Preventing Culture Crash Trajectories through Pre-Emergent Pest Detection and Process Control in Mixed Microalgae Cultivation

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The overarching goal of the proposed project is to advance the stability of high-productivity, mixed community microalgal cultivation systems by developing holistic crop protection strategies that minimize culture crash (i.e., upset) events due to pests. This project will tackle a critical barrier to scaling and intensification of mixed community algal biomass production – the inability to consistently maintain stable cultures with high areal productivity due to invasive and deleterious bacterial, fungal, and zooplankton pests. This barrier stems from a lack of understanding of how pests upset algal processes through microalgal community turnover that undercuts areal productivity and process stability.

To overcome this barrier, the proposed research will leverage the EcoRecover process, an intensive mixed algal cultivation system for wastewater treatment, to develop mechanistic insights on algae-pest interactions and to develop monitoring and process control strategies to mitigate the impact of pests. This project will enable our team to develop innovative algal crop protection strategies that leverage real-time autonomous imaging, integrated 'omics, process modeling, and deep learning for early (i.e., pre-emergent) pest detection and proactive process control to correct culture upset trajectories and maintain high areal productivities. While our focus is on mixed algal communities treating wastewater, insights from this project will advance understanding of operational and environmental factors that drive algae-pest dynamics; these insights will be applicable across pure culture and polyculture cultivation systems.

The objectives of the proposed research plan are (1) ***to identify pre-emergence factors that predict culture upset trajectories, (2) to enable real-time monitoring of pest-induced algal phenotypic changes, and (3) to develop and implement a pre-emergent pest detection and control strategy to guide culture trajectories to maintain process performance and stability***. These objectives will be accomplished by integrating data from long-term monitoring of an existing full-scale EcoRecover process with systematic laboratory-scale experiments, novel approaches for real-time algal phenotyping with ARTiMiS (the autonomous real-time microbial scope), process modeling, techno-economic analysis, life cycle assessment, and multi-scale testing of process controls for mixed community culture trajectory correction.

Key outcomes of this work include the development of (1) framework for pre-emergent detection of pests, (2) an open-source process simulator for algal-pest dynamics, (3) the generation of pest/algae integrated 'omics data, and (4) a low-cost monitoring platform for the real-time detection of algal-pest community dynamics and algal phenotype-based early detection of pest contamination across algal crops and cultivation strategies.