You are invited to attend the presentation of the

Final PhD Examination of
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Date September 21, 2021
Time 2:00 pm
Location Zoom link

https://ualberta-ca.zoom.us/j/96271181727?pwd=WENjRmVPdjhLMFhUSnlxSWNUbU0rdz09

Modelling phytoplankton across many scales: transient dynamics, human interactions, and niche differentiation in the light spectrum

In recent decades freshwater lakes have seen an increase in human presence. A common byproduct of this human presence is anthropogenic nutrient pollution resulting in eutrophication, a term that is becoming all too synonymous with harmful algal blooms. It is well known that phytoplankton require both light and nutrients for growth but their dynamics are ecologically complex with dependencies on lake characteristics and resource dynamics. In this thesis, I take a holistic approach towards understanding the complexities of phytoplankton dynamics and their dependencies on resource dynamics, niches, and human interactions.

I first introduce concepts relevant to the study of phytoplankton dynamics including a background on phytoplankton and lake characteristics, ecological stoichiometry, human environmental systems and a brief overview of singular perturbation theory, stability and bifurcation theory, and monotone dynamical systems theory. In the second part I gain insight towards the transient dynamics of phytoplankton. I study a stoichiometrically derived model for cyanobacteria dependent on phosphorus and light availability. There is natural separation of time scales between the internal nutrient dynamics and growth dynamics. The internal nutrient dynamics are much faster allowing for the utilization of multi-scale analysis to gain an in-depth mechanistic understanding of the transient dynamics.

In the third part I couple a well-studied stoichiometric cyanobacteria model to a socio-economic model for describing human-ecosystem interactions. The socio-economic model considers two strategies humans assume, to be environmentally friendly by lowering anthropogenic nutrient inputs into a lake, or the opposite. Various costs related to social ostracism, social norms, financial burden, and environmental concern of cyanobacteria influence how the population behaves. The coupled model exhibits bistable dynamics in the case of a single lake, with one stable state corresponding to the environmentally friendly state with low cyanobacteria abundance, and the other to high pollution rates and high cyanobacteria abundance. Furthermore, I consider a network of lakes connected via social interactions and show tristability of three network regimes corresponding to high cooperation, low cooperation, and mixed levels of cooperation throughout the network. In each case I show the potential for regime shifts between levels of cooperation and cyanobacteria abundance based on costs associated with social ostracism, social pressure and concern for cyanobacteria.

In the fourth part I offer support for the hypothesis that niche differentiation in the light spectrum is an explanation of the paradox of the plankton. The paradox of the plankton highlights the contradiction between the competitive exclusion principle and the observed diversity of phytoplankton. By explicitly considering the visible light spectrum I can treat light as a continuum of resources rather than a single resource. I propose a spatially explicit reaction-diffusion-advection model to explore under what circumstances coexistence is possible from mathematical, numerical and biological perspectives with a focus of niche differentiation. Furthermore I consider realistic scenarios of phytoplankton competition and water turbidity and show how the model helps to explain the paradox of the plankton.

Finally, I summarize key results and discuss their implications in the literature. I discuss some limitations of the modelling efforts and provide suggestions for areas of future work based on the current state of knowledge.