Imperial College London

Natural Environment Research Council

2024_52_DoLS_SP: Assembling Functionally Stable Microbial Communities Under Fluctuating Environments

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Microbes, and in particular, Bacteria, Archaea 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 merge Genome-scale Models (GEMs) and ecological theory to predict the assembly and stability of microbial communities 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 maximise functional stability in the face of directionally changing or fluctuating environmental temperatures?

The student will take the novel approach of merging genome-scale stoichiometric modelling of microbial metabolic networks with consumer-resource dynamic theory to predict community dynamics under different temperature and resource conditions. The model will be implemented as a software package, and 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. 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 and engineering.

This project, a collaboration of the Pawar (http://www.pawarlab.org/), Kontoravdi (https://shorturl.at/flu58), Chachuat (https://shorturl.at/hrtPV) and Ledesma-Amaro (https://www.rlalab.org/) Labs at Imperial's College with ConcertBio (https://www.concert.bio). We seek a researcher excited to combine mathematical modelling with empirical data. Depending on the student's interests, different degrees of balance can be struck between the theoretical and empirical components of this study. The student will receive advanced training in 6 of the 15 “most wanted skills” identified in NERC's 2012 report: Modelling, Multi-disciplinarity, Data Management, Numeracy, Microbiology, and Risk and Uncertainty. Additionally, the SSCP DTP program (https://shorturl.at/aE258) within which this project is embedded, will provide the student with awareness of and training in how to tackle issues relating to Earth and the environment through bespoke courses, networking events and internship opportunities in NGOs and companies (including our CASE Partner, ConcertBio and external collaborator, the DIIEM group in INRAE, France (https://shorturl.at/wyW12)).