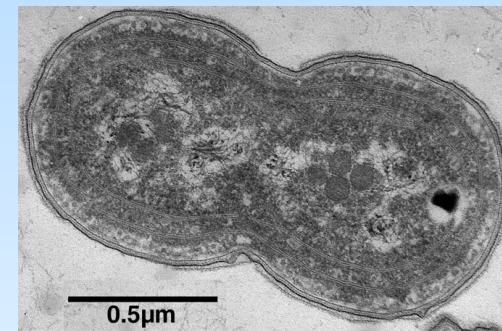
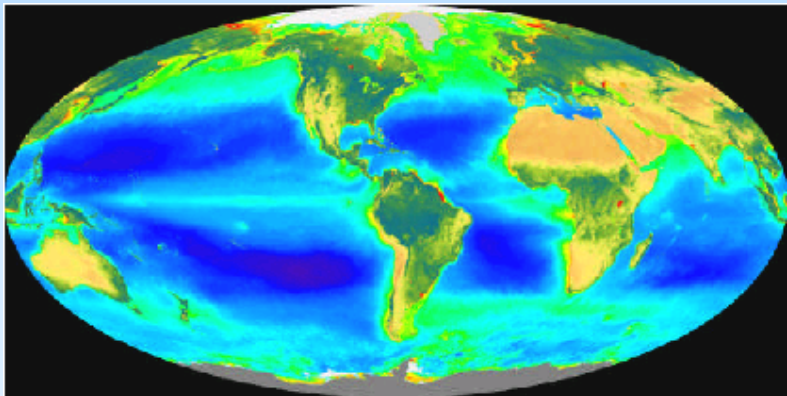


Marine Plankton Community Modeling

Scott Doney

Woods Hole Oceanographic Institution

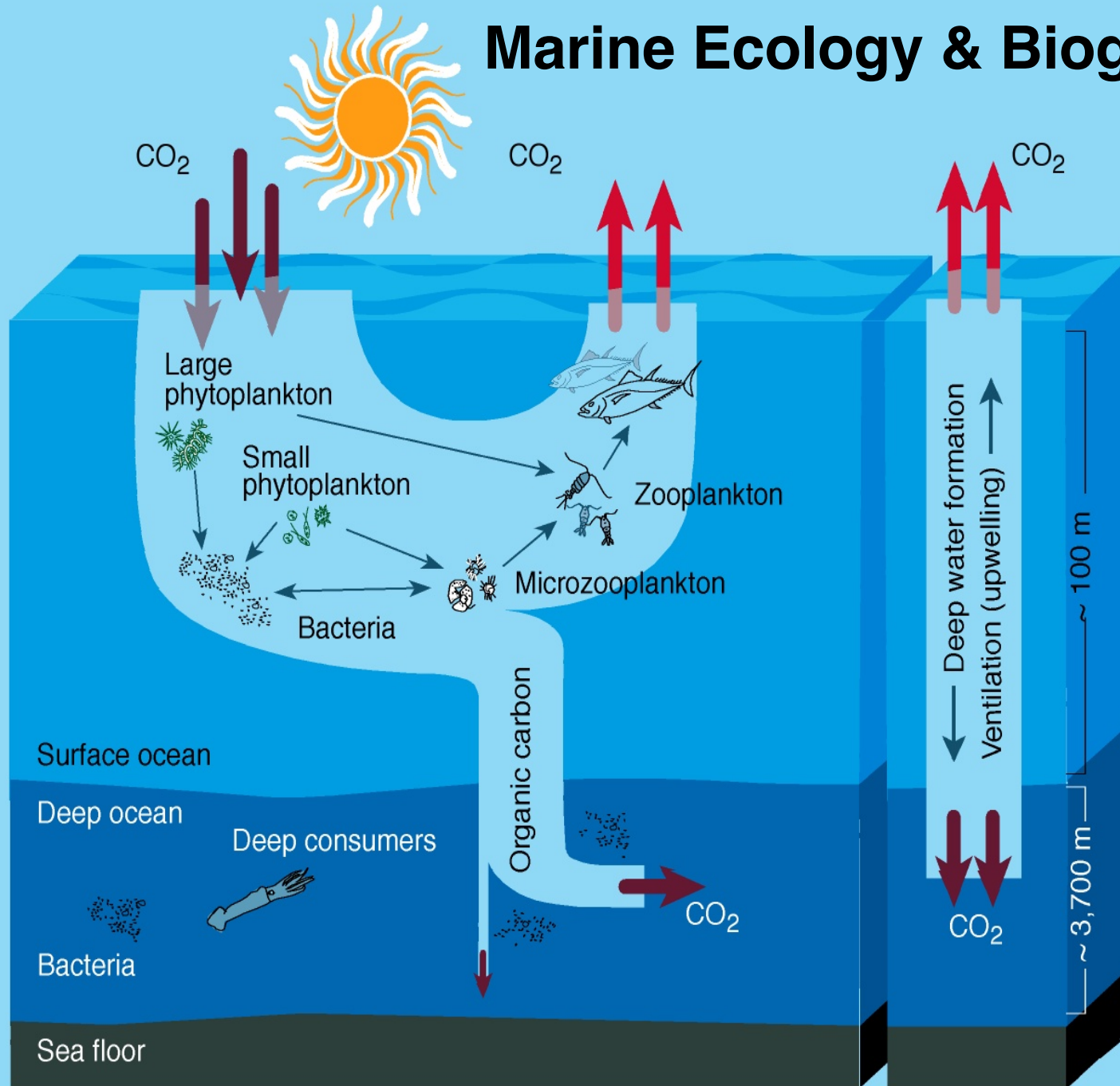
NCAR ASP Colloquium 2013



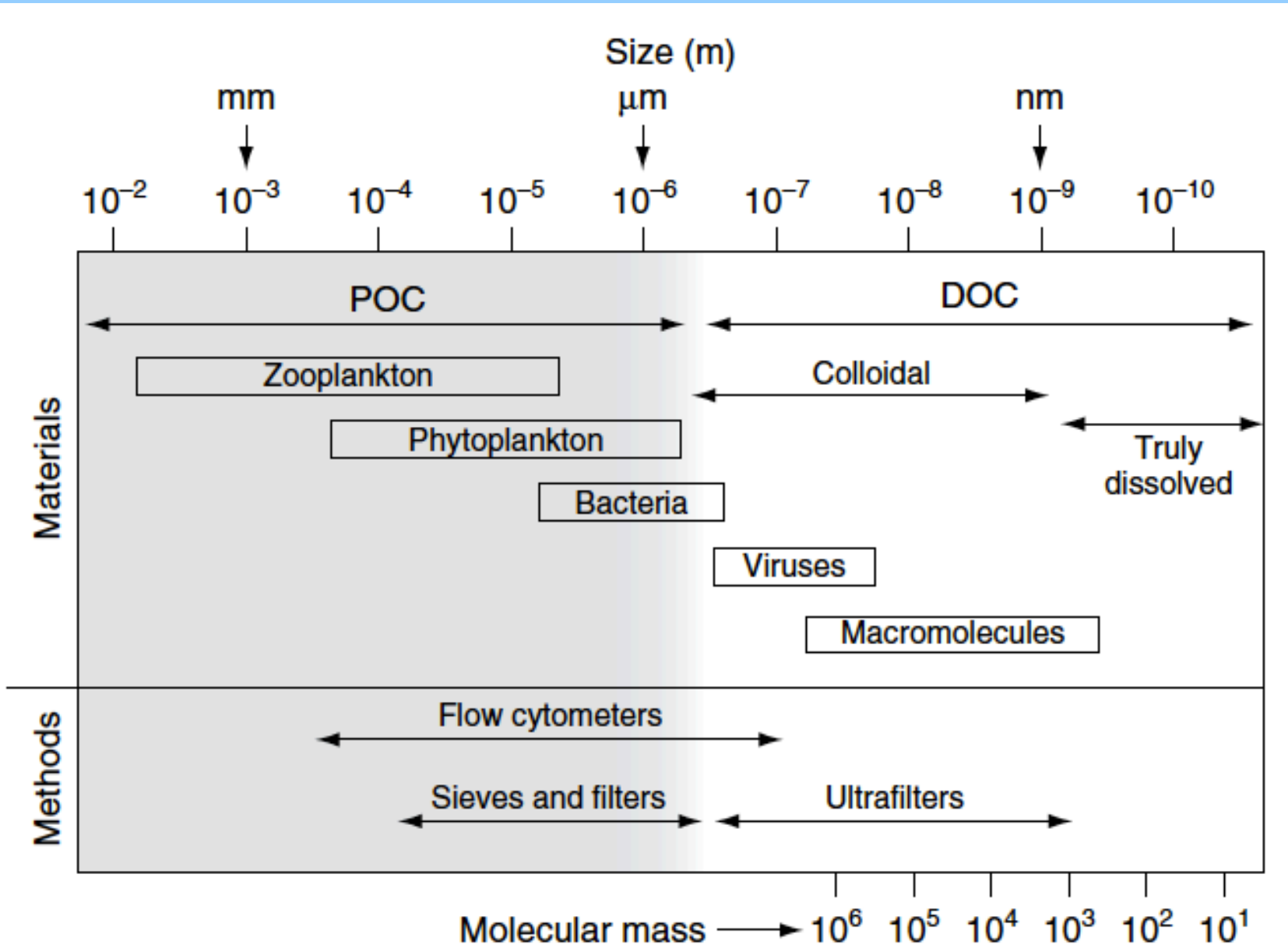
Supported by:



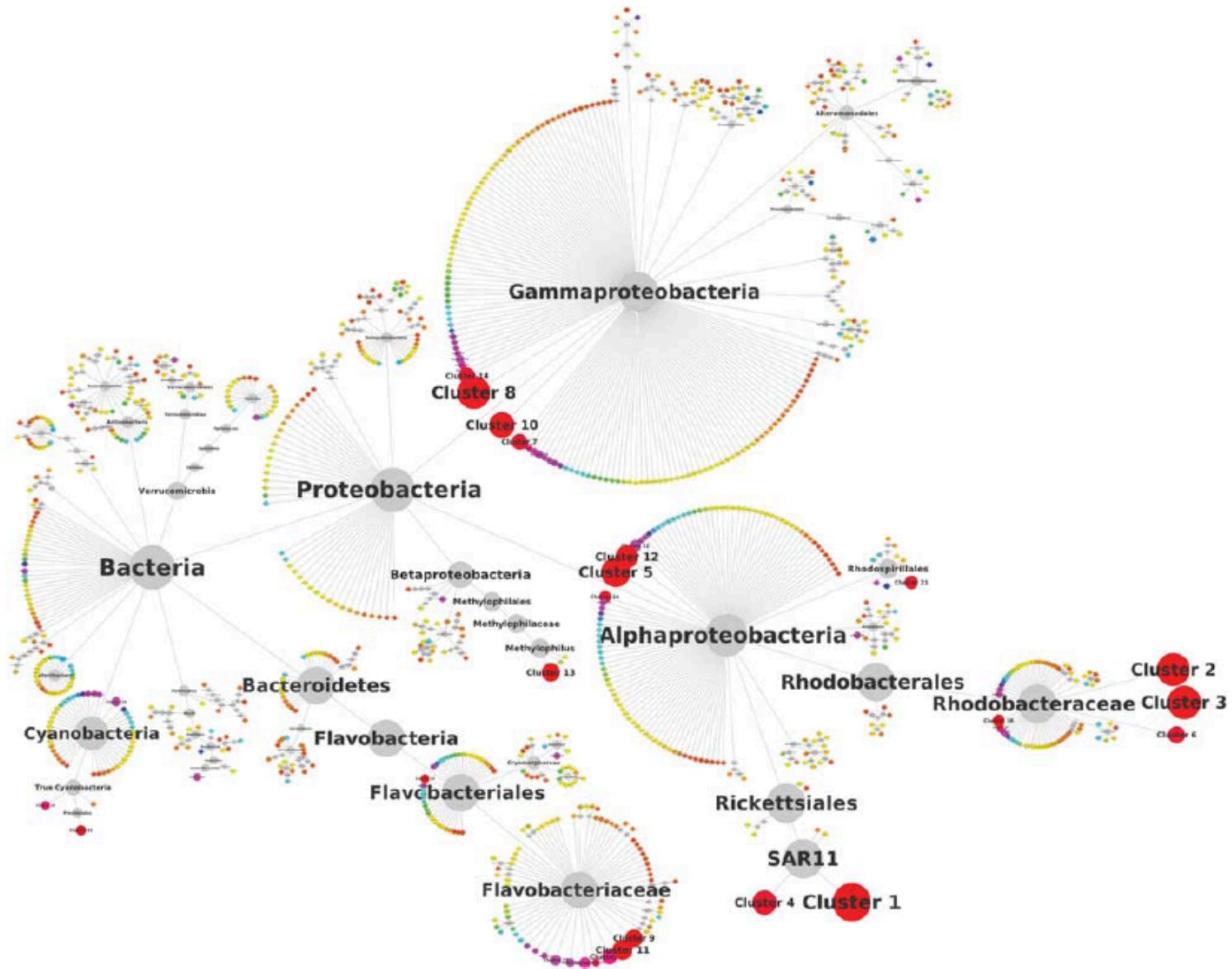
Marine Ecology & Biogeochemistry



Size Matters



Taxonomy Matters



Model Elements Depend on Science Questions

Carbon Cycle & Biogeochemistry

Ecology & Food-webs

- Phytoplankton, zooplankton, bacteria, ...
- Biological interactions (growth, predation, competition, disease, vertical migration, ...)

Biodiversity

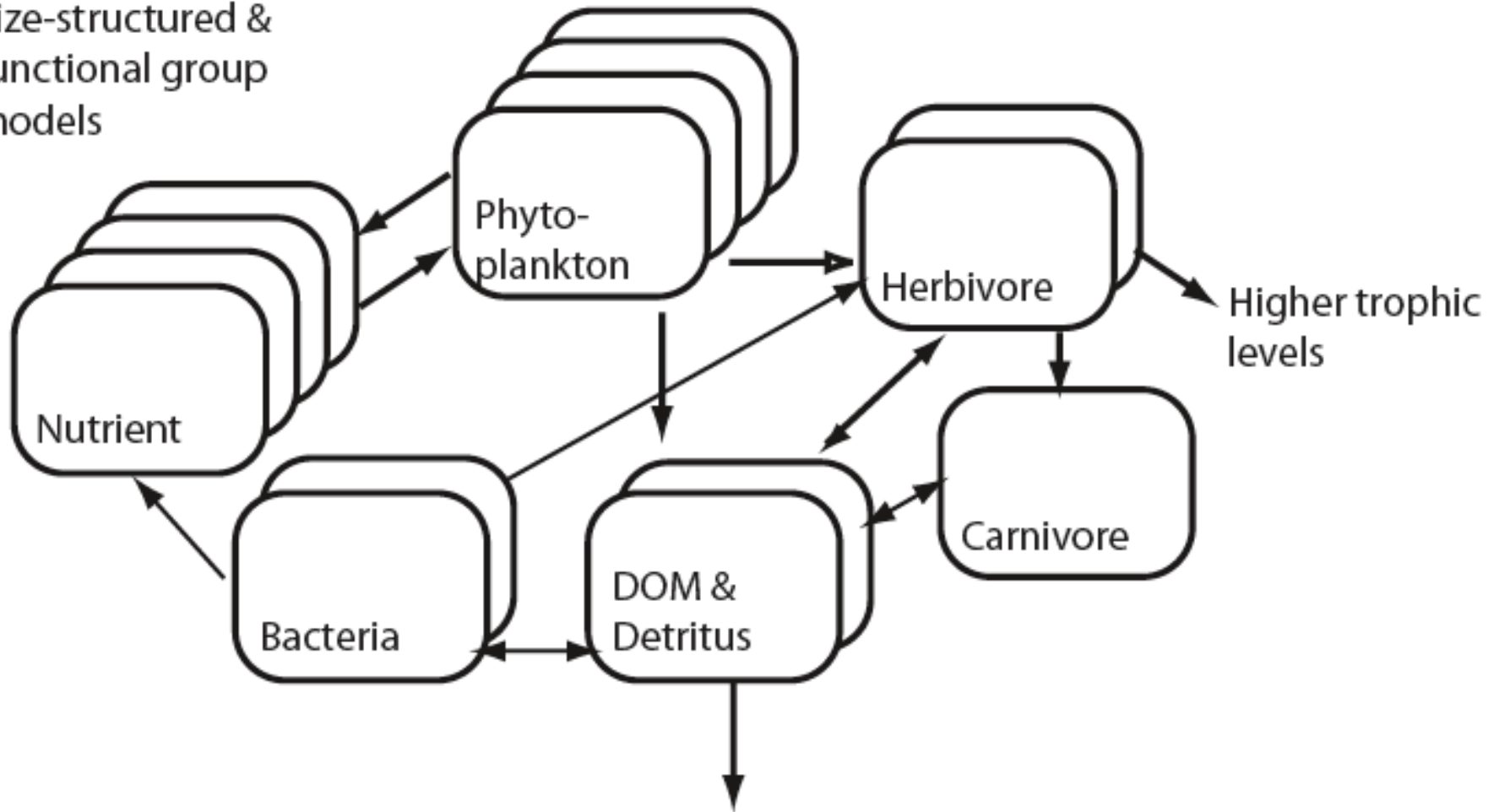
- Variability within populations
- Species diversity
- Community ecology

Fisheries & Conservation

- Higher trophic levels
- Demography, size & age-structure, ...
- Swimming, behavior (individual-based models)

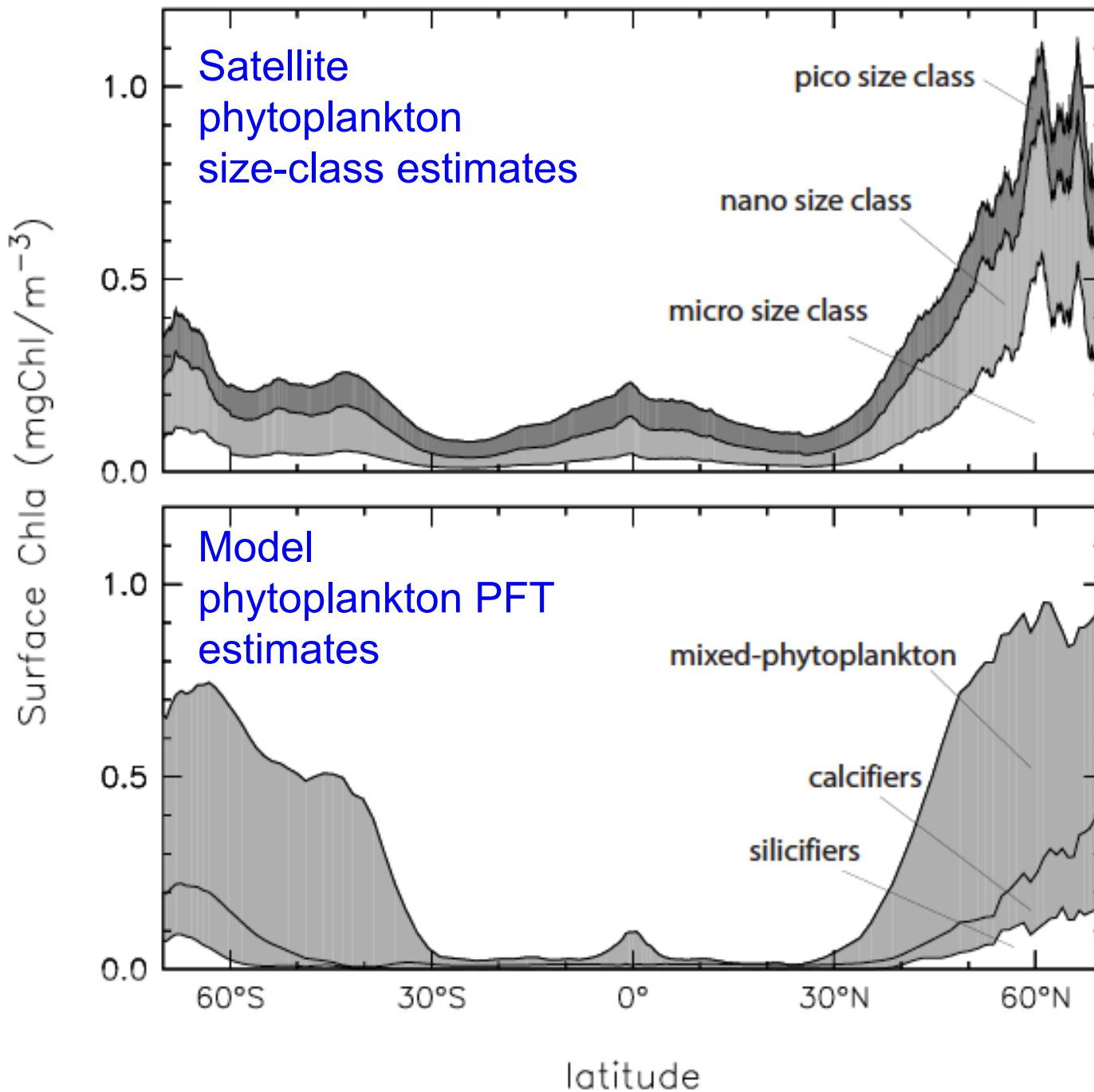
Plankton Functional Type (PFT) Models

Size-structured & functional group models



-Aggregate into trophic levels/functional groups/size classes

Moore et al. Global Biogeochem. Cycles 2004; LeQuere et al. Global Change Biology 2005; Hood et al. Deep-Sea Res. II 2006



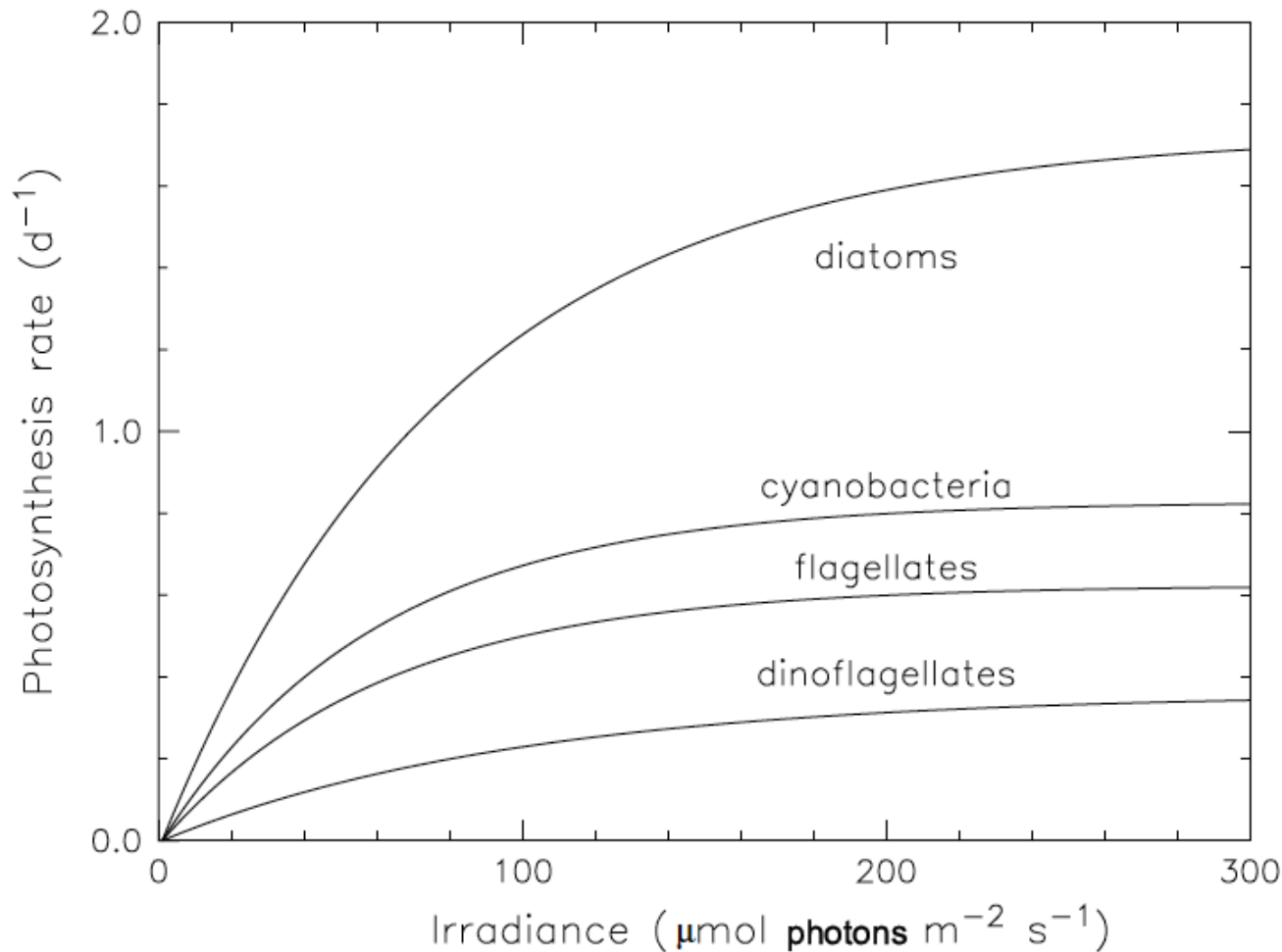
Size-class & Functional Group Variations

Model PFTs blend size & geochemistry (e.g. formation of CaCO₃, opal, nitrogen fixation)

LeQuere et al.
 Global Change
 Biology 2005



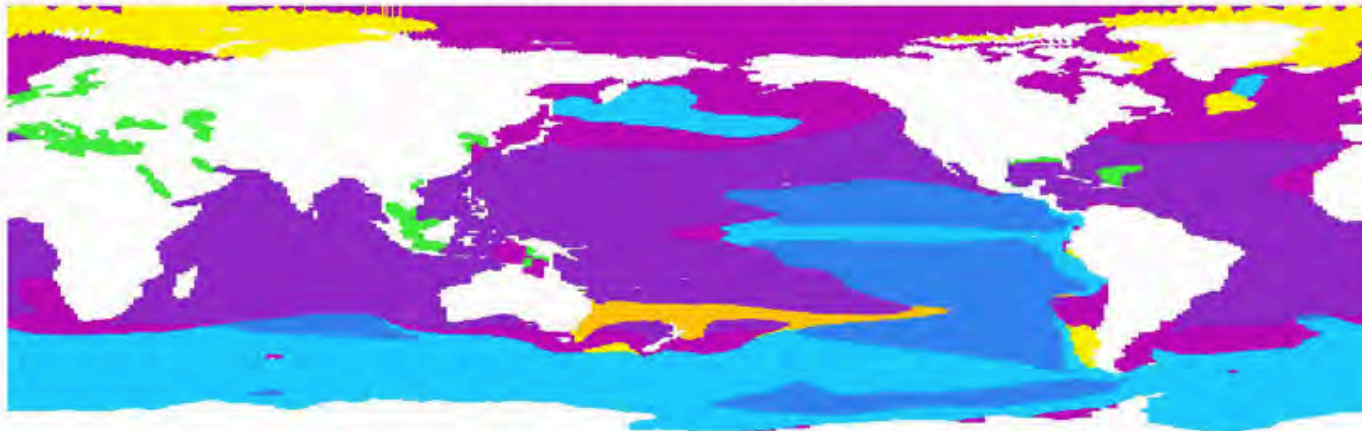
Factors Governing Phytoplankton Competition



Differential growth, nutrient & light limitation, grazing and mortality among PFTs

LeQuere et al. Global Change Biology 2005

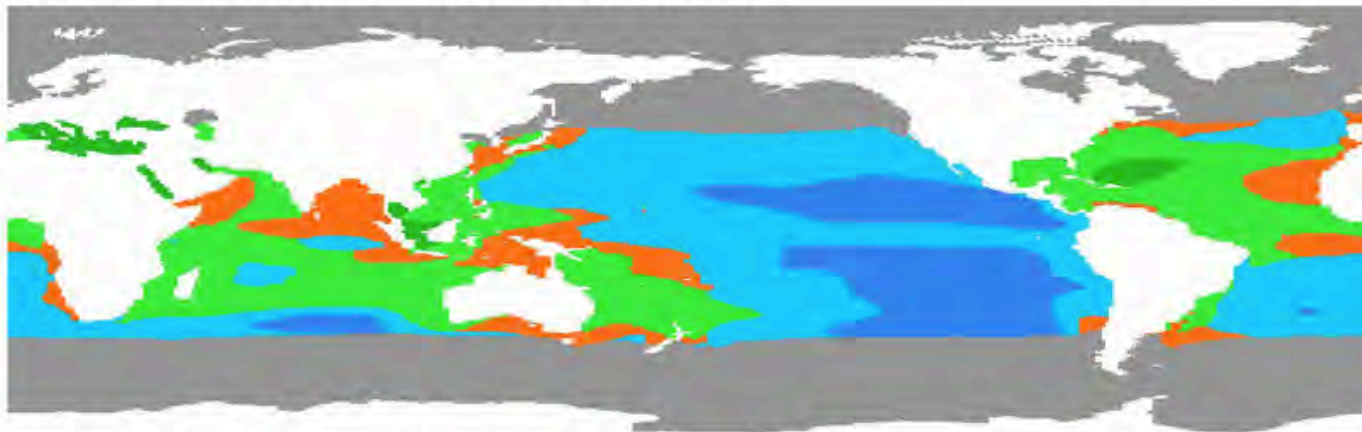
A) Diatom Growth Limitation 1990s



Nitrogen 57.70%, Iron 37.90%, Silica 2.255%, Phosphorus 2.137%
Replete 0.000%

■ Nitrogen ■ Iron ■ Phosphorus ■ Silicon
■ Temperature ■ Replete

C) Diazotroph Growth Limitation

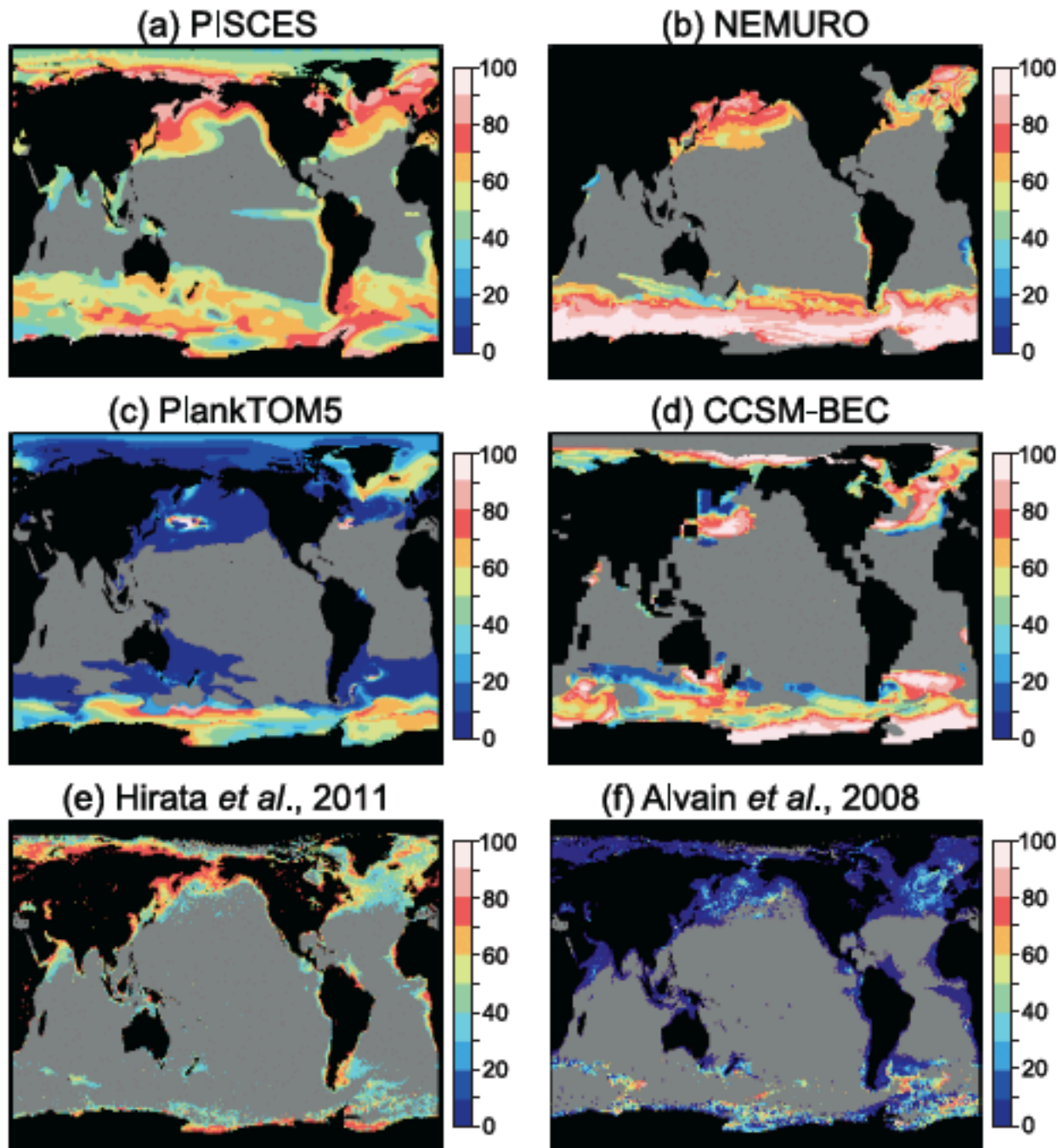


Nitrogen 0.000%, Iron 38.18%, Phosphorus 21.74%
Replete 9.144%, Temperature 30.92%

Nutrient Limitation

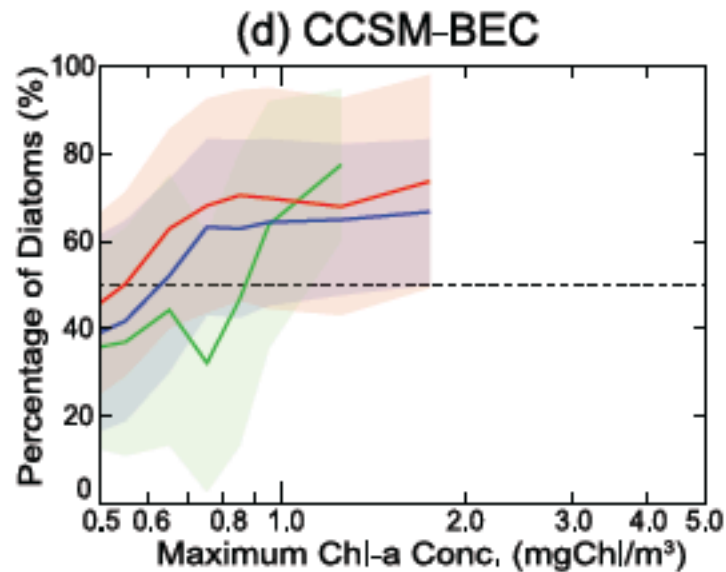
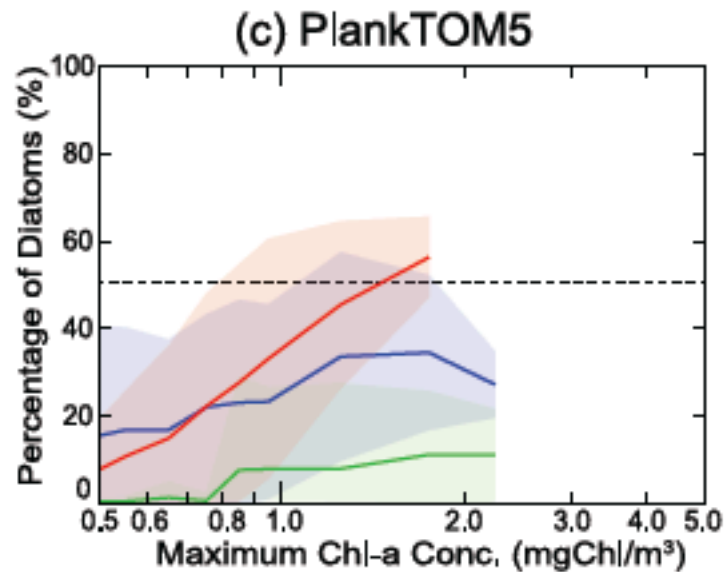
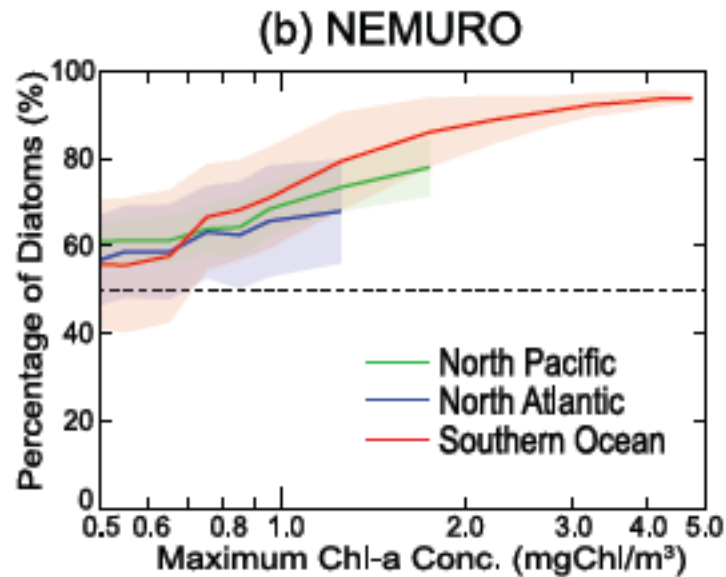
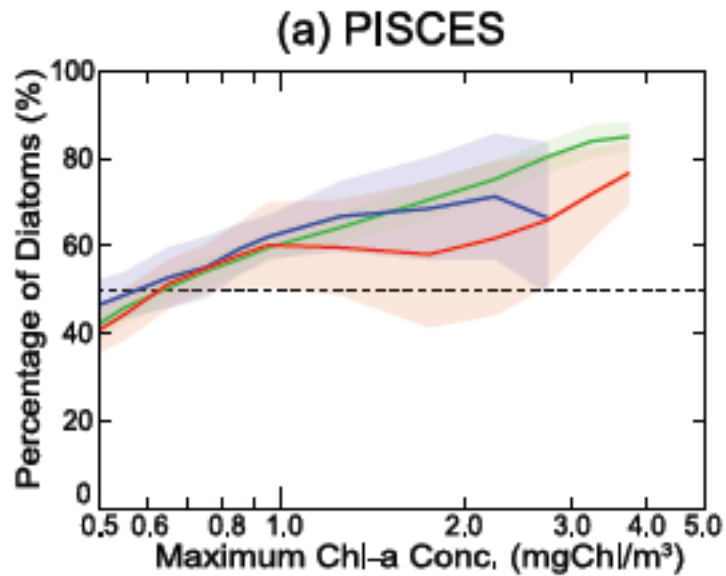
Moore et al.
J. Climate
In press

Diatom Fraction in Blooms



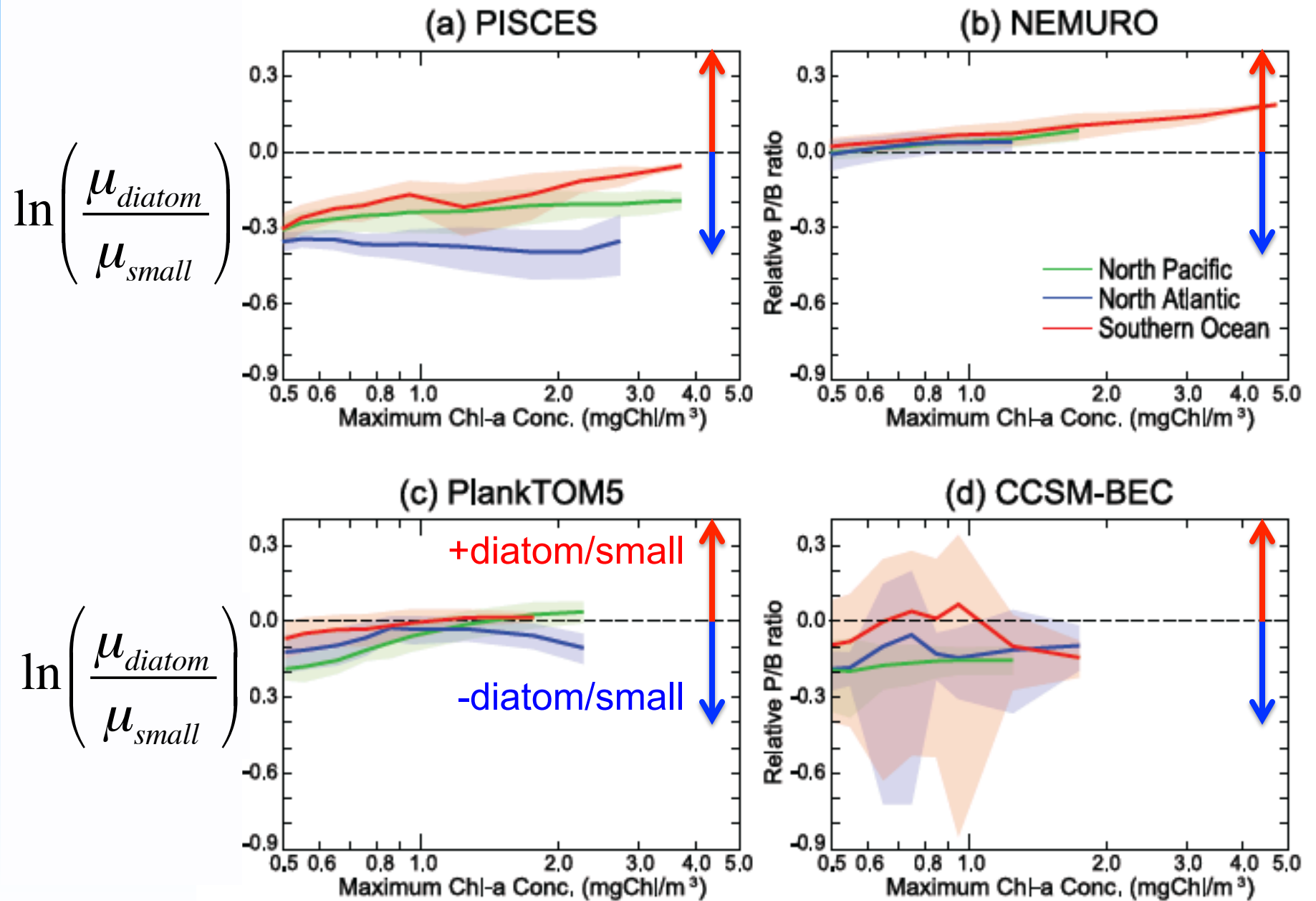
Hashioka et al.
Biogeosciences
submitted

Diatom Fraction vs. Bloom Magnitude



Hashioka et al.
Biogeosciences
submitted

Phytoplankton Growth: Diatom/small Ratio



Summary of Model Factors: Diatom/small Ratio

| | | PISCES | NEMURO | PlankTOM5 | CCSM-BEC |
|-----------|------------------------|------------------|--------------------|-----------------------|--------------------|
| Bottom-up | V_{\max} | – | UP | UP | – |
| | Nutrient limit. | Down | Down | Down | Down |
| | Light limit. | – * | – | Down (NA) | UP (NA, SO) |
| | Temp. dep. | – | – | – | – |
| Top-down | Grazing by Zooplankton | Microzoo. UP | Microzoo. UP | Microzoo. UP | Generic zoo. UP |
| | | Mesozoo. Down | Meso/Macro Down | Mesozoo. Down (NP) | |

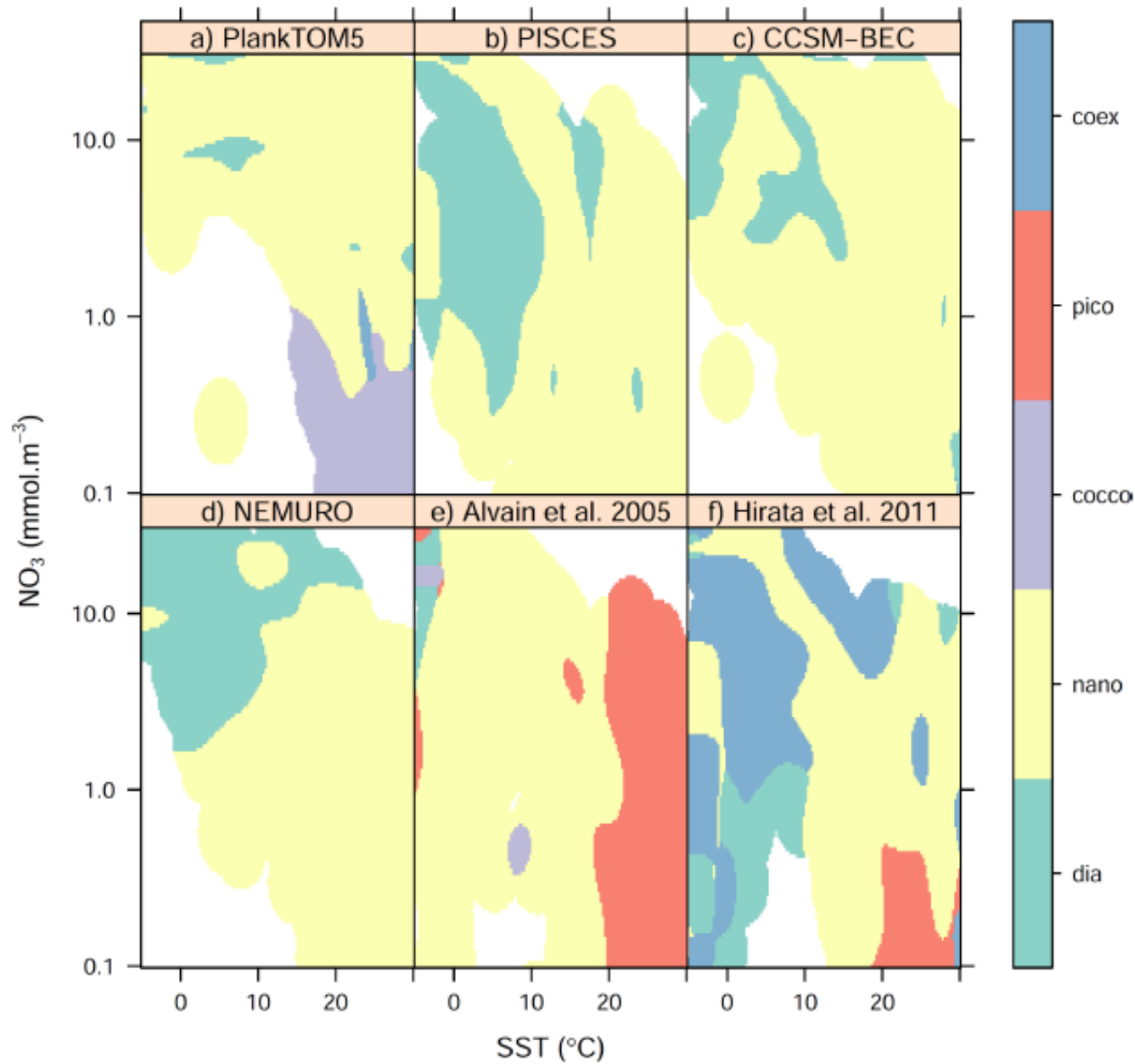
+diatom/small

-diatom/small

Hashioka et al.
Biogeosciences
submitted



Plankton Niches



Dominant
Phytoplankton
Group

Voigt et al.
Biogeosciences
In prep.



Model Food-webs & Interaction Strengths

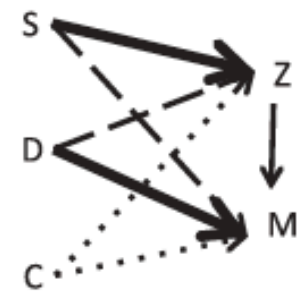
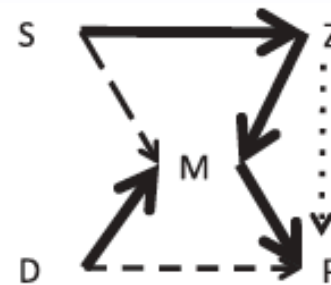
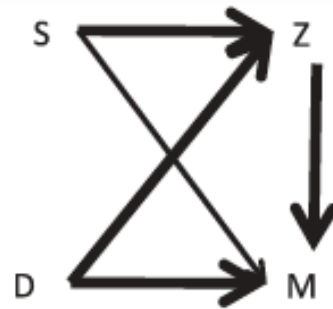
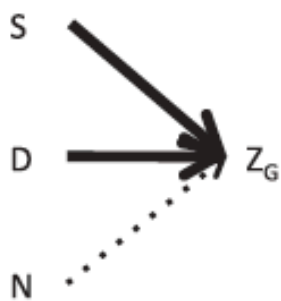
CCSM

PISCES

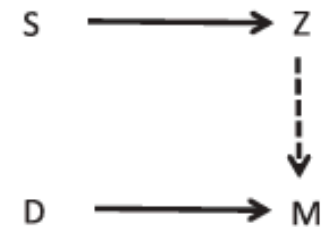
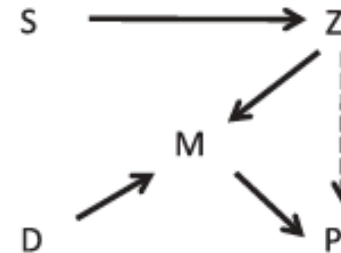
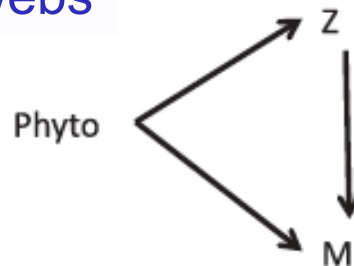
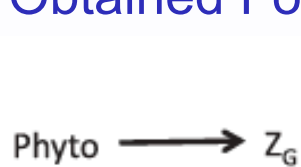
NEMURO

PlankTOM5

Intended Food-webs (heavy lines strong interactions)



Obtained Food-webs

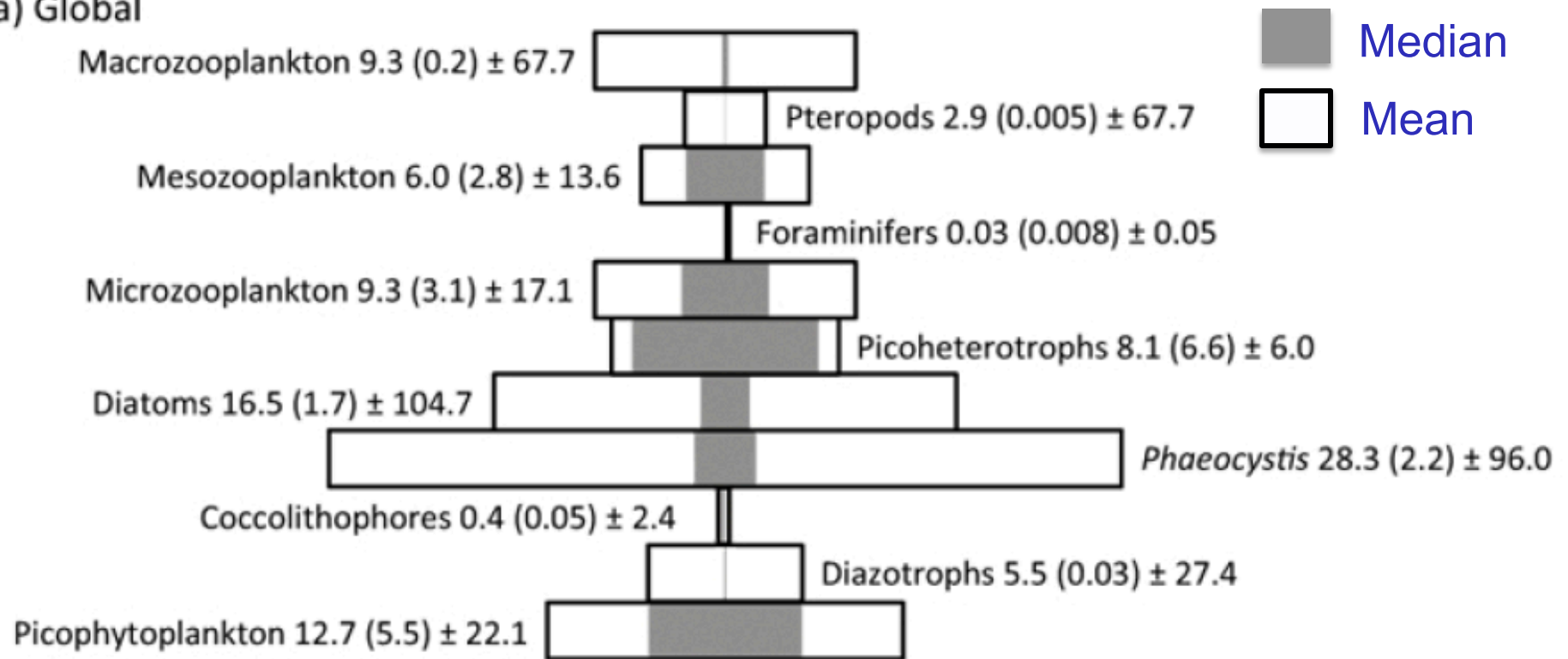


Sailley et al.
Ecological Modelling
2013



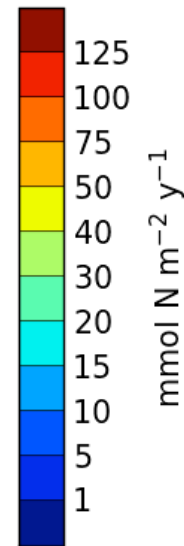
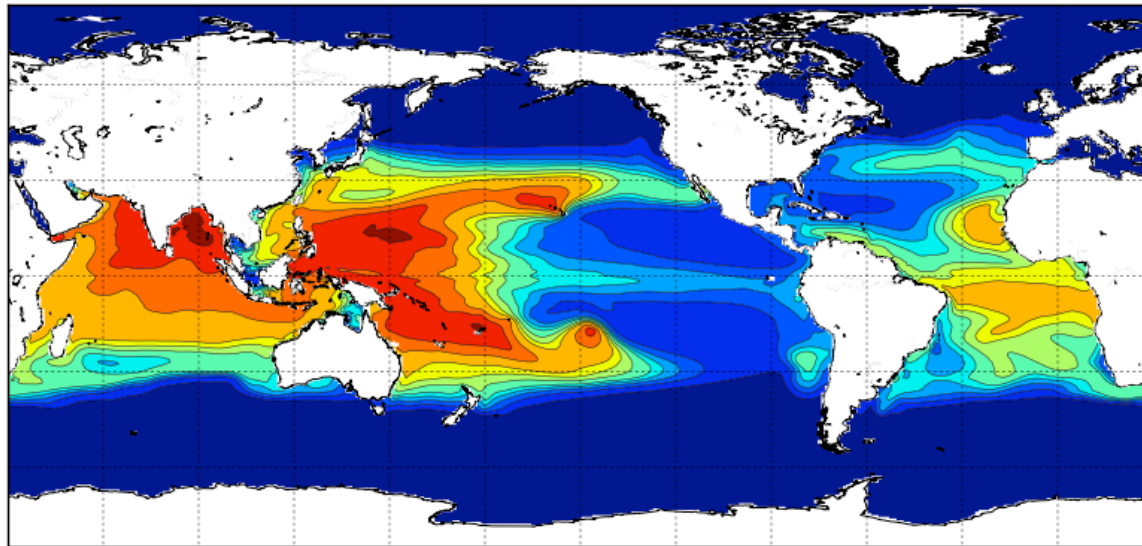
MAREDAT - Towards a world atlas of MARine ecosystem DATa

(a) Global



Buitenhuis et al.
 Earth System Science Data 2013

Total Diazotrophs Nitrogen Fixation = 129.69 Tg N y⁻¹



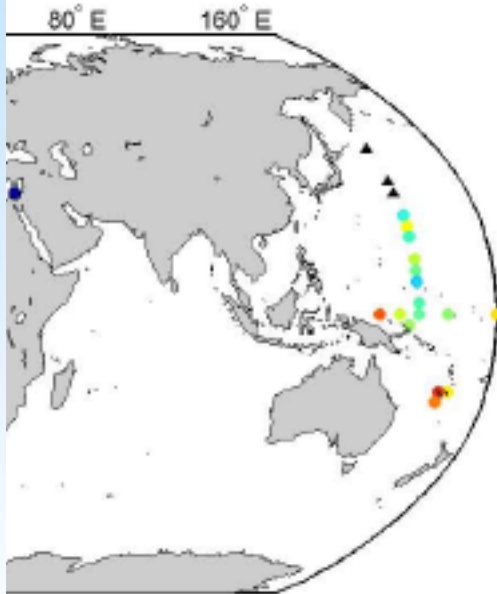
Nitrogen Fixation Rate

Lou et al.
Earth System
Sci. Data
2012

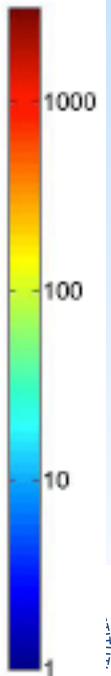
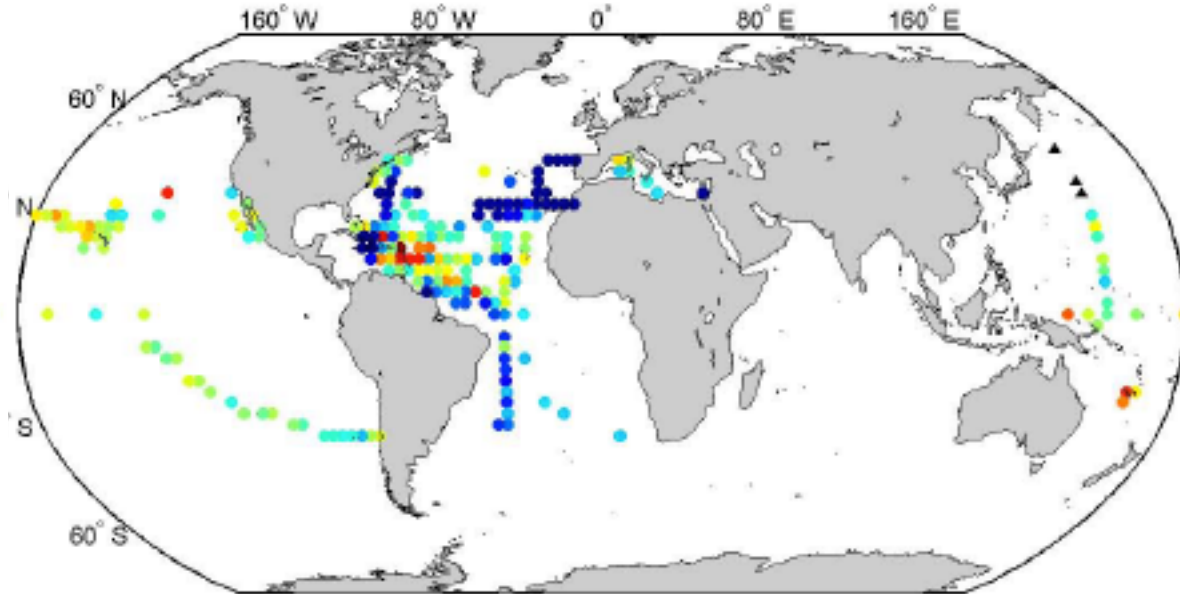
GECO.IAF.20th.x1.CESM1.001

1998-2007

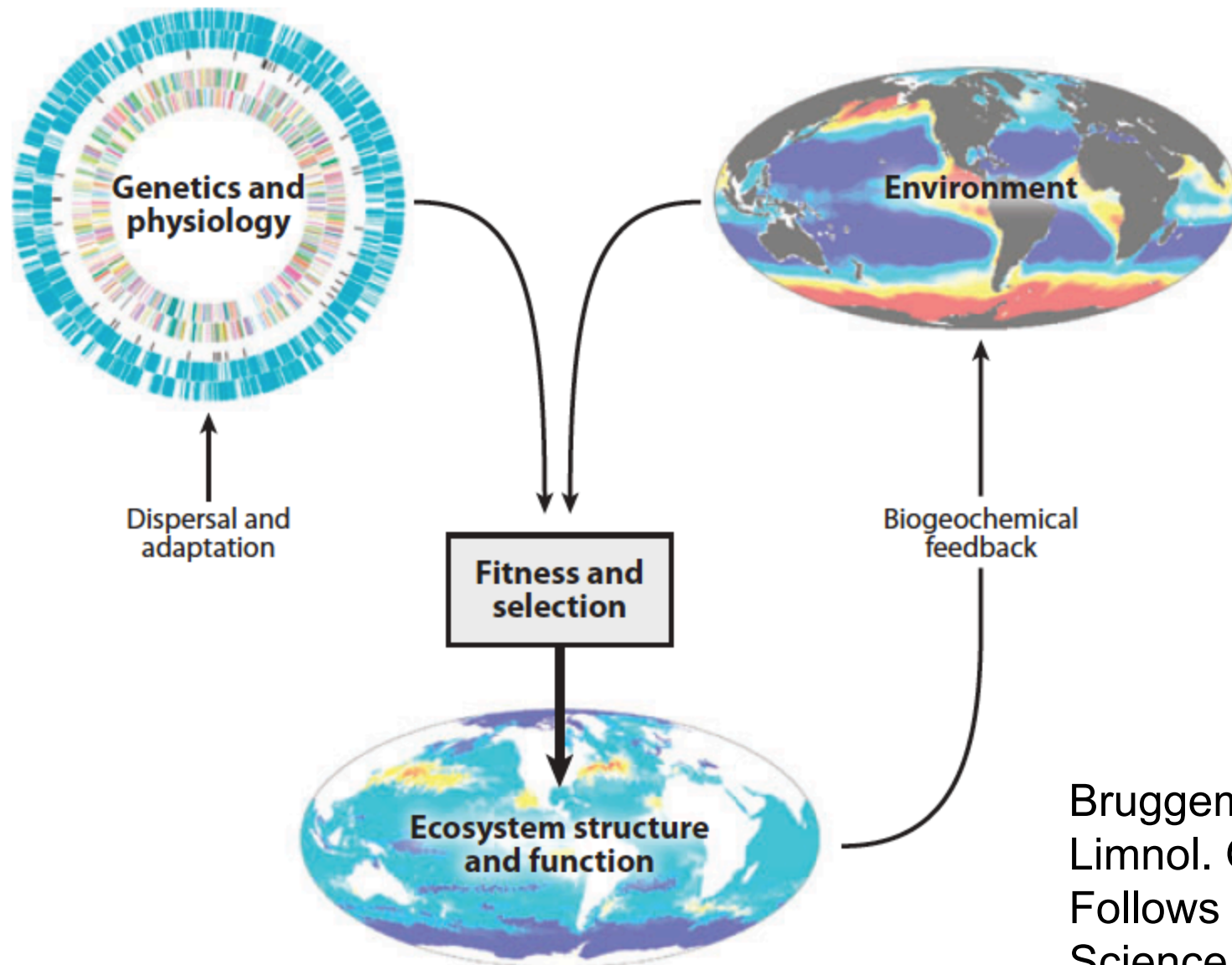
Fixation Rates ($\mu\text{mol N m}^{-2} \text{d}^{-1}$)



Geometric Mean Depth-Integrated N₂ Fixation Rates ($\mu\text{mol N m}^{-2} \text{d}^{-1}$)

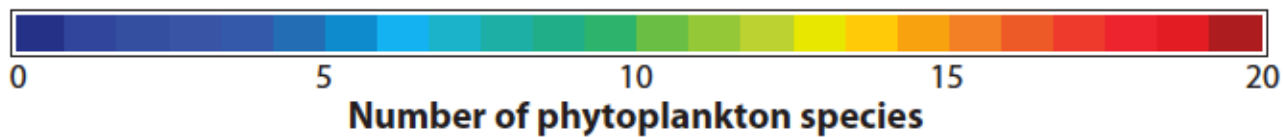
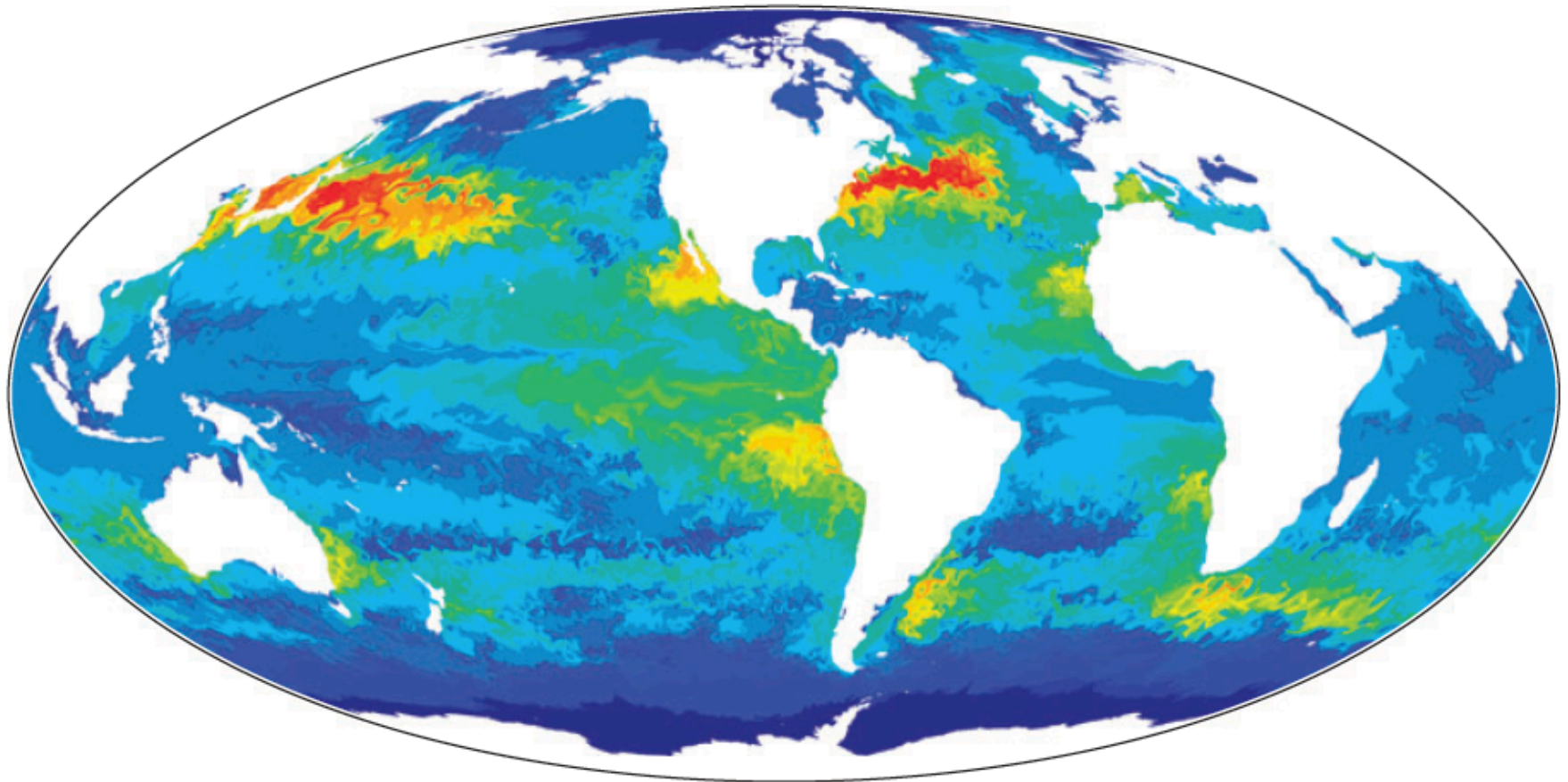


Everything is Everywhere but Environment Selects



Bruggeman & Kooijman
Limnol. Ocean. 2007
Follows et al.
Science 2007

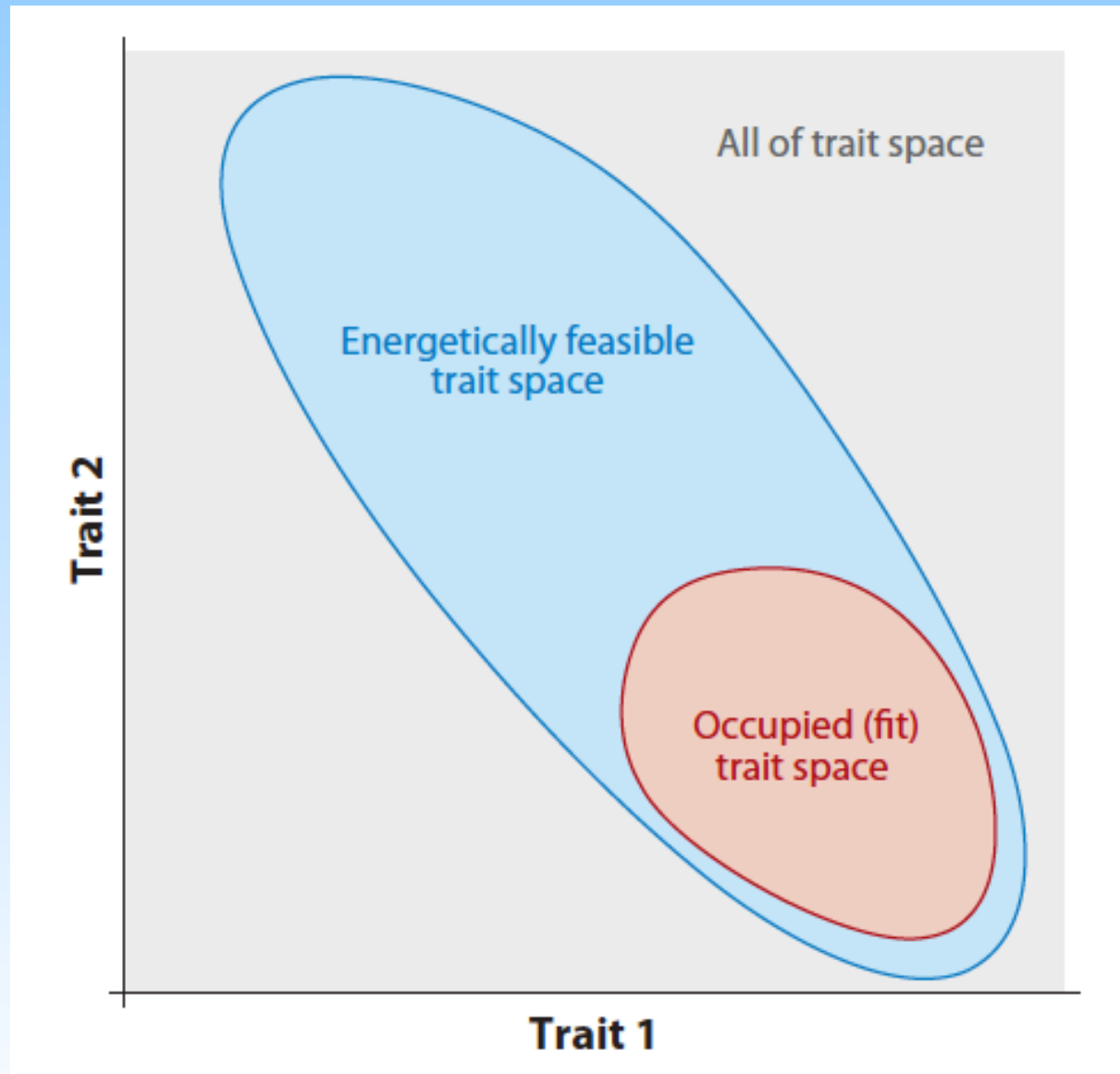
Biodiversity & Biogeography



Barton et al. Science 2010

Follows & Dutkiewicz Ann. Rev. Mar. Sci. 2011

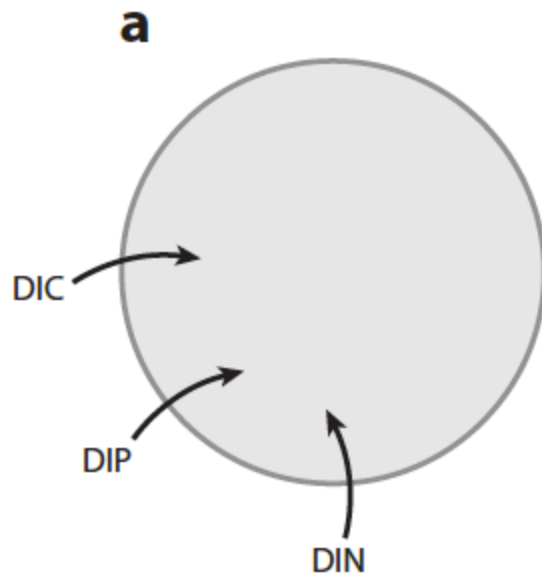
Trait-based Modeling & Energetic Trade-offs



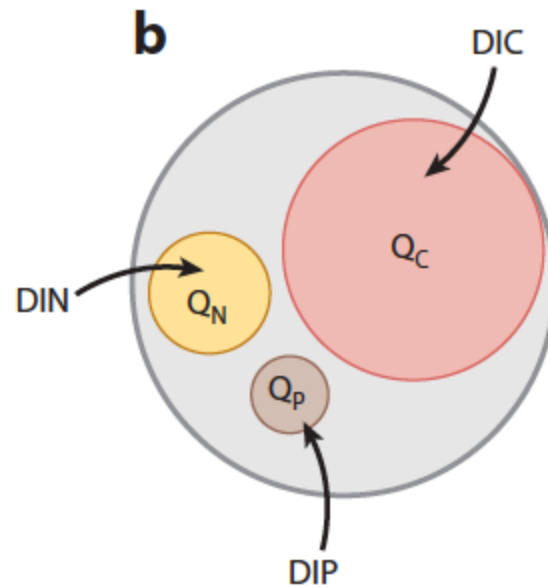
Litchman et al.
Ecol. Lett. 2007
Litchman & Klausmeier
Annu. Rev. Ecol. Evol.
Syst. 2008

Cell Physiology/Allocation Modeling

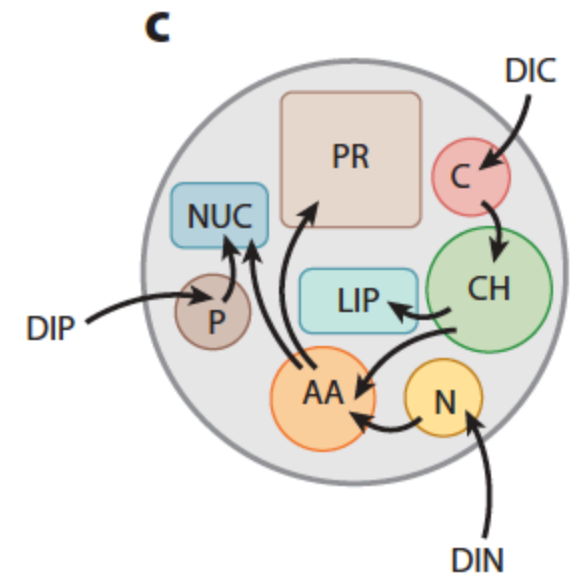
Monod Uptake



Droop Quota

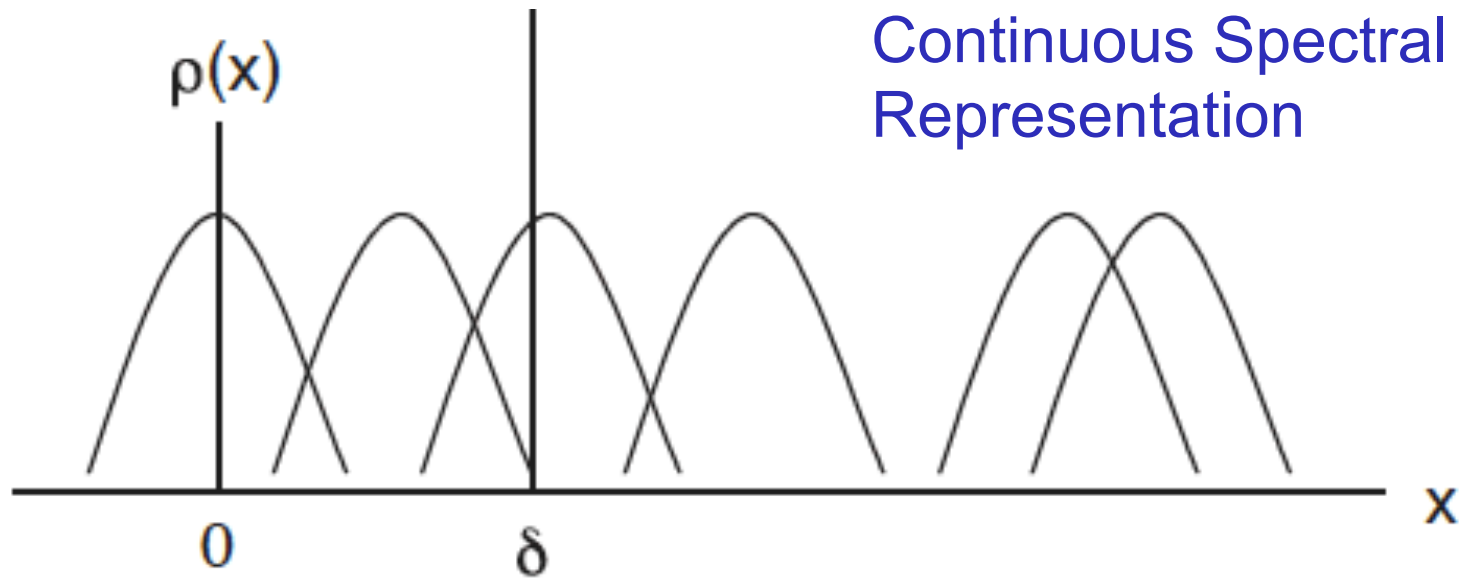
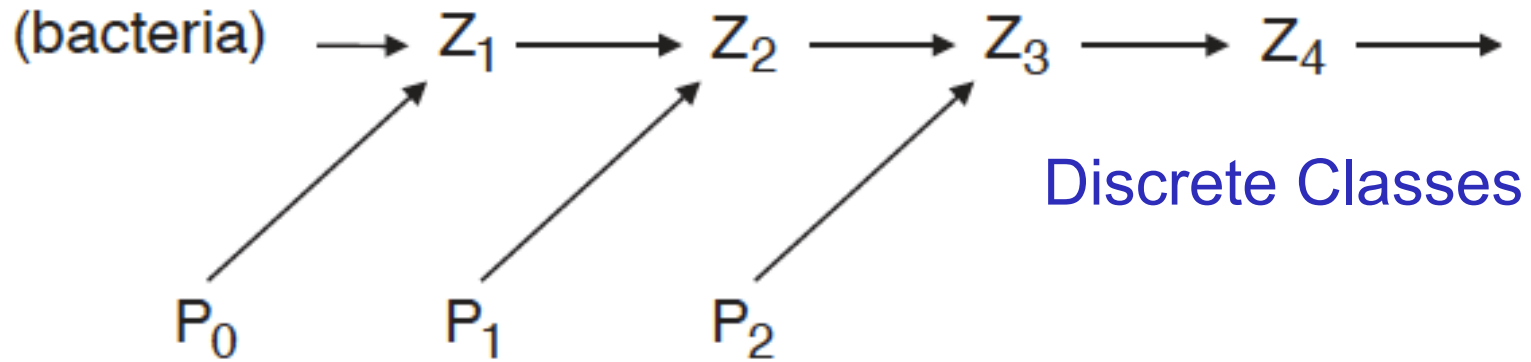


Biochemical Components



Shuter J. Theor. Biol. 1979
Klausmeier et al. Nature 2004
Follows & Dutkiewicz
Ann. Rev. Mar. Sci. 2011

Discrete versus Continuous Size Classes



Size

Armstrong Deep-Sea Res. II 2003



BIG SCIENCE



LITTLE SCIENCE

