Limits on predictability in a size-spectral plankton model: A strategy for ensemble ecosystem forecasting

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Two new programs: predicting Pacific NW harmful algal blooms on timescales from weeks to decades

**PNWTOX**
*Pseudonitzschia* transport & growth on the Washington-Oregon coast

**PS-AHAB**
Climate impacts on *Alexandrium* blooms in Puget Sound
Hawkins and Sutton (*BAMS*, 2010)

climate model uncertainty = internal variability + model uncertainty + scenario uncertainty; all three are important for some timescale of prediction.

In biogeochemical models, we usually **suppress** internal variability in order to make bottom-up linkages clear and clean.

What if we **resolve** and **quantify** the internal variability instead?

- omitting diversity (the standard NPZ approach)
- including phytoplankton diversity but omitting zooplankton diversity (Follows et al., *Science*, 2007; Bruggeman and Kooijman, *L&O*, 2007)
- constructing a grazer field that eliminates predator-prey instabilities (Armstrong, *DSR*, 2003)

transient blooms = predator-prey oscillations = ecosystem weather
Size-spectral models
use **allometry** to resolve diversity in vital rates and functional responses without adding free parameters.

**Relative prey preference**
(Hansen et al., *L&O*, 1994)

What happens if we include zooplankton prey preferences at a matching level of detail and empiricism?
The model: ASTroCAT (Allometric/Stochastic Trophic Complexity Analysis Tool)

NPZ style, with 40 size classes of P (1 – 20 μm) and 40 size classes of Z (2 – 300 μm)

Optimal prey size is an allometric power law, with Gaussian prey preferences around it.

This application: zero-dimensional testbed, **flowthrough**, not closed.

One bottom-up control (nutrients), one top-down (higher mortality), one level of trophic interactions well-resolved in between.
chaotic, long-term time evolution:

Phytoplankton biomass
(μmol N l⁻¹)

Mean phytoplankton biomass
(μmol N l⁻¹)

Total

< 5 μM

Nutrient supply (μmol N l⁻¹ d⁻¹)

Under steady nutrient supply
Under steady nutrient supply,
annual cycle repeated 10x

“seasonally entrained chaos”  
Annual cycle of N supply (μmol l⁻¹ d⁻¹)

Total P biomass, 10 yrs (μmol N l⁻¹)
Total P biomass

Fraction < 5 µm

n = 2

n = 4

n = 40
Conclusions

Including diverse grazing preferences in a size-spectral NPZ model, based on a general fit to laboratory data, leads to **factor-of-two uncertainty** in total biomass in response to seasonal nutrient supply.

Resolving this internal variability in a realistic biophysical model would allow for **a new dimension of ensemble uncertainty estimation**—more similar to quantification of the eddy field or storm statistics than to traditional parameter-sensitivity analysis.

These dynamics begin to appear with only **a modest increase in the number of P, Z classes** (~4 where a conventional NPZ model would have 2). The limiting factor is not computing power, but the availability of system-specific field and lab data on what eats what.

**http://faculty.washington.edu/banasn/models/astrocat**