Nontechnical Research Statement

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The focus of my research is to develop and analyze mathematical models that investigate the behavior of systems in biology and ecology. I am particularly interested in the collective behavior of small organisms such as plankton, addiction dynamics (including control strategies), species-environment interactions, and how population demographics can change over time in response to external drivers and community structure.

The following projects have been key focuses of my work in the last five years. Building on my postdoctoral work at UNC Chapel Hill, I have developed new theoretical and data-driven results related to opioid use disorder epidemiology. With my collaborators, we published the first ordinary differential equation model of prescription opioid use disorder in 2019 and later extended this model to heroin and fentanyl in 2021 based on Tennessee data. More recently, we have been further developing the background mathematical theory for these and future models while exploring results for optimal control strategies.

Using agent-based and partial differential equations approaches, my collaborators and I modeled collective motion in Australian plague locusts based on field and experimental data. This work advanced theory on how locusts swarm by exploring the relationship between swarm pulse shape and resource availability.

In further work on agent-based modeling, I recently (2022) authored an agent-based modeling software library called *Planktos* geared at understanding how small organisms in fluid flow interact with each other, nearby structures, and their environment. Applications of this work include better understanding the resultant structure, behavior, and potential resilience to climate change of certain predators of plankton (e.g. coral and jellyfish), and quantifying how small organisms search their environment for often similarly-small resources and targets while navigating non-trivial fluid flows. In the latter case, I am particularly interested in parasitoid wasps, which are critical organisms for agriculture, and my work in that field extends beyond agent-based modeling to research on stochastic processes.

I am also interested in studying how bees respond to environmental stressors. Mathematical modeling has emerged as a promising tool to compliment empirical work in the study of Colony Collapse Disorder, and recent work with my graduate student, David Elzinga, has successfully combined many previous modeling efforts of the last decade while revealing nuances behind how sub-lethal stressors and the timing of those stressors can lead to colony collapse through a process known as hive abandonment.

Finally, I also have conducted research in the use of modeling to better understand tree composition in savanna systems resulting from human interaction, weather patterns, and fire. The latest such effort was focused on non-lethal harvest of African mahogany in Benin.

The mathematical approach I use to study each of these problems is highly motivated by the scientific setting and can involve a diverse range of topics including scientific computing, probabilistic modeling, network theory, dynamical systems, optimal control, and Bayesian model selection. The modeling approach I use is based on principles of analytical tractability and broad scientific utility with a focus on theory development. My methods are often computational and aim to provide results that can be compared to and informed by data. As a result, I also utilize certain aspects of data science including managing different data formats, carrying out data manipulation and analysis in Python, or visualizing 3D spatial-temporal results. Throughout the research process, I often collaborate closely with scientists to ensure that my work is contextually relevant and provides new, actionable insight into the biological problem at hand.