A Trait Based Dynamic Energy Budget Approach to Explore Emergent Microalgal-Bacterial Dynamics and Productivity

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Project Goals: The LLNL Biofuels SFA seeks to support robust and sustainable microalgae fuel production through a systems biology understanding of algal-bacterial interactions. We hypothesize that by understanding the factors that control cellular physiology and biogeochemical fluxes in and out of algal cells, particularly through the phycosphere, we can advance the efficiency and reliability of algal biofuel production. Our research includes studies of beneficial traits of phycosphere-associated bacteria, systems biology studies of model algae, and genome-enabled metabolic modeling to predict the interspecies exchanges that promote algal growth, lipid production and healthy co-cultures. Our overall goal is to develop a comprehensive understanding of complex microbial communities needed to advance the use of biological properties for practical energy production.

URL: http://bio-sfa.llnl.gov/

Research has been underway for decades to realize the full potential of algal biofuels at the commercial scale; however, open pond algal monocultures are frequently subject to collapse due to a range of factors including microalgal grazing, pathogens and parasite invasions. Recently, it has been proposed that functionally diverse microalgal-bacterial communities can achieve higher biomass and/or lipid yields, and exhibit greater resistance to invasion relative to monocultures. Similar positive diversity-productivity relationships have been observed in a wide range of ecosystem studies, but the purposeful maintenance of a diverse microbiome is less common in managed systems.

In order to explore the relationship between microalgal functional diversity, bacterial-algal interactions, and pond productivity we have developed a trait-based dynamic energy budget model to explore emergent microalgal community structure under various environmental (e.g. light, nutrient availability) conditions. We reduced the complex algal community into functional groups (guilds). Each algal guild is characterized by a distinct combination of physiological traits (e.g. nutrient requirement, substrate affinity, growth rate) constrained by biochemical trade-offs. The trait values (i.e. relating to light, N and P harvesting) follow those from the literature. Trait values relating to N and P harvesting kinetics show allometric scaling as shown in previous studies. Trade-offs between maximum uptake rate and substrate affinity also follow known relationships.

We have explored competition between algal guilds, distinguished by light harvesting kinetic traits, using Monte Carlo simulations under constant light intensity and nutrient influx conditions. Simulations of reconstructed guilds showed that the dominant guilds to be functionally similar to Diatoms and Haptophytes, consistent with literature observations. A second suite of Monte Carlo simulation was conducted, where N and P harvesting traits distinguished the competing algal guilds. Simulations were conducted across N and P input gradients, and under constant light. Results demonstrate that higher N and P inputs are correlated with higher productivity of the system. Across the nutrient gradients, the Diatom guild consistently exerts dominance due to their larger cell size and higher maximum uptake rates. Further simulations are underway to explore these relationships under variable environmental conditions (diurnal light and temperature profiles, nutrient pulses) and in the presence of phycosphere bacterial associates that alter nutrient flux.

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