Report

The adaptive capacity of multitrophic plankton communities in a changing ocean (ADACAP – Subproject 19 – DFG-SPP1704 DynaTrait Phase I)

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Trait-based approaches have emerged as a paradigm shift in community ecology. In contrast to the classic taxonomic-based approach, the trait-based perspective focuses investigations on organismal traits. Typical areas of enquiry include (1) how traits relate to one another and (2) how traits interact with the environment. This has led ecologists to interpret communities as adaptive entities, which adjust their traits towards those that tend to maximize (on average) community fitness under a particular set of environmental conditions. In turn, these communities alter the environment thus changing the selection pressure and consequently leading to a shift in organismal trait values towards those that maximize fitness in the new environment. However, the general mechanisms underpinning the trait-environment feedback are unclear, although, they are important to understand the changes observed in the structure and functioning of phytoplankton communities under changing environmental conditions. This is particularly relevant for marine planktonic communities since evidence is accumulating on the way climate change drives shifts of planktonic communities towards organisms with smaller sizes, with major implications to the global carbon cycle and the structure of marine food webs.

Ecosystem models are crucially important tools for the quest aiming at addressing this knowledge gap. Particularly important is the development of models that allow us to capture the adaptive responses of diverse communities. At the same time, these models need to be able to that capture the plankton biodiversity patterns observed in the ocean. Existing methods that capture the adaptive responses of planktonic communities have adopted the “adaptive dynamics” mathematical framework (Wirtz & Eckhardt 1996; Norberg *et al.* 2001; Merico *et al.* 2009) in which communities are described as “collections of types distributed over the trait space”(Follows & Dutkiewicz 2011).

During the first phase of Dynatrait, as part of our ADACAP project, we develop an adaptive dynamics model with the aim of investigating how plankton communities assemble in regions of the ocean characterised by environtentally contrasting features, e.g. tropical *versus* temperate regions (Acevedo-Trejos *et al.* 2014, 2015). In parallel to our project, a novel modelling method, that extended the existing implementation of adaptive dynamics models (Wirtz & Eckhardt 1996; Norberg *et al.* 2001; Merico *et al.* 2009), was proposed (Merico *et al.* 2014). This new method assumes that the adaptive capacity of phytoplankton is associated to an intrinsic physiological process, i.e. a trait-mediated reproduction, rather than being based on an arbitrarily fixed trait variance (Wirtz & Eckhardt 1996) or on an unspecified external source of trait variance (Norberg *et al.* 2001; Merico *et al.* 2009). As part of ADACAP, we also developed a new modelling framework, called PhytoSFDM (Acevedo-Trejos *et al.* 2016) that describes the phytoplankton community in terms of three macroecological properties: total biomass, mean cell size, and size diversity (linked to size variance). In addition, in PhytoSFDM, we implemented different ways to calculate size diversity based on adaptive dynamics methods mentioned above. The different model variants can be easily applied to different locations of the ocean. In the effort of fostering reproducibility, transparency, and flow of ideas, we openly shared the code with the broad modelling community (GitHub, https://github.com/systemsecologygroup/PhytoSFDM) so that it can be used, modified, and redistributed freely.

Using PhytoSFDM and high-resolution observations of phytoplankton size spectrum along the Atlantic Meridional transect, we investigated how the size composition of phytoplankton communities and its relationship to primary production and export. We found that the main mechanism behind these macroecological patterns is an environment mediated trade-off between the acquisition of nutrients by small cells and the reduced vulnerability of larger cells to predation (Acevedo-Trejos *et al.* 2018).

In addition, during the course of our Dynatrait project, we contributed to two articles lead by our external collaborator Lan Smith. On the first one, a model that combines one tradeoff for growth and another for nutrient uptake is implemented following the optimality assumption (intracellular resources are dynamically allocated by phytoplankton to maximise growth rate). The model captures the acclimation response of phytoplankton in two environmentally contrasting locations of the north Pacific ocean (Smith *et al.* 2015). The second contribution focuses on the effect of disturbances on size diversity and productivity relationship. The theoretical observations suggest a stronger diversity productivity relationship as the mean size and environmental perturbation increase (Smith *et al.* 2016).

References

(in **bold face** are highlighted our main topic related contributions generated during the project)

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