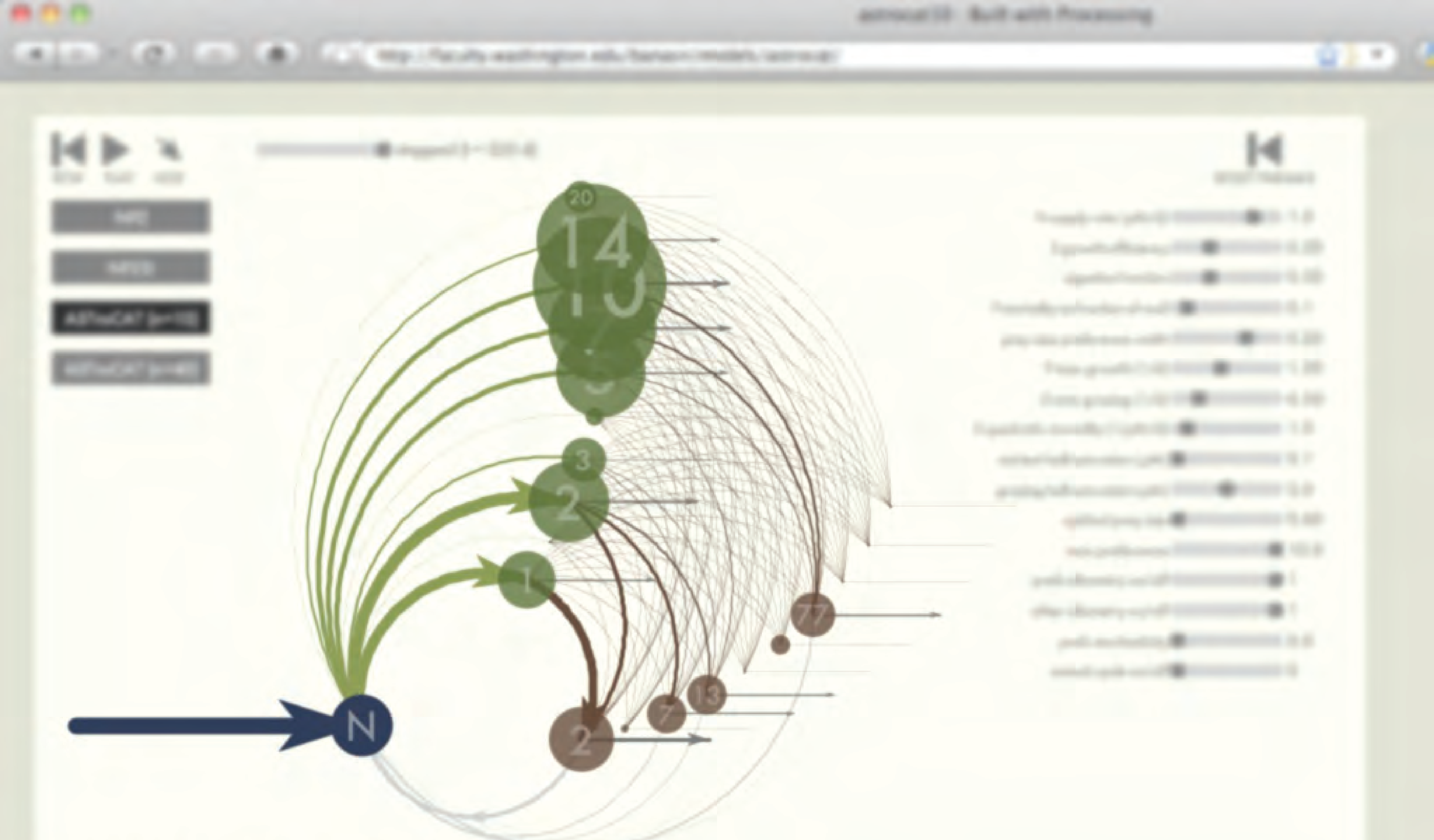
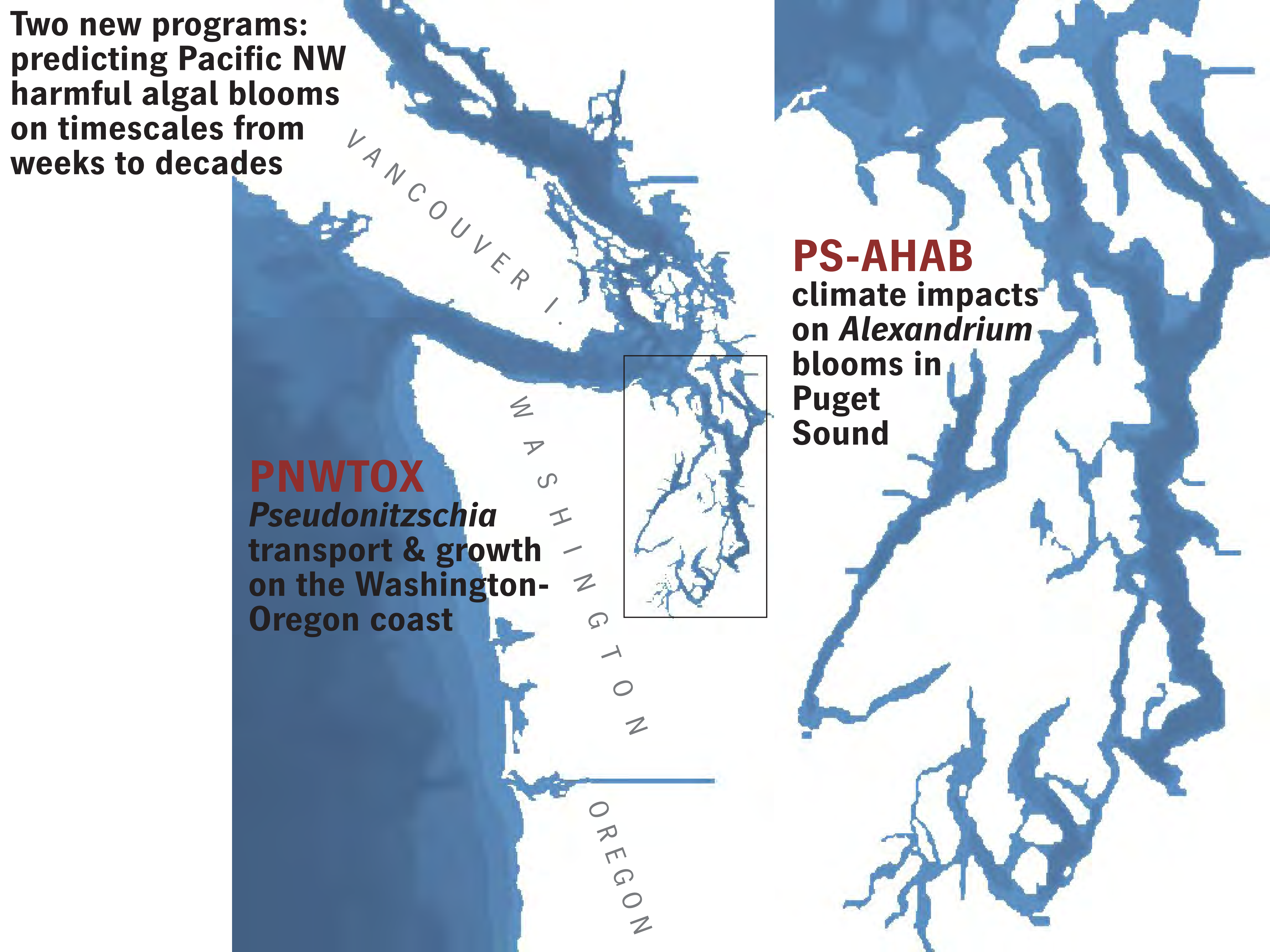


Limits on predictability in a size-spectral plankton model: A strategy for ensemble ecosystem forecasting

Neil Banas
Univ of Washington
Applied Physics Lab



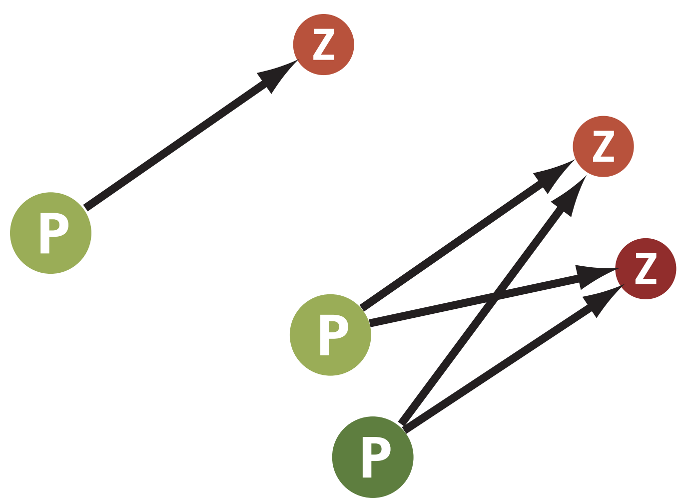
Two new programs: predicting Pacific NW harmful algal blooms on timescales from weeks to decades
VANCOUVER I.
WASHINGTON
OREGON
PNWTOX
Pseudonitzschia transport & growth on the Washington-Oregon coast
PS-AHAB
climate impacts on Alexandrium blooms in Puget Sound

Hawkins and Sutton (*BAMS*, 2010)

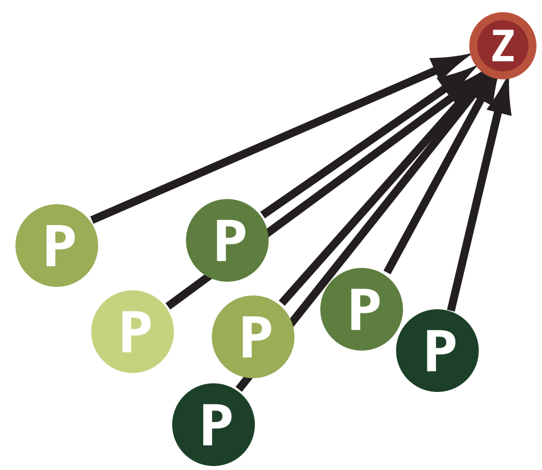
climate model uncertainty =
internal variability + model uncertainty + scenario uncertainty;
all three are important for some timescale of prediction.

transient blooms
= predator-prey oscillations
= ecosystem weather

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

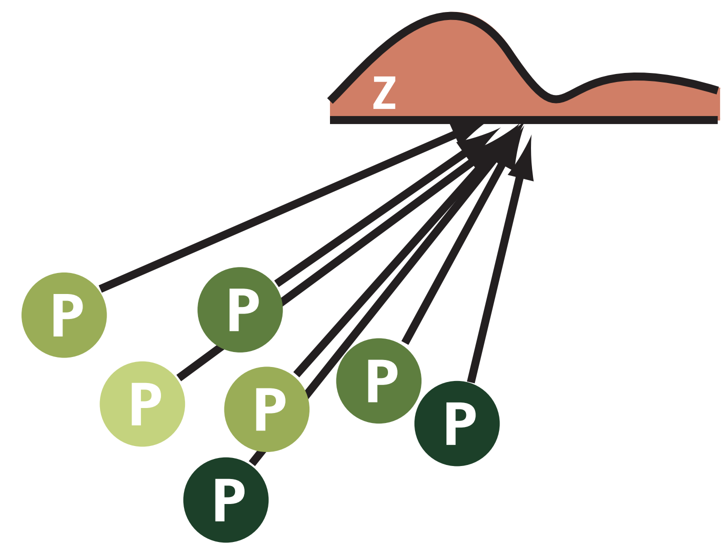


omitting diversity
(the standard NPZ approach)



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)

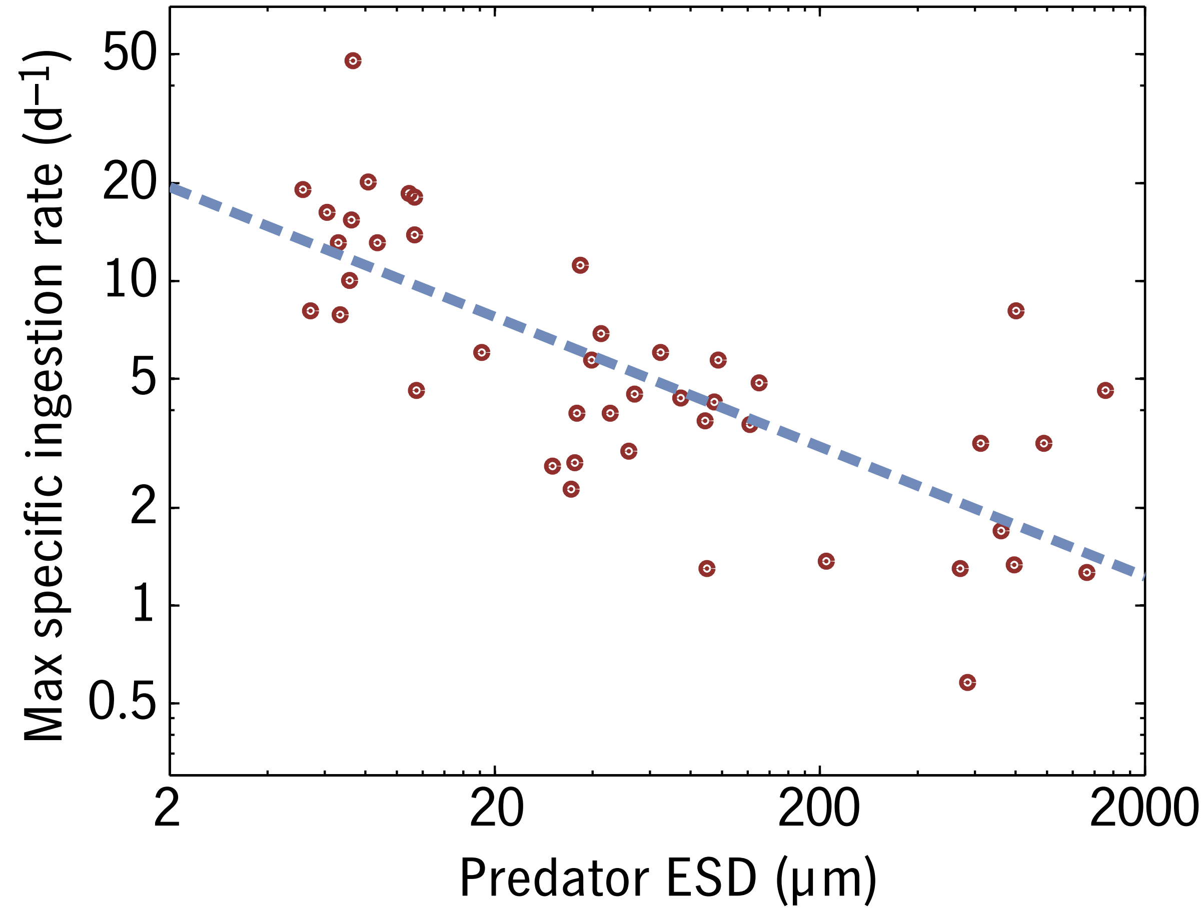
What if we **resolve** and **quantify** the internal variability instead?

Size-spectral models

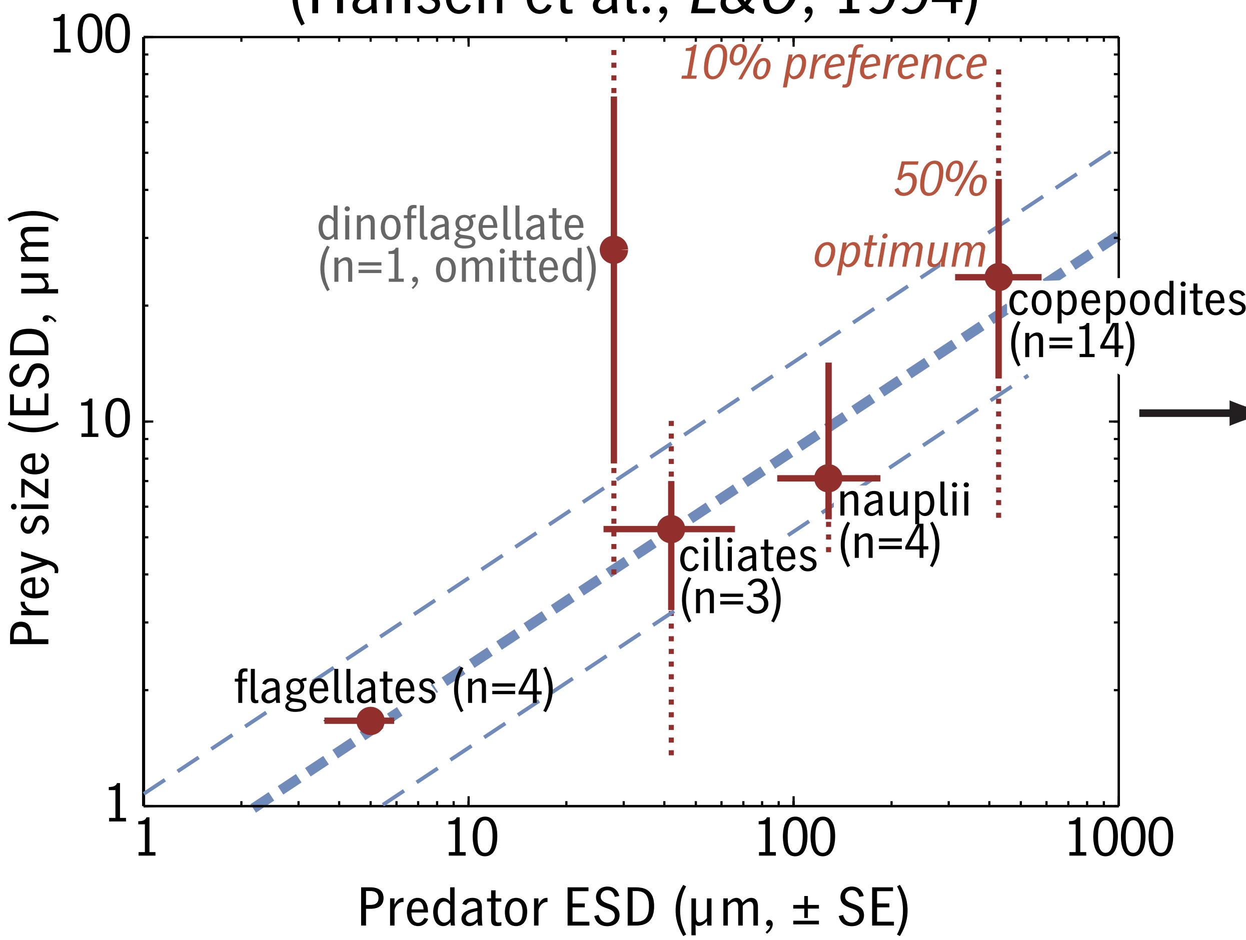
(Baird and Suthers, *Ecol. Modelling*, 2007; *J. Plankt. Res.* special issue, Aug 2009)

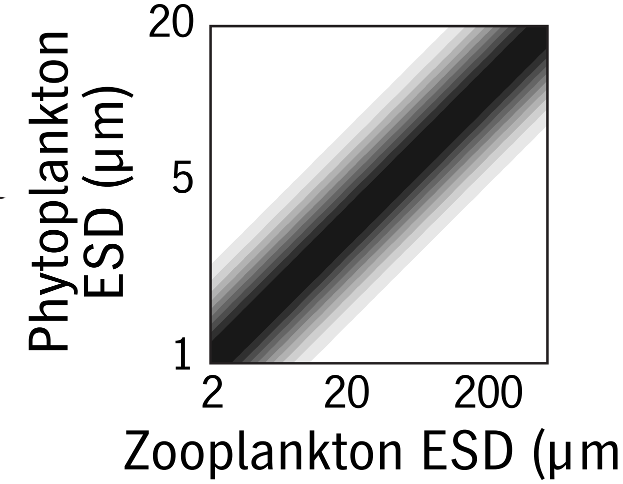
use **allometry** to resolve diversity in vital rates and functional responses without adding free parameters.

Zooplankton ingestion rate (d^{-1})
(Hansen et al., *L&O*, 1997)



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

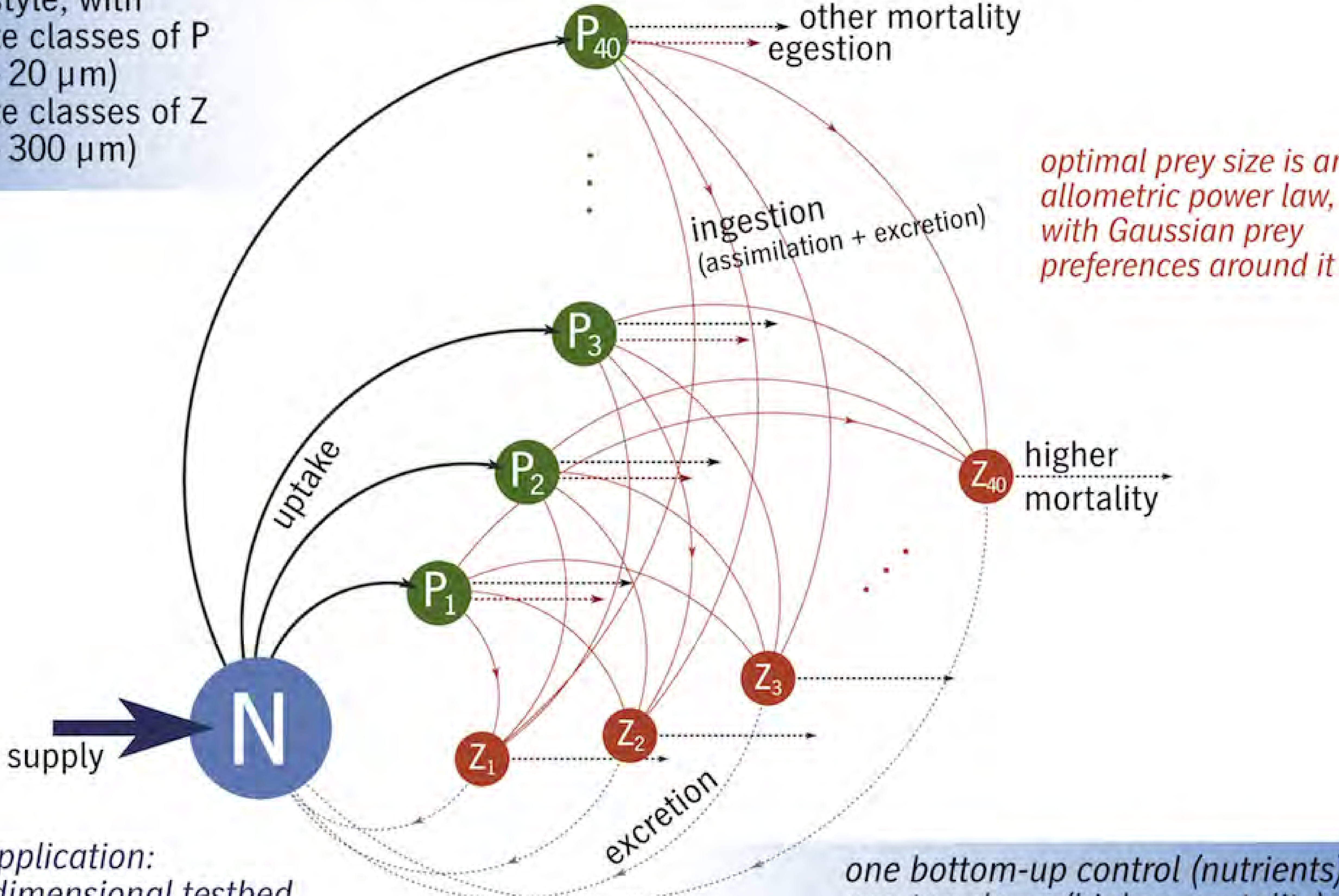




What happens if we include zooplankton prey preferences at a matching level of detail and empiricism?

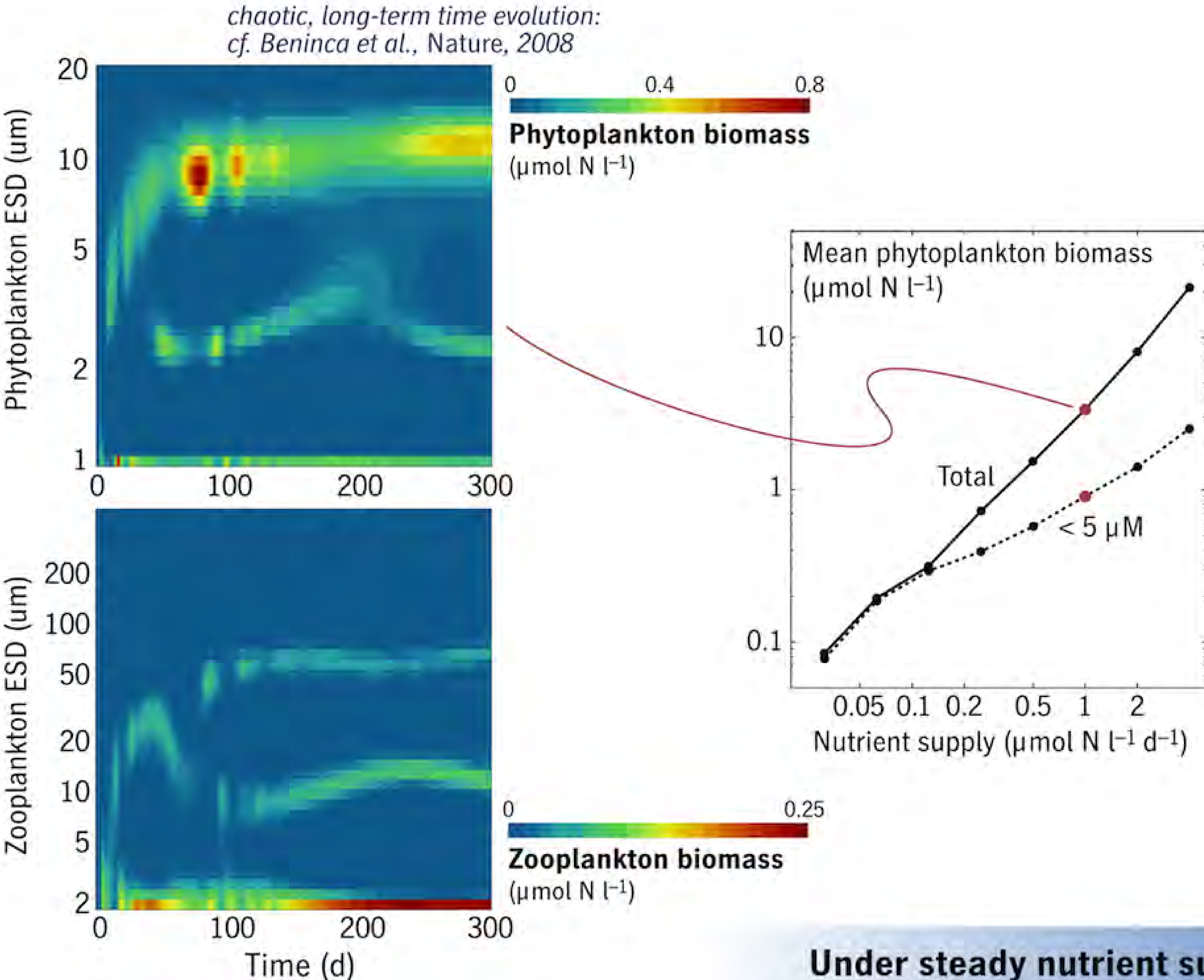
The model: ASTroCAT (Allometric/Stochastic Trophic Complexity Analysis Tool)

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

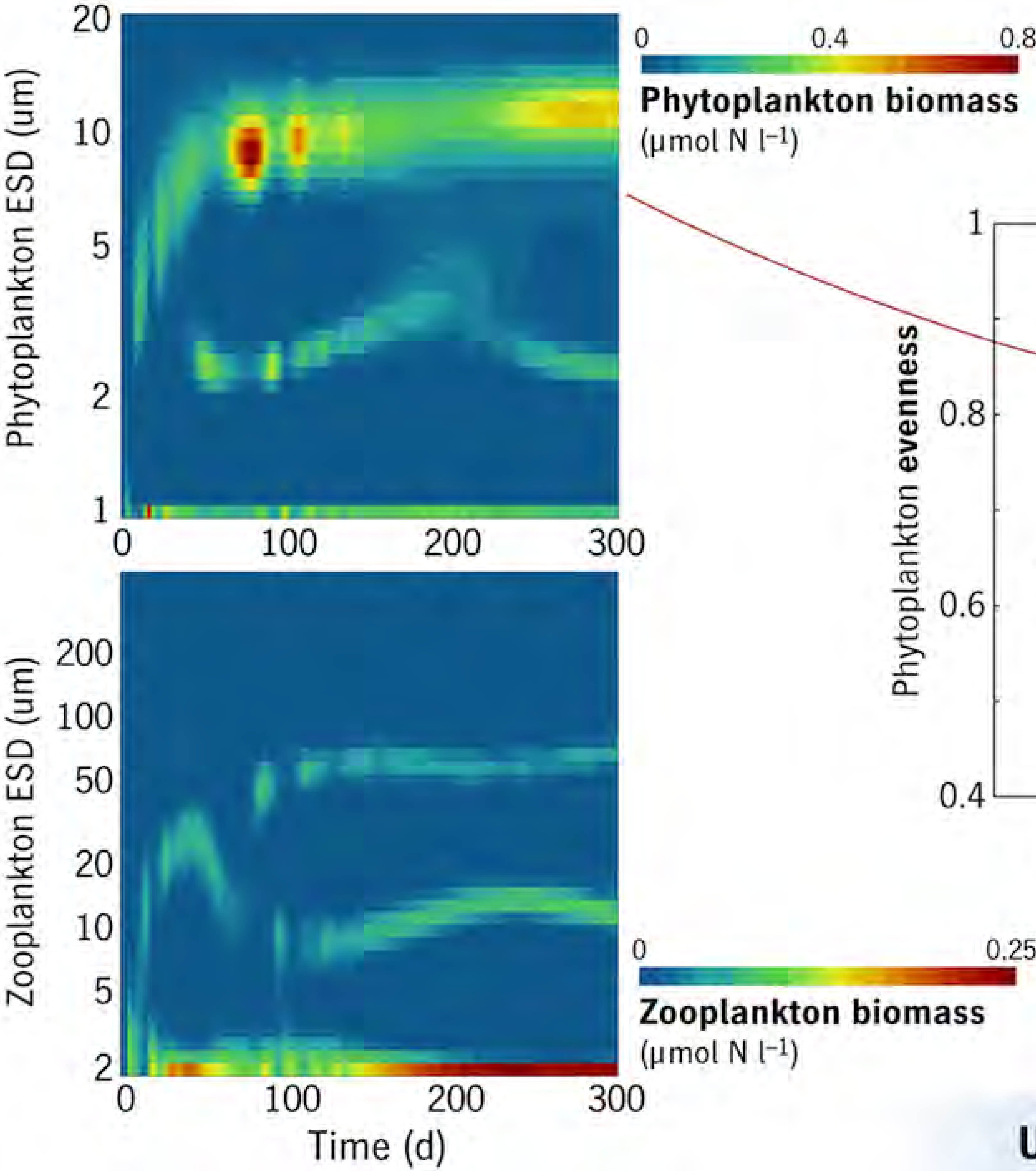


this application:
zero-dimensional testbed,
***flowthrough**, not closed*

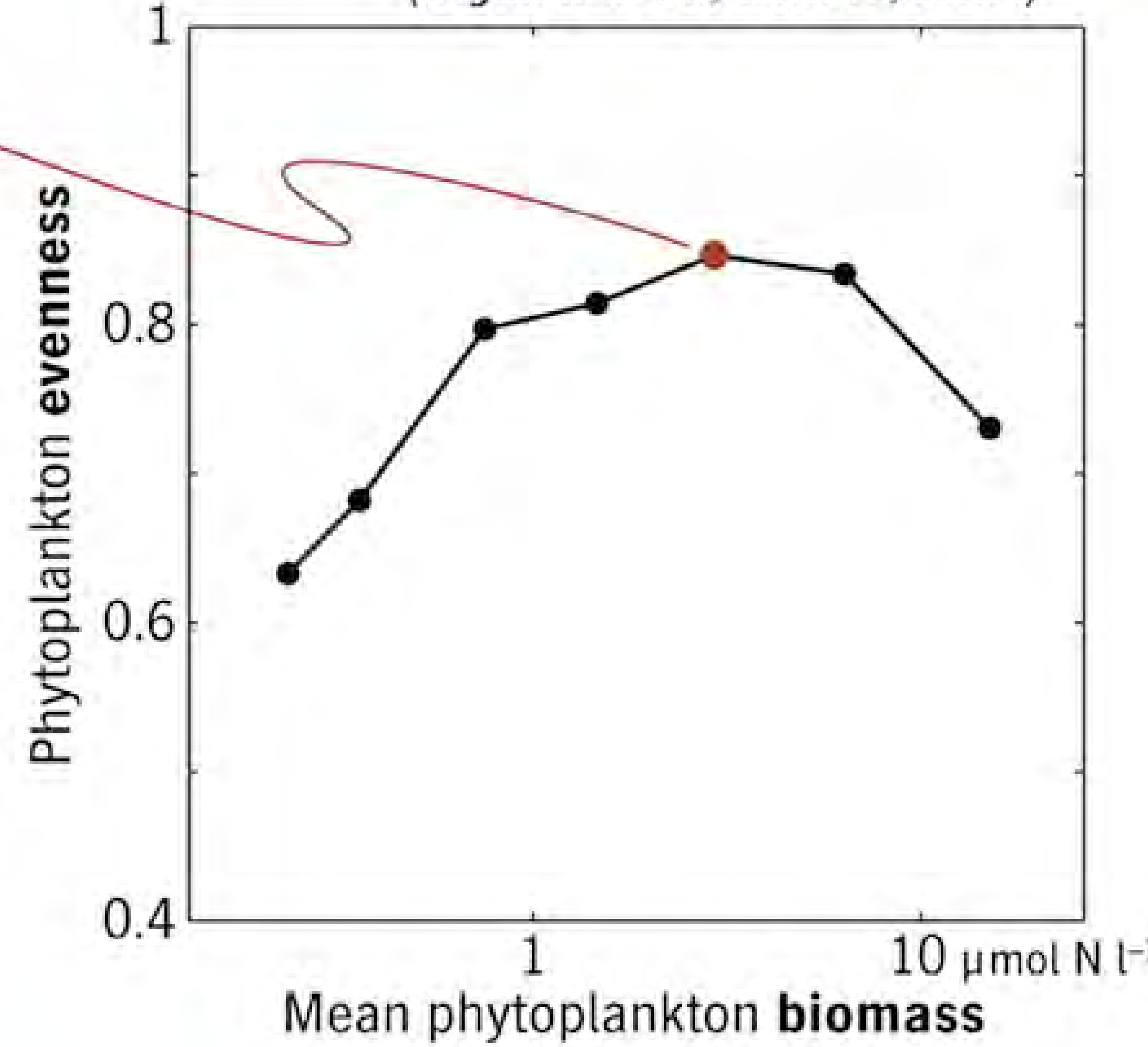
one bottom-up control (nutrients),
one top-down (higher mortality),
one level of trophic interactions
well-resolved in between



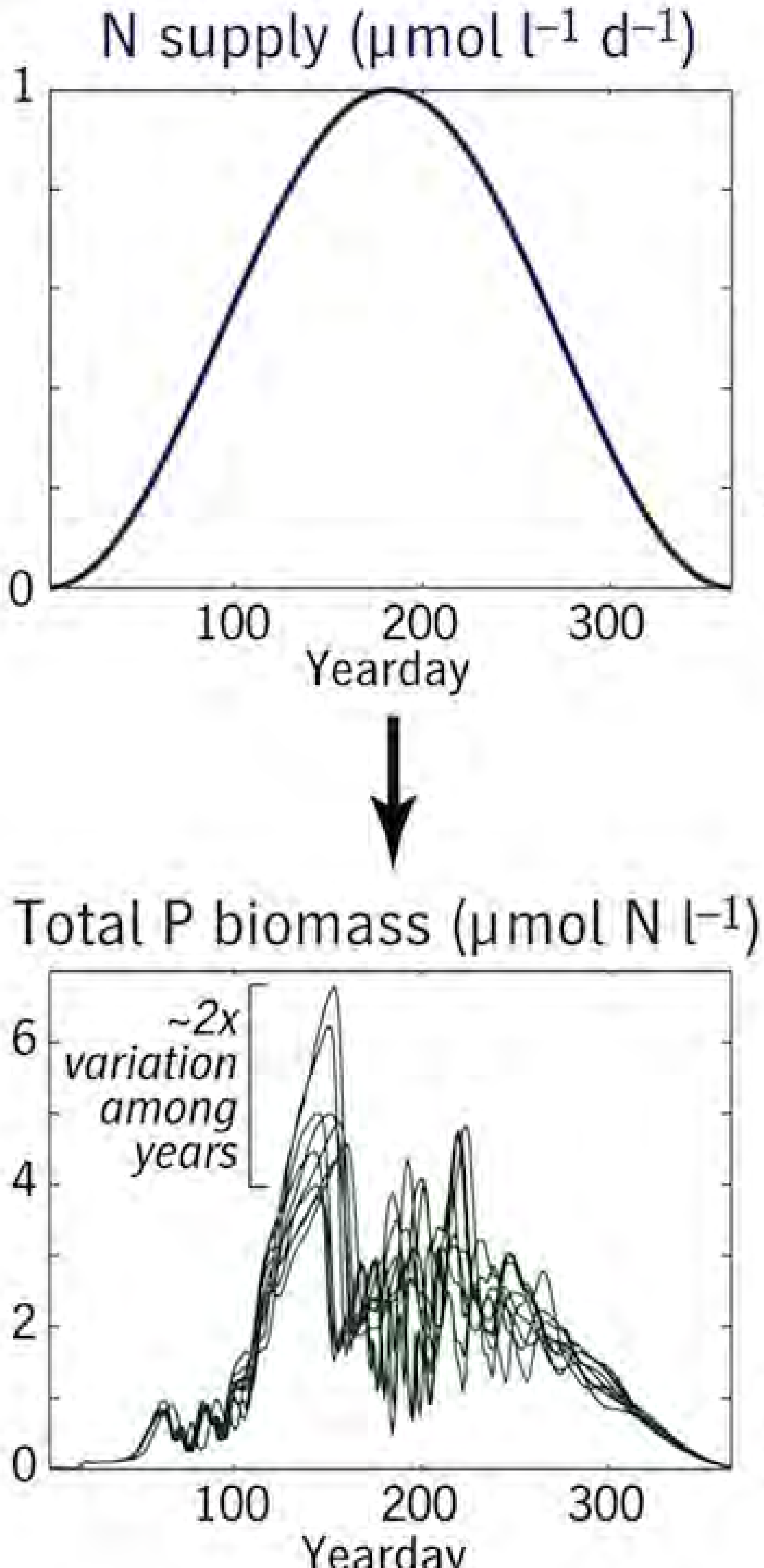
Under steady nutrient supply



"Similar to terrestrial vegetation, marine phytoplankton [show] maximum diversity at intermediate levels of phytoplankton biomass" (*Irigoien et al.*, Nature, *2004*)

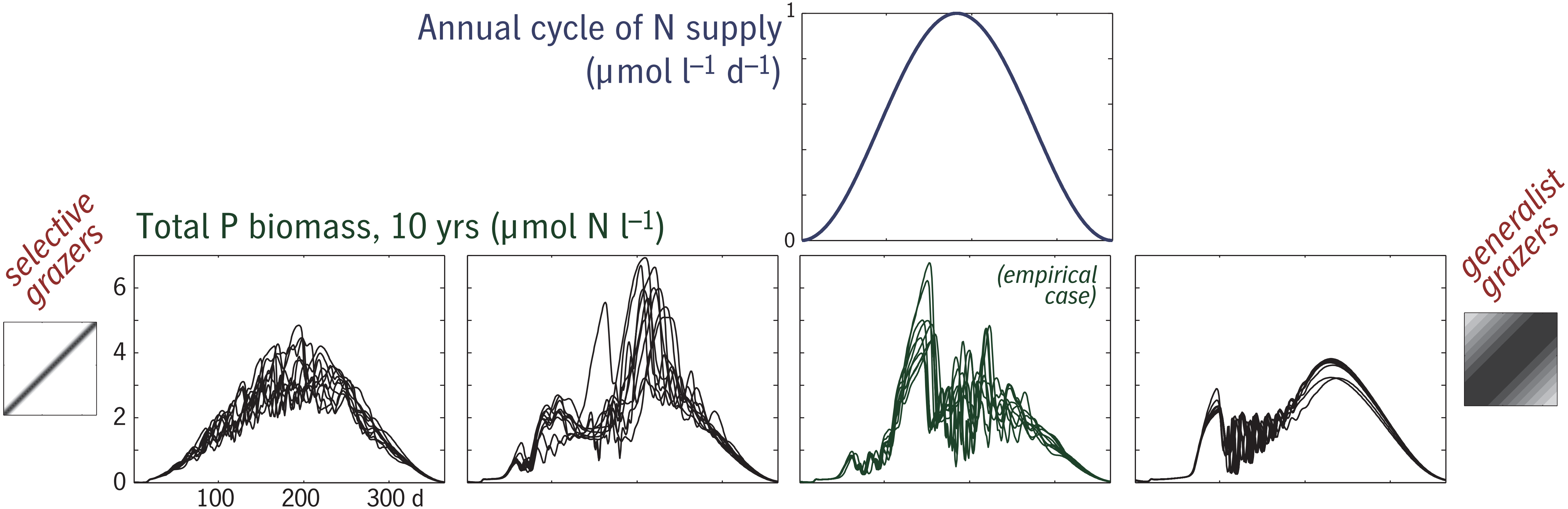


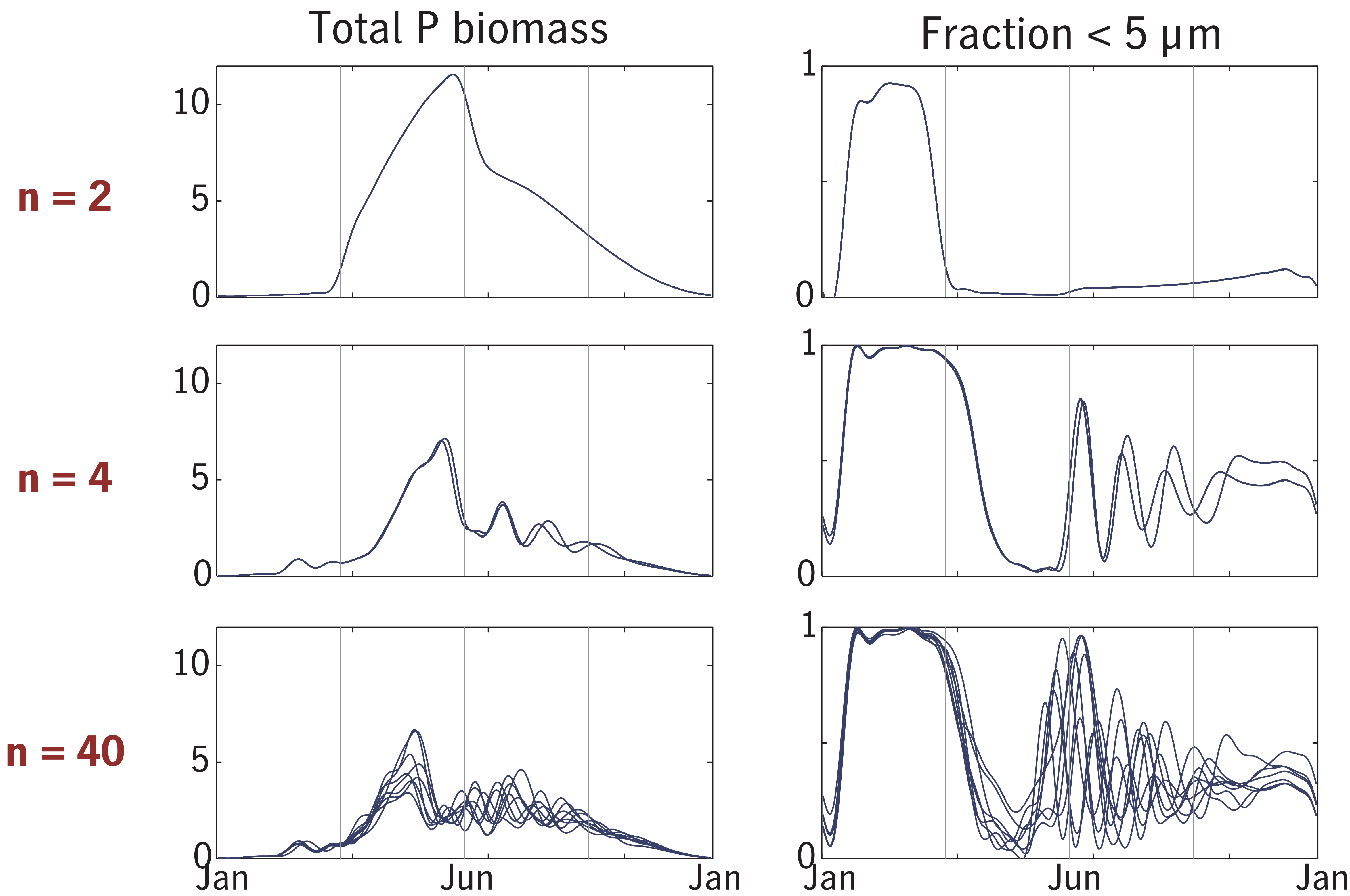
Under steady nutrient supply



annual cycle repeated 10x

"seasonally entrained chaos"
(Dakos et al., Proc. Roy. Soc. B, *2009)*


Annual cycle of N supply
(μmol l−1 d−1)
1
0
Total P biomass, 10 yrs (μmol N l−1)
selective grazers
generalist grazers
6
4
2
0
100
200
300 d
(empirical case)



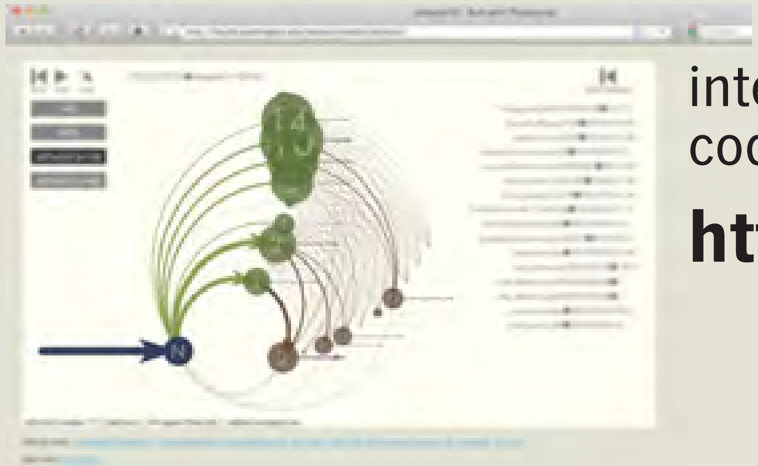
Total P biomass
Fraction < 5 µm
n = 2
n = 4
n = 40
10
5
0
1
0
Jan
Jun
Jan
Jan
Jun
Jan

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 repsonse 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**.



interactive version, source
code, and these slides:

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