2022_64_DoLS_Pawar: Assembling Functionally Stable Microbial Communities Under Fluctuating Environments

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Microbes (Prokaryotes and Fungi) play a dominant role in carbon and nutrient cycling globally by decomposing organic matter in aquatic as well as terrestrial ecosystems. Therefore, understanding how microbial communities assemble and function in nature is among the foremost challenges in ecology. However, these communities are extraordinarily complex with myriad interacting species, and our ability to predict their dynamics in the face of environmental changes, especially, short-term temperature fluctuations and longer-term climatic warming, is severely limited. The goal of this PhD project is to develop a novel modelling framework to predict the assembly and stability of microbial communities over time in thermally-fluctuating environments. Some key questions that may be addressed are:

1. What combination of resource competition and cooperation through cross-feeding on metabolic by-products (species interaction structure) guarantee functionally stable communities in a given thermal regime?

2. How does temperature change affect the stability of community-level species interaction structure over time?

3. What species functional capabilities (traits) and interaction structures maximize functional stability in the face of directionally changing or fluctuating environmental temperatures?

The student will take the novel approach of combining metabolic (biochemical) network and ecological community theories. This entails the merger of genome-scale stoichiometric modeling of microbial metabolic networks with models of consumer-resource dynamics to more accurately capture community dynamics under different resource availability and temperature conditions. The model will be applied to data from laboratory experiments, testing predictions about which microbial strains are likely to coexist in a shared environment based on their functional traits, and the resultant effects on community respiration rate, metabolite production, and population abundances. Respiration quantifies the carbon processing rate of the community and is a crucial factor in ecosystem and global carbon cycles. Metabolite production reflects the functional composition of the community. Total abundance reflects secondary productivity (capture carbon ability) of the community while strain-level abundances and covariances between them reflect how distinct metabolic strategies interact to produce community function. Successfully developing such an integrated, mechanistic modelling framework holds great potential to reveal general ecological rules, and will be a significant step towards predicting the effects of climate change on ecosystem functioning, with applications in ecosystem conservation, restoration and engineering, as well as microbiome research.

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