The paradox of the plankton

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Biodiversity has puzzled ecologists for decades. In aquatic ecosystems, the puzzle is particularly troublesome, and known as the paradox of the plankton (Hutchinson 1961). Phytoplankton species are limited by only a handful of resources (e.g., nitrogen, phosphorus, iron, light). Yet a single milliliter of seawater may contain dozens of different phytoplankton species. How can this surprising biodiversity be explained? This presentation will focus on a number of potential solutions for the plankton paradox that have recently been proposed.

First, we tested Tilman's resource-ratio hypothesis, which states that differential utilization of nutrients and light may allow coexistence of species along a nutrient-light gradient. We investigated this hypothesis in chemostat experiments with phytoplankton species. Would differential utilization of nutrients and light generate species coexistence, alternative stable states, or competitive exclusion?

Second, we shift our focus to the underwater light spectrum as a potential axis for niche differentiation. Phytoplankton species often differ in pigment composition, which might potentially favor their coexistence. We tested this hypothesis using competition models and chemostat experiments with red and green picocyanobacteria. Would the reds and greens wipe each other out, or would they be able to share the spectrum?

Third, the complexity of multi-species interactions may generate non-equilibrium dynamics, like oscillations and chaos. Usually, chaos is seen as a destructive force. Or, could chaos promote biodiversity?

Fourth, incomplete mixing can favor species coexistence, especially if species separate in different spatial niches, and thereby avoid intense competition. Climate-ocean models predict that warming of the ocean waters strengthens vertical stratification, which reduces vertical mixing. Could reduced mixing, by global warming, promote phytoplankton biodiversity?

In each of these studies, we make use of a combination of models, lab experiments, and field research. They illustrate how such a multi-faceted research program may shed new light on potential mechanisms that determine the world's biodiversity, thereby providing novel solutions to Hutchinson's classic paradox.