DynaTrait Subproject 1.20: "Diversity effects of trait-based zooplankton feeding interactions in a global ecosystem model"

A.E.F. Prowe, B. Su & M. Pahlow

Ocean ecosystems are under continuing pressure from changing environmental conditions. Plankton communities, at the base of oceanic food webs, allow many of the ocean's ecosystem functions, and plankton biodiversity is deemed a governing factor. However, the diversity of trophic interactions, their flexibility and effects on ecosystem functioning are not well understood given the challenges of observing natural (diverse) marine plankton communities. Hence, many global ocean ecosystem models employ an oversimplified plankton representation characterized by few traits and rigid trophic interactions.

Subproject 1.19 aims at addressing these problems from three different sides: a) by investigating effects of flexible trophic interactions with a non-rigid feeding model for observed natural communities (Su et al. 2018), b) by enhancing trophic trait resolution in a global ocean ecosystem model (Prowe et al. 2019), and c) by revealing the role of trophic structure on ecosystem functions and their sensitivity to changing community structure (Prowe et al., submitted). A DynaTrait synthesis paper inspired by the findings of these studies systematically describes the mechanisms underlying a flexible trophic structure, their experimental basis and implementation in models across scales, their relevance for ecosystem functions and the need for a joint effort such as DynaTrait in making this knowledge accessible to global ocean ecosystem modellers (VERTUP, to be submitted).

Trophic interactions in global ocean ecosystem models are often formulated as non-mechanistic, rigid links, depending only on prey concentration and fixed prey preferences. Su et al. (2018) instead employ a mechanistic, optimality-based model of zooplankton feeding strategies to simulate near-natural plankton communities in a suite of mesocosm experiments. Optimisation of the model against the observations reveals that the trophic structure is decisive for the model's ability to capture the observations, and cannot be compensated for by adjusting parameter values. Only when dinoflagellates and ciliates are allowed to prey on each other can the model reproduce the differential development of the plankton communities. This intraguild predation within the microzooplankton community is identified as a crucial trophic interaction that needs to be well represented in order to understand plankton community dynamics.

Prowe et al. (2019) address the representation of trophic interactions on the global scale by implementing different mesozooplankton feeding strategies based on traits and trade-offs in a global ocean plankton functional type (PFT) model. Resolving two functional types each for small (micro-) and large (meso-) zooplankton, characterized by specific feeding strategies, i.e. ambush or cruise feeding, enhances the trait diversity resolved and with it the complexity of the food web. The idealized model generates a global biogeography of feeding strategies that for large zooplankton agrees with an observation-based estimate for copepods. The simulated biogeography arises from different dominant food chains that are driven by trophic trait cascades of active and passive feeders in the two zooplankton trophic levels. The different food web structures in turn affect simulated ecosystem functions, relevant, e.g., for biogeochemical cycling. This link emphasizes that understanding what drives trophic traits, their trade-offs and resulting food webs on the spatial scale is the basis for enhanced model projections of global ocean ecosystems. The limited availability, however, of adequate observations, in particular of zooplankton traits on the global scale presents a serious challenge.

The study by Prowe et al. (submitted) further unravels the role of plankton food web structure and its effect on ecosystem functioning. Again, observations of near-natural plankton communities in a mesocosm experiment are used to optimize parameters of model configurations differing in food web structure and thus complexity. The configurations extend an existing plankton model with rigid trophic interactions by adding microzooplankton intraguild predation and other feeding links. Different model food webs can capture the biomass observations similarly well, but the underlying food web structures represent either a classic diatom-copepod food chain or a more complex food web with an intense microbial loop. Microzooplankton intraguild predation in particular increases ecosystem functions like primary production and organic matter recycling and decreases trophic transfer efficiency. Trophic transfer as well as production and trophic role of copepods are notably more sensitive to changes in initial biomass values in projections of chain-like compared to more complex food webs. A more mechanistic implementation of plankton trophic interactions and observations of trophic traits, not only biomass, is urgently needed to reduce model uncertainty and enhance projections of ocean ecosystem functioning.

The preceding work inspired a DynaTrait Synthesis group (lead by F. Prowe and E. van Velzen) on how trophic flexibility affects plankton ecosystem functioning. The paper presents a synthesis of mechanisms generating trophic flexibility across ecological scales like phenotypic plasticity, rapid evolution and species sorting. These processes are investigated by different approaches (based on observations, experiments and models) on the small scale (within a water parcel or experimental system). In contrast, trophic flexibility is not well resolved in spatially explicit (e.g., global) plankton ecosystem models. In order to promote linking such large-scale applications and the process-oriented small-scale research, the synthesis highlights examples of studies demonstrating how flexible trophic traits affect ecosystem functioning. Concrete suggestions of how to upscale small-scale knowledge by utilising it for improving large-scale models and how to address open questions with small-scale research complete this effort of both limnic and oceanic, small- and large-scale, empirical and theoretical researchers in the interdisciplinary spirit of DynaTrait.

Publications:

Su B, Pahlow M, and Prowe AEF (2018). The role of microzooplankton trophic interactions in modelling a suite of mesocosm ecosystems. Ecological Modelling 368, p.169-179, doi: 10.1016/j.ecolmodel.2017.11.013.

Prowe AEF, Visser AW, Andersen KH, Chiba S, and Kiørboe T (2019): Biogeography of zooplankton feeding strategy. Limnology and Oceanography 64: 661-678, doi:10.1002/lno.11067.

Prowe AEF, Su B, Nejstgaard JC, and Schartau, M (submitted): Intraguild predation and food web structure affect ecosystem functioning in models of observed Arctic plankton communities. Limnology and Oceanography.

VERTUP (Gaedke U, Grossart HP, Kasada M, Kerimoglu O, Klip H, Moorthi S, Prowe AEF, Shatwell T, Thongthaisong P, van Velzen E, Wollrab S; in alphabetical order). Flexibility in aquatic food web structure: linking scales and approaches. To be submitted to Oikos as Forum paper.