Cell Fate Research, University of California - Irvine

Title: Systems Learning of Single Cells.
Abstract: Cells make fate decisions in response to dynamic environments, and multicellular structures emerge from multiscale interplays among cells and genes in space and time. The recent single-cell genomics technology provides an unprecedented opportunity to profile cells for all their genes. While those measurements provide high-dimensional gene expression profiles for all cells, it requires fixing individual cells that lose many important spatiotemporal information. Is it possible to infer temporal relationships among cells from single or multiple snapshots? How to recover spatial interactions among cells, for example, cell-cell communication? In this talk I will present our newly developed computational tools to study cell fate in the context of single cells as a system. In particular, I will show dynamical models and machine-learning methods, with a focus on inference and analysis of transitional properties of cells and cell-cell communication using both high-dimensional single-cell and spatial transcriptomics, as well as multi-omics data for some cases. Through their applications to various complex systems in development, regeneration, and diseases, we show the discovery power of such methods in addition to identifying areas for further method development for spatiotemporal analysis of single-cell data.

Glenn Webb, Department of Mathematics, Vanderbilt University

Title: Population Models of Epidemics with Infection Age and Vaccination Age Structure.
Abstract: A population dynamics epidemic model is developed that incorporates age of infection and age of vaccination. The model analyzes pre-symptomatic and symptomatic periods of an infected individual in terms of infection age. The model analyzes the efficacy of vaccination in terms of vaccination age. The model is applied to the 2003 SARS epidemic in Taiwan and the COVID-19 epidemic in New York State.

Jianhong Wu, Department of Mathematics and Statistics, York University, Canada

Title: The Role of Species Behavioural Utility in Multi-stability and Multi-waves of Infestation and Disease Transmission Dynamics.
Abstract: I will touch on two classes of delay differential equations/renewal equations arising from viral infection spread (during both acute phases and endemic phases) and tick-borne disease transmission in the respective populations. These equations involve components for individual behaviors, leading to renewal and delay equations governing the behavioural adaptation dynamics. I will talk about some preliminary results on the qualitative properties (multiple waves and multi-stability) of the disease spread and behavioural adaptation coupled systems.

Dongmei Xiao, School of Mathematical Sciences, Shanghai Jiao Tong University, China

Title: Analytical Study of the Stability of the Ecological Community with an Energy Landscape.
Abstract: A central topic in ecology is understanding the relationship between stability and complexity within ecological communities consisting of many interacting species. This relationship can be explored mathematically through the dynamics of models, often governed by first-order nonlinear differential equations, such as the generalized Lotka-Volterra system. This talk aims to analyze this relationship within the framework of an ecological energy landscape, which reflects the exchange of energy through food webs, growth, and reproduction. Our mathematical model incorporates the generalized Lotka-Volterra system with an additional small perturbation. We demonstrate that this model exhibits predominantly periodic or quasi-periodic orbits when the ecological energy landscape is represented by a Hamiltonian function. Notably, the analytical results regarding the stability of ecological communities are analogous to those observed in the N-body problem of solar system motion.

Invited Talks (alphabetical order)

Shangbing Ai, University of Alabama - Huntsville

Title: Traveling Wave Solutions for a Keller-Segel System with Nonlinear Chemical Gradient.
Abstract: In this talk we present new results on the existence of traveling wave solutions for a generalized Keller-Segel system. The system incorporates the nonlinear gradient response of the cells to the chemical signal (describing the chemotactic effect) and nonlinear and non-monotone degradation rate of the chemical signal. Using the geometric singular perturbation theory and the phase plane analysis, we establish the existence of a family of traveling wave solutions of the system and obtain the explicit necessary and sufficient condition for the maximal wave speed equal to the positive infinity. We also obtain an upper bound of the wave speed so that if the wave speed is smaller than this bound, then the corresponding wave profile of the chemical is strictly decreasing.

Dimitri Breda, University of Udine, Italy

Title: Sparse Identification of Nonlinear Dynamics for Delay and Stochastic Differential Equations.
Abstract: Recently, data-driven model discovery has emerged has a powerful approach to recover governing equations of dynamical systems from temporal data series [5]. In particular, the SINDy algorithm, initially proposed for learning the right-hand side of ordinary differential equations [4], has been extended and applied to diverse classes of problems, including delay differential equations [2,6,7] and stochastic (ordinary) differential equations [1]. In this talk we present a further development by proposing a new SINDy algorithm to address the case of stochastic delay differential equations [3]. The relevant MATLAB implementation is tested on several examples, including stochastic models with delay used to describe and investigate supply chains.

[1] Boninsegna, L., Nüske, F., and Clementi, C. (2018). Sparse learning of stochastic dynamical equations. J. Chem. Phys., 148, 241723.

[2] Bozzo, E., Breda, D., and Tanveer, M. (2024). Sparse identification of time delay systems via pseudospectral collocation, to appear on IFAC-PapersOnLine.

[3] Breda,D.,Conte,D.,D'Ambrosio,R.,Santaniello,I.,andTanveer,M.(2024).Sparse identification of nonlinear dynamics for stochastic delay differential equations. in preparation.

[4] Brunton, S.L., Proctor, J.L., and Kutz, J.N. (2016). Discovering governing equations from data by sparse identification of nonlinear dynamical systems. PNAS, 113(15), 3932–3937.

[5] Brunton, S.L. and Kutz, J.N. (2019). Data-Driven Science and Engineering – Machine Learning, Dynamical Systems, and Control. Cambridge University Press.

[6] Pecile, A., Demo, N., Tezzele, M., Rozza, G., and Breda, D. (2024). Data-driven discovery of delay differential equations with discrete delays, submitted.

[7] Sandoz, A., Ducret, V., Gottwald, G. A., Vilmart, G., and Perron, K., (2023). SINDy for delay-differential equations: application to model bacterial zinc response, Proc. Roy. Soc. Lond. A, 479:20220556, 2023.

Cameron Browne, University of Louisiana - Lafayette

Title: Emergence of Antibiotic Resistance in Stochastic Model of Bacterial Competition and Mutation during Drug Treatment.
Abstract: Based on published estimates in 2019, antimicrobial resistance (AMR)-associated illnesses killed more people than HIV/AIDS or Malaria. Understanding the evolution of AMR is critical for mitigating this issue. Mathematical models, including differential equations and Markov chains, have gained considerable attention for understanding this evolution. However, most existing models assume standing genetic variation or the introduction of a new bacterial strain from an external source and do not consider the possibility of random or drug-induced mutation of reference bacterial strains. Therefore, we propose a pharmacodynamics- based continuous-time Markov chain considering the emergence of a bacterial strain via random or drug-induced mutations during treatment. We reduce the model to a generalized birth–death process with immigration, explicitly capturing the stochasticity of de novo emergence of a resistant bacterial strain. The resulting analytical and numerical studies also offer insight into the evolutionary rescue of an organism in deteriorating environments. Further, we explore the effect of nutrient availability on antibiotic resistance and susceptibility. Using the

proposed model, we aim to facilitate decision analysis for AMR treatment, such as when to choose a biostatic or biocidal drug and use low or high doses. This is a joint work with Chimezie Izuazu, Department of Mathematics, University of Louisiana at Lafayette.

Sue Ann Campbell, University of Waterloo, Canada

Title: Dynamics of a Conservative Nutrient-Phytoplankton-Zooplankton Model with Diffusion and Spatio-Temporal delay.
Abstract: We study a diffusive nutrient-phytoplankton-zooplankton (NPZ) model with spatio-temporal delay. The closed nature of the system allows the formulation of a conservation law of biomass that governs the ecosystem. We formulate stability conditions for the equilibria for a general distribution of delays and analyze the Hopf bifurcations for a specific delay kernel. We show that diffusion predominantly has a stabilizing effect; however, if sufficient nutrient is present, complex spatio-temporal dynamics, both transient and long lasting, may occur.

Tianyu Cheng, York University, Canada

Title: Modelling the Impact of Precaution on Disease Dynamics and Its Evolution.
Abstract: In this work, by introducing the notion of the practically susceptible population, which is a fraction P of the biologically susceptible population, and assuming that the fraction P depends on the severity L of the epidemic and the level X of precaution of the public, and we propose a general framework model with the response level X involving the epidemic. We verify the well-posedness and confirm the disease's eventual vanishing for the framework model under the assumption that the basic reproduction number $R_0 < 1$. For $R_0 > 1$, when the precaution level X is taken to be the instantaneous best response function, the endemic dynamic is shown to be the dynamic of converging to the endemic equilibrium, while when the precaution level $X(t)$ is the delayed best response; the endemic dynamic can be either convergence to the endemic equilibrium, or convergence to a periodic solution. Our derivation offers a justification/explanation for the best response used in some literature. By replacing "adopting the best response" with "adapting toward the best response", we also explore the adaptive long-term dynamics.

Yulei Cheng, University of Alberta, Canada

Title: Free Habitat Boundaries Expand, Balance or Shrink for One Species and Two Species.
Abstract: We propose a novel free boundary problem to model the movement of two interacting species, predator and prey, based on an existing single-species model. The single-species boundary equation generalizes the classical Stefan problem. In our two-species model, the predator's habitat boundary shifts in response to the spatial distribution of the prey, resulting in a dynamic boundary influenced by prey density. This adjustment models the predator's movement toward areas with higher prey density. We examined the effects of various parameter changes on the model's outcomes through numerical simulations and obtained some conclusions from the mathematical analysis.

Stanca Ciupe, Virginia Tech

Title: Understanding Long-term Virus Dynamics: Lessons from Hepatitis B and HIV Infections.
Abstract: Understanding short and long-term viral dynamics following therapy or immune interventions can help uncover previously unknown feedback interactions and drug's mode of action. In this presentation, I will investigate short and long-term dynamics in hepatitis B viral infection following therapy with ARC-520, an RNA interference drug, in humans. Moreover, I will investigate long-term dynamics in non-human primates inoculated with SHIV and receiving no immune intervention, the HuAd5SIVGat/Tat vaccine, an PGT121 antibody infusion, or both antibody and HuAd5SIVGat/Tat vaccine. We study the effect of interventions by developing mathematical models of within-host dynamics and comparing them to patient/subject data. We examined biological hypotheses describing the different outcomes and propose mechanisms of action explaining post-intervention control. The results can help identify treatment markers of cure.

Troy Day, Queen's University, Canada

Title: A PDE Model for the Evolution of Epigenetically Inherited Drug Resistance.
Abstract: Epigenetic inheritance is the transmission of nongenetic material such as gene expression levels,

mRNA, and other biomolecules from parents to offspring. There is a growing realization that such forms of inheritance can play an important role in evolution. Bacteria represent a prime example of epigenetic inheritance because a large array of cellular components are transmitted to offspring, in addition to genetic material. For example, there is an extensive and growing empirical literature showing that many bacteria become resistant to antibiotics through such epigenetic inheritance. In this talk I will present a PDE model of such epigenetically inherited drug resistance and detail the predictions that it makes.
This is joint work with PhD student Chongming Li.

Guihong Fan, Columbus State University

Title: One Health Modelling for the Transmission Dynamics of West Nile Virus with Multiple Hosts.
Abstract: The One Health approach is a collaborative effort that considers the health of humans, animals, and the environment as an integrated whole. It has significant strategic meaning in the sense of disease control and prevention. For example, the West Nile virus has been detected in over 320 types of birds, two types of reptiles, and 25 types of mammals including human beings. There are numerous dynamical modelling studies for the transmission West Nile virus (WNv), but most of them ignore the impact of multiple hosts and their interaction. In this work, we formulate a system of delay differential equations to model the transmission of WNv with an emphasis on the impact of bird species diversity. We classify birds into n species and for each species, we define a competent index $D(\mathcal{R}_j)$ which is a function of species-specific basic reproduction number $\mathcal{R}_j$. We also find the basic reproduction number $\mathcal{R}_0$ for the model with n species of birds and explore the dynamics of the model. Study shows that under certain conditions, if you split the given number of total host into more species, it will decreases the basic reproduction number $\mathcal{R}_0$. But if a "super-spreader" has been added to the system, it will increase the basic reproduction number.
This is a joint work with Prof. Juan Li and Prof. Huaiping Zhu.

Teresa Faria, University of Lisbon, Portugal

Title: Extinction and Periodic Solutions for a Competitive Chemostat Model with Delays.
Abstract: We consider a chemostat system with discrete delays and periodic coefficients for the nutrient input and washout rate, modelling n species in competition. Sufficient conditions on the coefficients and consumption functions for the species are given, for both the extinction of the species and for the existence of n nontrivial and nonnegative periodic solutions. Further criteria guarantee that the system admits at least one strictly positive periodic solution.

Daozhou Gao, Cleveland State University

Title: Some Recent Progress on Epidemic Patch Models.
Abstract: Infectious diseases remain a serious threat to public health. For example, malaria alone caused 249 million cases and 608,000 deaths globally in 2022. Large disease outbreaks and even pandemics have become more frequent over the last two decades. One of the major reasons is massive human migration and tourism. Patch models play a crucial role in describing the geographical spread of infectious diseases in discrete spaces. In this talk, I will briefly report some of our research progress on modeling and analyzing epidemic patch models. These involve directly transmitted diseases and vector-borne diseases, Lagrangian and Eulerian movements, behavior change and trave frequency, disease persistence and prevalence, etc. This is based on numerous joint projects, including several with Shigui Ruan.

Antonio Mateus Barreto Gondim, University of Miami

Title: On the Geographic Spread of Chikungunya between Brazil and Florida: A Multi-patch Model with Time-delay.
Abstract: Chikungunya (CHIK) is a viral disease transmitted to humans through the bites of Aedes mosquitoes infected with the Chikungunya virus (CHIKV). CHIKV has been imported annually to Florida in the last decade due to Miami's crucial position as a hub for international travel, particularly from Central and South America including Brazil, where CHIK is endemic. This paper presents a comprehensive mathematical model for the geographic spread of CHIKV, incorporating pivotal factors such as human movement, temperature, vertical transmission, and time-delay. Central to the model is the integration of a multi-patch framework, considering human movement between endemic Brazilian states and Florida. We establish crucial correlations between the mosquito reproduction number Rm and the disease reproduction number R_0, thereby advancing

our understanding of CHIKV transmission dynamics in complex multi-patch environments. Through numerical simulations, validated with real population and temperature data, it is possible to understand the disease dynamics under many different scenarios and make future projections, offering crucial insights for devising effective control strategies.

Quentin Griette, Université Le Havre Normandie, France

Title: Continuous and Discontinuous Traveling Waves in a Hyperbolic Keller–Segel Equation.
Abstract: We describe a hyperbolic model with cell–cell repulsion with a dynamics in the population of cells. More precisely, we consider a population of cells producing a field (which we call "pressure") which induces a motion of the cells following the opposite of the gradient. The field indicates the local density of population and we assume that cells try to avoid crowded areas and prefer locally empty spaces which are far away from the carrying capacity. We describe the traveling wave solutions for this equation and in particular the sharp traveling waves that are identically zero after some point in space; we show that these waves are necessarily discontinuous and give and estimate of their speed. We also construct continuous traveling waves which have a speed that is strictly greater than the one of the sharp waves. Finally, we investigate the behavior of a related model with diffusion and show that the behavior of the vanishing viscosity solutions is consistent with the limit equation.

Hayriye Gulbudak, University of Louisiana - Lafayette

Title: Bistability in a Model of Hepatitis B Virus Dynamics.
Abstract: Understanding the mechanisms responsible for different clinical outcomes following hepatitis B infection requires a systems investigation of dynamical interactions between the virus and the immune system. To help elucidate mechanisms of protection, we developed a deterministic mathematical model of hepatitis B infection that accounts for cytotoxic immune responses resulting in infected cell death, non-cytotoxic immune responses resulting in infected cell cure and protective immunity from reinfection, and cell proliferation. We analysed the model and presented outcomes based on three important disease markers: the basic reproduction number R_0, the infected cells death rate δ (describing the effect of cytotoxic immune responses), and the liver carrying capacity K (describing the liver susceptibility to infection). Using asymptotic and bifurcation analysis techniques, we determined regions where virus is cleared, virus persists, and where clearance-persistence is determined by the size of viral inoculum. These results can guide the development of personalized intervention.

Xiaoying Maggie Han, Auburn University

Title: Dynamic and Probabilistic Analysis of the Lottery Model in Nonstationary Environments.
Abstract: This presentation will examine the effects of nonstationary environmental conditions on species coexistence through a multi-species lottery competition model. First, we develop a diffusion approximation and a nonautonomous stochastic differential equation (SDE) from a traditional discrete-time model. Then we focus on the dynamics and stability of solutions. Our findings identify the conditions necessary for species coexistence in changing environments, supported by numerical simulations that confirm our theoretical predictions. Our work expands ecological modeling by integrating variable reproductive and mortality rates, offering insights relevant to the study of ecosystems affected by environment change.

Wenrui Hao, Pennsylvania State University

Title: Data-Driven Modeling of Alzheimer's Disease.
Abstract: Alzheimer's disease (AD) affects over 5 million people in the United States, presenting an urgent public health challenge. Personalized treatment strategies offer a promising pathway for improving patient outcomes, yet they require innovative methods to analyze the growing body of electronic brain data. In this talk, I present a mathematical modeling approach to capture the progression of AD clinical biomarkers, integrating patient-specific data to enable personalized predictions and guide optimal treatment strategies. Our model will be validated using a multi-institutional dataset of AD biomarkers, offering tailored predictions for individual patients.

Daihai He, The Hong Kong Polytechnic University, China

Title: The Effectiveness of the COVID-19 Vaccination Campaign in 2021: Inconsistency in Key Studies.

Abstract: In this work, we revisited the evaluation of the effectiveness of the COVID-19 vaccination campaign in 2021, as measured by the number of deaths averted. The published estimates differ a lot: from one widely referenced paper by Watson et al. (2022) estimating 0.5-0.6% of the USA population being saved, to average-level estimates of 0.15-0.2%, and to some estimates as low as 0.0022%. For other countries, Watson et al. gave much higher estimates than all other works too.

We reviewed 30 relevant papers, carried out an in-depth analysis of the model by Watson et al. and of several other studies, and provided our own regression-based analysis of the US county-level data. The model by Watson et al. is very sophisticated and has many features; some of them that make it more realistic (age-structured epidemiology, "elderly first" vaccination, healthcare overload effects), but others that are likely inaccurate (substantial reinfection rates (i.e., immunity loss) for the Alpha and Delta variants, possible overfitting due to overly flexible time-dependent infection transmission rate) or questionable (45% increase in fatality rate for the Delta variant). Yet, the main argument is that Watson et al.'s model does not reproduce the trends observed in the county-level US data.

Eventually, we concluded that Watson et al.'s 0.5-0.6% is an overestimate, and 0.15-0.2% of the US population saved by vaccination – as estimated by regression studies on subnational-level data (e.g., Suthar et al. (2022) and by He et al. (2022)) – is much more plausible value. In our view, in order to be considered reliable, mathematical models should be tested on more detailed real data that was not used in model fitting. On the other hand, detailed data bring about new challenges in statistical modelling and uncertainties in data reliability.

Thomas Hillen, University of Alberta, Canada

Title: Mathematical Modelling of Microtube Driven Invasion of Glioma.
Abstract: Malignant gliomas are highly invasive brain tumors. Recent attention has focused on their capacity for network-driven invasion, whereby mitotic events can be followed by the migration of nuclei along long thin cellular protrusions, termed tumour microtubes (TM). Here I develop a mathematical model that describes this microtube-driven invasion of gliomas. I show that scaling limits lead to well known glioma models as special cases such as go-or-grow models, the PI model of Swanson, and the anisotropic model of Swan. I compute the invasion speed and I use the model to fit experiments of cancer resection and regrowth in the mouse brain. (Joint work with N. Loy, K.J. Painter, R. Thiessen, A. Shyntar).

Yu Jin, University of Nebraska-Lincoln

Title: A Time-Periodic Parabolic Eigenvalue Problem on Finite Networks and Its Applications.
Abstract: We investigate the eigenvalue problem of a time-periodic parabolic operator on a finite network. The network under consideration can support various types of flows, such as water, wind, or traffic. Our focus is to determine the asymptotic behavior of the principal eigenvalue as the diffusion rate approaches zero, or the advection rate approaches infinity, under reasonable boundary conditions that can be derived from ecosystems. Our results demonstrate that such asymptotics is primarily influenced by the boundary conditions at the upstream and downstream vertices of the network, rather than the geometric structure of the finite network itself provided that it is simple and connected. We then apply our results to a single-species population model and two SIS epidemic systems on networks and reveal the substantial impact of the diffusion and advection rates as well as the boundary conditions on the long-time dynamics of the population and the transmission of infectious diseases.

Christopher Kribs, The University of Texas - Arlington

Title: Impact of ADE and Dengue Vaccination with Screening on the Toll of a Dual Dengue-Zika Outbreak
Abstract: The tetravalent dengue vaccine Dengvaxia may prime dengue-seronegative vaccinees for antibody-dependent enhancement (ADE) of any subsequent dengue (in case of vaccine failure) or Zika infections. Many researchers associate ADE of such cases with more severe outcomes including death. This talk uses a mathematical model of transmission dynamics that distinguishes ADE and non-ADE cases for each virus, to identify the potential impact of a dengue vaccination campaign on the economic cost and disease burden of a dual dengue-Zika outbreak, under the hypothesis that severe outcomes are associated with ADE. Results indicate that when all dengue exposure is to a single serotype, in most cases vaccination increases both cost and burden because they are dominated by the high costs associated with complications from ADE Zika cases. However, if per-case ADE Zika costs are lower than estimated (a real possibility given the limited data available), sufficiently high

vaccination coverage can reduce total cost and burden substantially. Analysis also identifies variations across countries, dengue serotypes, and timeframes of evaluation.

King-Yeung (Adrian) Lam, Ohio State University

Title: On the Shape of Expansion of a Population in the Presence of a Fast Road.
Abstract: We consider the road-field reaction-diffusion model introduced by Berestycki, Roquejoffre, and Rossi. By performing a "thin-front limit," we are able to deduce a Hamilton-Jacobi equation with a suitable effective Hamiltonian on the road that governs the front location of the road-field model. Our main motivation is to apply the theory of strong (flux-limited) viscosity solutions in order to determine a control formulation interpretation of the front location. We then cast the ecological invasion problem as one of finding optimal paths that balance the positive growth rate in the field with the fast diffusion on the road. Along the way we provide a new proof of known results on the one-road half-space problem via our approach. This is joint work with Chris Henderson.

Xinfeng Liu, University of South Carolina

Title: Data-driven Mathematical Modeling, Computation and Experimental Investigation of Dynamical T-Cells with Tumor Growth.
Abstract: Solid tumors are heterogeneous in composition, and understanding the tumor growth kinetics is critical for development of novel strategies for cancer treatment. For this talk, I shall introduce mathematical modeling and computational exploration to study the dynamical interaction between T-cells and tumor cells, and our findings reveal that feedback loops are critical in controlling the balance between the population of tumor cells and that of T-cells and immune cells. Furthermore, the neural networks were introduced for data fitting of various mathematical models with experimental data.

Yijun Lou, The Hong Kong Polytechnic University, China

Title: Stage-structured Models with Stage Distributions and Intraspecific Competition.
Abstract: Stage structured models, by grouping individuals with similar demographic characteristics together, have proven useful in describing population dynamics. This talk presents two widely-used modeling frameworks, in the form of integral equations and age-structured partial differential equations. Both modeling frameworks can be reduced into same differential equation structures with/without time delays under Dirac and gamma distributions for the stage durations. Advantages and inherent limitations will be discussed. Further recent modeling studies will be presented when the stage duration distribution and survival probability are regulated by population density.

Jaqueline Mesquita, University of Brasília, Brazil

Title: Neutral FDEs with State-dependent Delays: Linearized Instability Principle.
Abstract: In this talk, we will present a version of the linearized instability principle for neutral FDEs with state-dependent delays and some applications.

Libin Rong, University of Florida

Title: Recent Developments in Modeling HIV Infection and Treatment.
Abstract: HIV infection remains a significant global public health challenge. While highly active antiretroviral therapy (HAART) effectively controls viral replication, complete eradication of the virus remains elusive. Mathematical models, integrated with experimental data, provide valuable insights into HIV infection dynamics, drug treatments, and immune responses. However, several key questions about HIV persistence despite long-term therapy remain unanswered. In this talk, I will outline recent modeling advancements aimed at addressing these questions and discuss their implications for managing HIV infection.

Gergely Röst, University of Szeged, Hungary

Title: Asymptotic Stability for Non-autonomous Linear Delay Differential Equations Representing Birth-Death Dynamics.
Abstract: We consider the fundamental non-autonomous linear scalar delay differential equation $x'(t) = -a(t)x(t) + b(t)x(t-\tau)$, with non-negative time-varying coefficients, representing the birth-death process of a population

with maturation delay. We review previous results for this equation, then we prove a new asymptotic stability result for the zero solution. We construct a specific class of examples showing that our conditions for population extinction are indeed complement all previous theorems in the literature.

Rachidi Salako, University of Nevada - Las Vegas

Title: Dynamics of Classical Solutions to a Diffusive Epidemic Model with Varying Population Demographics.
Abstract: We study the asymptotic dynamics of solutions to a diffusive epidemic model with varying population dynamics. The large-time behavior of solutions is completely described in spatially homogeneous environments. When the environment is spatially heterogeneous, it is shown that the magnitude of the ratio of the susceptible population diffusion rate over the infected population diffusion rate plays an important role on the structure of the endemic equilibrium (EE) solutions. Results on the asymptotic profiles of the EEs for small population diffusion rates will also be discussed. Our results shed some light on the differences on disease predictions for constant total population size models versus varying population size models.

Francesca Scarabel, University of Leeds, UK

Title: Numerical Stability and Bifurcation Analysis of Equations with Infinite Delay.
Abstract: Delay differential and renewal equations with infinite delay are widely used in mathematical biology, and in particular in ecology and epidemiology, to describe physiologically structured population models, in which the individual rates are assumed to depend on a structuring variable (e.g., age, size, time since infection) which evolves as a function of the individual's age.

We consider nonlinear delay differential and renewal equations with infinite delay and derive a finite-dimensional ODE approximating the equivalent abstract differential equation. We discuss the one-to-one correspondence of equilibria between the original and the approximating system, and the convergence of the characteristic roots as the dimension of the approximation increases, when the collocation nodes are chosen as the zeros or the extrema of the Laguerre polynomials suitably scaled. We show examples of applications from population dynamics, including new analyses on periodic outbreaks emerging from time-since-infection models with waning immunity.

This work is in collaboration with Rossana Vermiglio (University of Udine) and based on the publication: F. Scarabel, R. Vermiglio, Equations with infinite delay: pseudospectral discretization for numerical stability and bifurcation in an abstract framework, SINUM (2024).

Sebastian Schreiber, University of California - Davis

Title: Impacts of the Tempo and Mode of Environmental Fluctuations on Population Growth.
Abstract: Populations consist of individuals living in different states and experiencing temporally varying environmental conditions. Individuals may differ in their geographic location, stage of development (e.g. juvenile versus adult), or physiological state (infected or susceptible). Environmental conditions may vary due to abiotic (e.g. temperature) or biotic (e.g. resource availability) factors. As survival, growth, and reproduction of individuals depend on their state and the environmental conditions, environmental fluctuations often impact population growth. Here, we examine to what extent the tempo and mode of these fluctuations matter for population growth. We model population growth for a population with d individual states and experiencing N different environmental states. The models are switching, linear ordinary differential equations $x'(t) = A(\sigma(\omega t))x(t)$ where $x(t) = (x_1(t), \ldots, x_d(t))$ corresponds to the population densities in the d individual states, $\sigma(t)$ is a piece-wise constant function representing the fluctuations in the environmental states $1, \ldots, N$, ω is the frequency of the environmental fluctuations, and $A(1), \ldots, A(n)$ are Metzler matrices representing the population dynamics in the environmental states $1, \ldots, N$. $\sigma(t)$ can either be a periodic function or correspond to a continuous-time Markov chain. Under suitable conditions, there exists a Lyapunov exponent $\Lambda(\omega)$ such that $\lim_{t\to\infty} \frac{1}{t} \log \sum_i x_i(t) = \Lambda(\omega)$ for all non-negative, non-zero initial conditions $x(0)$ (with probability one in the random case). For both random and periodic switching, we derive analytical first-order and second-order approximations of $\Lambda(\omega)$ in the limits of slow ($\omega \to 0$) and fast ($\omega \to \infty$) environmental fluctuations. When the order of switching and the average switching times are equal, we show that the first-order approximations of $\Lambda(\omega)$ are equivalent in the slow-switching limit, but not in the fast-switching limit. Hence, the mode (random versus periodic) of switching matters for population growth. We illustrate our results with applications to a simple stage-structured model and a general spatially structured model. When dispersal rates are symmetric, the first order approximations suggest that population growth rates increase with the frequency of switching – consistent with earlier work on periodic switching. In the absence of dispersal symmetry, we demonstrate that

$\Lambda(\omega)$ can be non-monotonic in ω. In conclusion, our results show that population growth rates often depend both on the tempo (ω) and mode (random versus deterministic) of the environmental fluctuations. This work is in collaboration with Pierre Monmarché (Institut universitaire de France) and Édouard Strickler (Université de Lorraine).

Ousmane Seydi, Ecole polytechnique de Thiès, Senegal

Title: Linking Within- and Between-Host Scales for Understanding the Evolutionary Dynamics of Quantitative Antimicrobial Resistance.
Abstract: The growing threat of antimicrobial resistance (AMR) is a critical global health issue that continues to demand urgent solutions. While experimentalists and epidemiologists work to understand the spread of resistant bacteria, theoretical models are essential for linking within-host bacterial evolution with population-scale transmission dynamics. In this talk, I will present a nested model that integrates within-host bacterial resistance, modeled as a continuous quantitative trait, with between-host epidemic dynamics. By using integro-differential equations, the model captures the emergence of resistance at both scales. We will explore key results related to the persistence and stability of bacterial populations, alongside an investigation into how treatment strategies impact resistance levels and epidemic control.
This is a joint work with Martin L Mann-Manyombe, Abdoulaye Mendy, and Ramsès Djidjou-Demasse.

Chunhua Shan, University of Toledo

Title: Bifurcations of a Predator-Prey System with Holling Type Functional Response and Allee Effects.
Abstract: In this talk we consider the bifurcations of a predator-prey system with Holling type functional response and Allee effects. We investigate the maximal orders of nilpotent saddle, cusp singularity and weak focus for Holling type I, II, III and IV functional response. Furthermore, simple formulas are derived to characterize the order of nilpotent saddle, through which the existence and order of the heteroclinic loop can be easily obtained for a general class of predator-prey systems with any smooth functional response.

Wenxian Shen, Auburn University

Title: Front Propagation Dynamics in Fisher KPP Equations on Unbounded Metric Graphs.
Abstract: This talk is concerned with front propagation dynamics in Fisher KPP equations on unbounded metric graphs. Such equations can be used to model the evolution of populations living in environments with network structure. There are several studies on front propagation phenoman in bistable equations on unbounded metric graphs. It is known that, in such equations, the network structure of the underlying environment may block the propagation of the fronts. It will be shown in this talk that the network structure of the environments does not block the propagation of the fronts in Fisher-KPP equations. In particular, it will be shown that the Fisher-KPP equation on an unbounded graph with finite many edges has the same spreading speed c^* as the Fisher KPP equation on the real line $\mathbb{R}$ and has a generalized traveling wave connecting the stable positive constant solution and the trivial solution with averaged speed c for any $c > c^*$.

Junping Shi, College of William & Mary

Title: Seasonal Disease Models of Blue Crab Population in the Chesapeake Bay.
Abstract: The emergence of pathogens in marine systems affects us all by damaging fisheries and their supporting ecological communities. Climate change magnifies the disease spreading through direct and indirect effects on both the host and pathogen dynamics. A stage-structured epidemic model is constructed to study the impacts of density-dependent predation, cannibalism, fishing, and Hematodinium infection on the blue crab population in the Chesapeake Bay. It is shown that extinction, disease-free and disease-outbreak dynamics can occur under different parameter conditions, and the disease-outbreak could happen in different frequencies.

Zhisheng Shuai, University of Central Florida

Title: Lyapunov Function(al)s for Large-Scale Dynamical Systems.
Abstract: This presentation revisits Lyapunov function(al)s and their applications in large-scale dynamical systems, such as Professor Ruan's early study on connective stability (IEEE Trans. Autom. Control, 1988) and recent global stability results for heterogeneous population models. We highlight advancements and ongoing challenges in establishing global stability for both disease-free and endemic equilibria in infectious disease models.

Notably, recent progress in discrete-time epidemiological models provides promising insights that may guide future research directions.

Karen R Rios Soto, University of Puerto Rico - Mayaguez, Puerto Rico

Title: On the Spread of Ultrafine Particulate Matter: A Mathematical Model for Motor Vehicle Emissions and Their Effects as an Asthma Trigger.
Abstract: Asthma is a respiratory disease that affects the lungs, with a prevalence of 339.4 million people worldwide. Many factors contribute to the high prevalence of asthma, but with the rise of the industrial age, air pollutants have become one of the main Ultrafine particles (UFPs), which are a type of air pollutant that can affect asthmatics the most. These UFPs originate primarily from the combustion of motor vehicles and although in certain places some regulations to control their emission have been implemented, they might not be enough. In this work, a mathematical model of reaction–diffusion type is constructed to study how UFPs grow and disperse in the environment and in turn how they affect an asthmatic population. Part of our focus is on the existence of traveling wave solutions and their minimum asymptotic speed of pollutant propagation $c_{\min}$. Through the analysis of the model, it was possible to identify the necessary threshold conditions to control the pollutant emissions and consequently reduce the asthma episodes in the population. Analytical and numerical results from this work prove how harmful the UFEs are for the asthmatic population and how they can exacerbate their asthma episodes.

Sabrina Streipert, University of Pittsburgh

Title: Derivation and Analysis of Discrete Population Models with Distributed Delayed Growth.
Abstract: We introduce a class of discrete single species models with distributed delay in the reproductive process and a cohort dependent survival function that accounts for survival pressure during that delay period. These delay recurrences track the mature population for species in which individuals reach maturity after at least τ and at most $\tau + \tau_M$ breeding cycles. Under realistic model assumptions, we prove the existence of a critical delay threshold, $\widetilde{\tau_c}$. For given delay kernel length τ_M, if each individual takes at least $\widetilde{\tau_c}$ time units to reach maturity, then the population is predicted to go extinct. We show that the positive equilibrium is decreasing in both τ and τ_M. In the case of a constant reproductive rate, we provide an equation to determine $\widetilde{\tau_c}$ for fixed τ_M, and similarly, provide a lower bound on the kernel length, τ_M for fixed τ such that the population goes extinct if $\tau_M \geq \widetilde{\tau_M}$. We compare these critical thresholds for different maturation distributions and show that if all else is the same, to avoid extinction it is best if all individuals in the population have the shortest delay possible. We apply the model derivation to a Beverton–Holt model and discuss its global dynamics. For this model with kernels that share the same mean delay, we show that populations with the largest variance in the time required to reach maturity have higher population levels and lower chances of extinction.
This is a joint work with Gail S. K. Wolkowicz.

Qiuyi Su, York University, Canada

Title: A Method to Quantify Immunity Gained from Vaccine by Mathematical Modeling: A Case Study for SARS-CoV-2.
Abstract: In this talk, we introduce a method to quantify efficacy of immunity gained from vaccine. As an example, we apply TEIV and TEIVF Markov Chain in-host models to reproduce outcomes of the clinical trials for SARS-CoV-2 vaccine efficacy. With estimated and assumed parameters, the risks of infection for both unvaccinated and vaccinated individuals are calculated from simulation and theoretical approximation. Under different scenarios on immune response mechanism, we generate 1000 groups of 1000 individuals by sampling from certain parameters spaces and back calculate the distribution for immunity to achieve a vaccine efficacy of 95%. We then investigate the impact of all parameters on the risk of infection.

Marco Tosato, York University, Canada

Title: Impact of Deer Migration on Tick Population Dynamics.
Abstract: Ticks are the carriers of several vector-borne diseases worldwide. In the past few decades, they have been spreading northward across Canada and have reached areas that were originally tick-free. Ticks have a limited geographical range and cannot move independently over large distances, so they are usually carried around by feeding hosts. Among these hosts, deer play a relevant role since they tend to cover a large geographical range.

In this talk, we discuss how the interaction between deer mobility and tick populations may play a significant role in shaping tick dynamics. We suggest exploring the indirect effects of deer migration on tick populations using a coupled system of ordinary and delay differential equations in a two-patch environment. Our model includes adult tick and deer populations, investigating how deer movement alters patch suitability for ticks. We present model analysis, including the tick reproduction number, equilibria, stability, numerical simulations, and scenario and sensitivity analyses.

Necibe Tuncer, Florida Atlantic University

Title: Understanding Usutu Virus Dynamics: Effects of Data and Model Structure Across Biological Scales.
Abstract: Understanding the epidemiology of emerging pathogens, such as Usutu virus infections, requires systems investigation at each scale involved in the host-virus ecology, from individual bird infections, to bird-to-vector transmissions, to USUV incidence in bird and vector populations, and eventually to spillover probability in humans. For new pathogens wild data is sparse, and predictions are based on laboratory-type inoculation and transmission experiments combined with dynamical mathematical modeling. In this study, we developed a multiscale vector-borne epidemiological model of Usutu virus infection in birds and mosquitoes and used individual within-host viral load data and host-to-vector probability of transmission data to predict USUV incidence in bird and mosquito populations exposed to two different Usutu viral strains. We addressed the role of model structure, data uncertainty and optimal experimental design on model predictions. We found that within-host peak viremia does not always correlate with infection incidence levels in host and vector populations and that uncertainty in predictions at one scale may change predicted results at another scale. We showed that optimal experimental design and increased frequency of data collection vastly improves these correlations. The results may be useful for predicting spillover events.

Gonzalo Ricardo Robledo Veloso, Universidad de Chile, Chile

Title: Persistence and extinction scenarios in an almost periodic metapopulation with competition and habitat destruction.
Abstract: We study an almost periodic version of a metapopulation model developed by Tilman et.al, which generalizes the classical Levins approach by considering several species in competition affected by habitat destruction. The novelty is to assume that colonization and extinction rates are positive almost periodic functions while our main results show that the predominance of either colonization or extinction forces of a specific species is equivalent to the property of exponential dichotomy of a scalar linear differential equation. The use of classical results of exponential dichotomy allow us to carry out a recursive and exhaustive description of persistence/extinction scenarios. In addition, we start a preliminary discussion describing a more elusive behavior when the colonization and extinction forces are similar.

Rossana Vermiglio, University of Udine, Italy

Title: Approximating Reproduction Numbers for Age-Structured Models.
Abstract: Reproduction numbers for age-structured models are typically defined as the spectral radius of operators acting on infinite-dimensional spaces. As a result, their analytical computation can be a quite hard task, especially without imposing further restrictive assumptions on the model coefficients - such as the separability of age-specific transmission rates. This difficulty highlights the need for efficient numerical methods.

In the talk, I will present a general numerical method for approximating reproduction numbers for a class of age-structured models with finite lifespan. The approach is based on on the pseudospectral discretization of the relevant operators, and introduces a significant flexibility in selecting the "birth/infection" and "transition" processes. This novel feature enables to approximate various reproduction numbers, including the commonly used basic and type reproduction numbers.

The advantages of the method will be illustrated through some examples from infectious disease modeling, exploring different interpretations of the age variable (e.g., demographic age, infection age, disease age) and various transmission terms (e.g., horizontal and vertical transmission).

This is a joint work with Francesca Scarabel, University of Leeds (Great Britain), and Simone De Reggi, University of Udine (Italy).

Christopher Walker, Leibniz University Hannover, Germany

Title: The Principle of Linearized Stability in Age-Structured Diffusive Populations.

Abstract: The principle of linearized stability is established for a classical model describing the spatial movement of an age-structured population subject to nonlinear death and birth processes. It is shown that the real parts of the eigenvalues of the corresponding linearization at an equilibrium determine the latter's stability or instability. The key observation is the eventual compactness of the semigroup associated with the linearized problem.

Xiang-Sheng Wang, University of Louisiana - Lafayette

Title: Periodic Solutions of Switching Scalar Dynamical Systems.
Abstract: In a recent paper published in Journal of Differential Equations 354 (2023), pages 237–263, Professor Ruan and collaborators explored the periodic dynamics of a single species model with seasonal Michaelis-Menten type harvesting. They established the global asymptotic stability of the trivial zero solution and a unique periodic solution under specific conditions on the model parameters. This talk seeks to extend their findings to a general switching scalar dynamical system. We first present a criterion to determine the stability of periodic solutions, deriving the conditions under which a periodic solution is locally asymptotically stable, globally asymptotically stable, or unstable. Next, we develop theorems to count the number of periodic solutions and identify the basins of attraction for both the periodic solutions and the trivial solution. Our general theorems not only unify and simplify existing results, but also yield new, comprehensive dynamical insights, including the bistability of the periodic and trivial solutions.

Xueying Wang, Washington State University

Title: Multiscale and Multi-Strain Modeling Approaches to COVID-19 Dynamics.
Abstract: COVID-19 has posed significant global public health challenges, driving the need for mathematical modeling to understand its transmission and control. This talk will cover two areas of modeling work related to COVID-19. The first part introduces a multiscale modeling framework that integrates both within-host and between-host dynamics, encompassing various transmission routes (human-to-human and environment-to-human) across population and individual levels. The analysis uncovers complex dynamics and emphasizes the environment's crucial role in transmission. While antiviral treatments may delay outbreaks, they cannot prevent them, highlighting the necessity of environmental control measures alongside human-to-human interventions, such as social distancing and mask-wearing. The second part presents a multi-strain model to examine how asymptomatic or pre-symptomatic infections influence strain transmission and control strategies. Results show that Omicron variants are more transmissible yet less fatal than earlier strains, and implementing mask mandates before the peak can mitigate and delay it, with the timing of lifting mandates impacting subsequent waves.

Joanna Wares, University of Richmond

Title: How Working with Dr. Shigui Ruan Taught Me to Love Population Dynamics (and Collaboration).
Abstract: If you are lucky enough to have worked with our been friends with Shigui Ruan, then you know how delightful it is to work with a warm genius biomathematician. This talk traces my research journey in population dynamics, from early collaborations with Dr. Ruan to current investigations. Our initial work examined disease transmission in healthcare settings, with particular emphasis on the role of antibiotic use in bacterial resistance. Building on these foundations, my recent research applies differential equations to model population dynamics in the context of the opioid epidemic with a focus on treatment efficacy. Throughout this progression, Dr. Ruan's pioneering contributions to biomathematics have remained a continuing source of inspiration.

James Watmough, University of New Brunswick, Canada

Title: Multi-scale, Host-based Network Models of Immune Landscapes.
Abstract: The progression and burden of disease outbreaks, and biological invasions more generally, is complicated by heterogeneities in the host population and its environment. There are two sides to this heterogeneity: the risk of infection or transmission, and the cost of disease. For the particular case of SARS-CoV-2 and CoViD, transmission risk is raised or lowered by host behaviour and by host immune history. Familiar aspects of the former being masking and isolation, and of the latter being the time lapsed since vaccination or past infections. Host behaviour and immune history also affect disease risk as does age (through immunosenescence) and various comorbidities. The main objective of this talk is to present preliminary results from simple compartmental and individual-based models designed to predict population-level disease burden and immune landscapes from host behaviour and within-host virus and immune dynamics.

Gail S. K. Wolkowic, McMaster University, Canada

Title: Decay Consistent Models of Growth, Competition, and Predation.
Abstract: Incorporating delay in various models of population interactions will be explored including competition and predation. In all of the models, any terms representing growth of a population take into consideration that individuals that do not survive, do not contribute to the growth of the population. The models are formulated so that survival is consistent with the decline terms in the model.

Yixiang Wu, Middle Tennessee State University

Title: On Degenerate Reaction-Diffusion Epidemic Models with Mass Action or Standard Incidence Mechanism.
Abstract: We consider reaction-diffusion epidemic models with mass action or standard incidence mechanism and study the impact of limiting population movement on disease transmissions. We set either the dispersal rate of the susceptible or infected people to zero and study the corresponding degenerate reaction-diffusion model. Our main approach to study the global dynamics of these models is to construct delicate Lyapunov functions. Our results show that the consequences of limiting the movement of susceptible or infected people depend on transmission mechanisms, model parameters, and population size.

Yanyu Xiao, University of Cincinnati

Title: Impact of Pulse Controls on a Network Model.
Abstract: We examined the transmission of some preventive infectious diseases via a network model with pulse control strategies. We derived the threshold and gained the persistence of the disease with additional restriction.

Linhao Xu, University of Miami

Title: Spatial Patterns as Long Transients in Submersed-Floating Plant Competition with Biocontrol.
Abstract: A cellular automata model was developed and parameterized to for the general purpose of testing the effectiveness of application of biological control insects to water hyacinth (*Pontederia crassipes*), which is an invasive floating plant species in many parts of the world and outcompetes many submersed native aquatic species in southern Florida. In the model, *P. crassipes* is allowed to compete with the native submersed species, Nuttall's waterweed (*Elodea nuttallii*). In the absence of biocontrol acting on the *P. crassipes*, *E. nuttallii* excluded *P. crassipes* at low concentrations of the limiting nutrient (nitrogen), and the reverse occurred at high nutrient concentrations. At intermediate values, alternative stable states could occur; either *P. crassipes* alone or a mixture of the two species. We found that adding a biocontrol agent, based on the biology of the weevil *Neochetina eichhorniae*, dramatically altered system dynamics. Model parameters for plant growth rates, competitive interactions of the plants, the dynamics of the biocontrol agent, and nutrient diffusion rates were varied to study the effects of these factors. For example, there was an initial rapid reduction of the *P. crassipes*, after which the system with evolved over time to a regular striped pattern of moving spatially alternating stripes of *P. crassipes* and *E. nuttallii.* In some simulations the pattern was suddenly replaced by an irregular temporally varying pattern that lasted indefinitely. Thus, the striped pattern is an example of a long transient. The irregular spatio-temporal pattern that replaces it appears to be permanent, though that has not yet been established. Despite the unexpected striped patterning, the biocontrol agent was able to substantially reduce the biomass of water hyacinth.
The emergence of regular spatial patterns and of long transients are important current areas of study in ecology and other scientific disciplines because they provide valuable insights into the underlying processes and dynamics of complex systems. Striped patterns, alternating patches of high and low vegetation biomass or biocontrol, can be indicative of specific ecological dynamics. They may represent signal competition, predation, or other interactions among species or populations. Understanding the formation of these patterns helps ecologists unravel the underlying ecological processes.
This is a joint work advised by Professor Donald L. DeAngelis, U.S. Geological Survey, Wetland and Aquatic Research Center, 3321 College Avenue, Davie, FL, USA 33314.

Yuan Yuan, Memorial University of Newfoundland, Canada

Title: Dynamics in a General Discrete Predator-Prey Model with Fear Effect.
Abstract: This study examines the dynamics of a discrete predator-prey model incorporating the fear effect. Initially, we introduce the impact of fearfulness for the prey in a general discrete predator-prey model, then

analyze the dynamical properties, including the existence of the fixed points, their local stabilities, and possible bifurcations, by using bifurcation theory and the center manifold theorem. We provide sufficient conditions for the system to undergo a flip bifurcation and a Neimark-Sacker bifurcation at the positive fixed point, by taking the degree of fear as the bifurcation parameter. Furthermore, we establish the criteria for the stability of the bifurcated periodic orbits and the invariant curves. The theoretical findings are validated through numerical simulations, which reveal that the fear effect enhances the stability of the predator-prey system within a specific range.

Guangyu Zhao, University of Nevada - Las Vegas

Title: When Small Fractional Powers Matter: How a Competitive Exclusion Occurs.
Abstract: This talk presents our recent study on the role of fractional powers in Lévy flight foraging via a Lotka-Volterra model subject to Lévy flight diffusion. The model was used to examine the factors contributing to both competitive exclusion and coexistence. One plausible biological implication of our analysis is that smaller fractional powers tend to forge the winner of interspecific competition in which two competing species occupy the same niches. The talk also addresses the interplay between fractional powers and competition coefficients, as well as the bifurcation analysis of coexistence states.

Xiaoqiang Zhao, Memorial University of Newfoundland, Canada

Title: Basic Reproduction Numbers for Biological Evolution Systems
Abstract: In this talk, I will first give a brief review of basic reproduction numbers (ratios) R_0 for evolution systems in population biology. Then I will report our recent research on the theory of R_0 for abstract functional differential equations (FDEs), and in particular, derive a general formula of R_0 for FDEs on finite dimensional space. For an illustrative purpose, I will also discuss a time-delayed model of black-legged ticks and a nonlocal spatial model of within-host viral infections.

Xinyue Zhao, University of Tennessee - Knoxville

Title: Optimal Control of Free Boundary Models for Tumor Growth.
Abstract: In this talk, we will investigate the optimal control of treatment in free boundary PDE models for tumor growth. The goal of the optimal control strategy is to inhibit tumor growth while minimizing side effects. We will prove the existence of an optimal control, derive the optimality system, and present a necessary condition for the optimal control. Numerical simulations will be shown to illustrate the theoretical findings and to assess the impact of the optimal control strategy on the dynamics of tumor growth.

Participant List

Don DeAngelis	University of Miami
Peng Feng	Florida Gulf Coast University
Abba Gumel	University of Maryland, College Park
Jaffar Ali Shahul Hameed	Florida Gulf Coast University
Fan Zhang	Bentley University