Trophic complexity, limits on predictability, and emergent ecosystem structure and function in a new size-spectral plankton model

1 · Background

Relationships among production, recycling, and export fluxes vary widely across aquatic ecosystems. Plankton community structure plays a huge role in this, but current marine biogeochemical models lack the flexibility to reproduce this diversity in ecosystem function, or to confidently relate community structure to net fluxes.

Most recent efforts to better include planktonic diversity in biogeochemical models have focused on phytoplankton diversity and adaptive strategies for maximizing primary production (see Smith et al. 2011 for a recent review, including exceptions). This poster describes theoretical experiments in a model chemostat that explore a parallel question.

How does resolving diversity in trophic interactions—turnover time, prey preference, phytoplankton defensive ability—change a model’s representation of community structure and ecosystem function?

2 · Adding a size-based growth-grazing tradeoff

ASTeCAT (Allometric/Stochastic Trophic Complexity Analysis Tool: Banas, Ecol Modeling, 2011) is a framework for systematically adding diversity to the trophic interactions in a planktonic nutrient-cycling model. The experiments described here were run in a euphotic zone chemostat.

There is a single tradeoff along the phytoplankton size spectrum: small phytoplankton grow faster and have lower nutrient requirements than large ones, but have grazers with faster turnover times.

This tradeoff could also be expressed in a simple ZPZ model; this experiment tests the effect of resolution.

3 · Adding a defense-based growth-grazing tradeoff

The discontinuities in the biomass spectra suggest that too much complexity is being lost. Giving the phytoplankton greater adaptive ability allows them to fill more niches, producing a higher level of consistence and a more continuous size spectrum.

This requires assuming a shape for the growth-defensibility tradeoff. Following Fussman et al. (2005),

\[ \text{defensive ability} = 1 - e^{-\text{size ratio}} \]

Where the trait is relative investment in defense.

Conclusions

Resolving two tradeoffs between phytoplankton growth and grazing—one defined by the allometry of growth rates, nutrient requirements, and prey preferences, the other based on a more theoretical model of optimal investment in defense against grazing—has several effects on a simple planktonic community: phytoplankton and zooplankton biomass increase, primary production increases, and export efficiency decreases. This last result in particular might well be different if the model resolved a spectrum of mesozooplankton along with microzooplankton.

The relationship between very slow changes in forcing and the ecosystem response becomes very noisy.

Transient predator-prey interactions (e.g., blooms and “ecosystem weather”) play the same role in biogeochemistry that eddies play in ocean circulation or decadal oscillations play in the climate system. Instead of designing biogeochemical models to eliminate them, we could focus instead on resolving them, quantifying their contribution to mean fluxes, and quantifying the unpredictability associated with them through ensemble methods.