Augmenting earth system models to capture global-scale energy flows through the planktonic food web to fish

Effects of Climate Change on the World's Oceans

Yeosu, Korea

May 17, 2012

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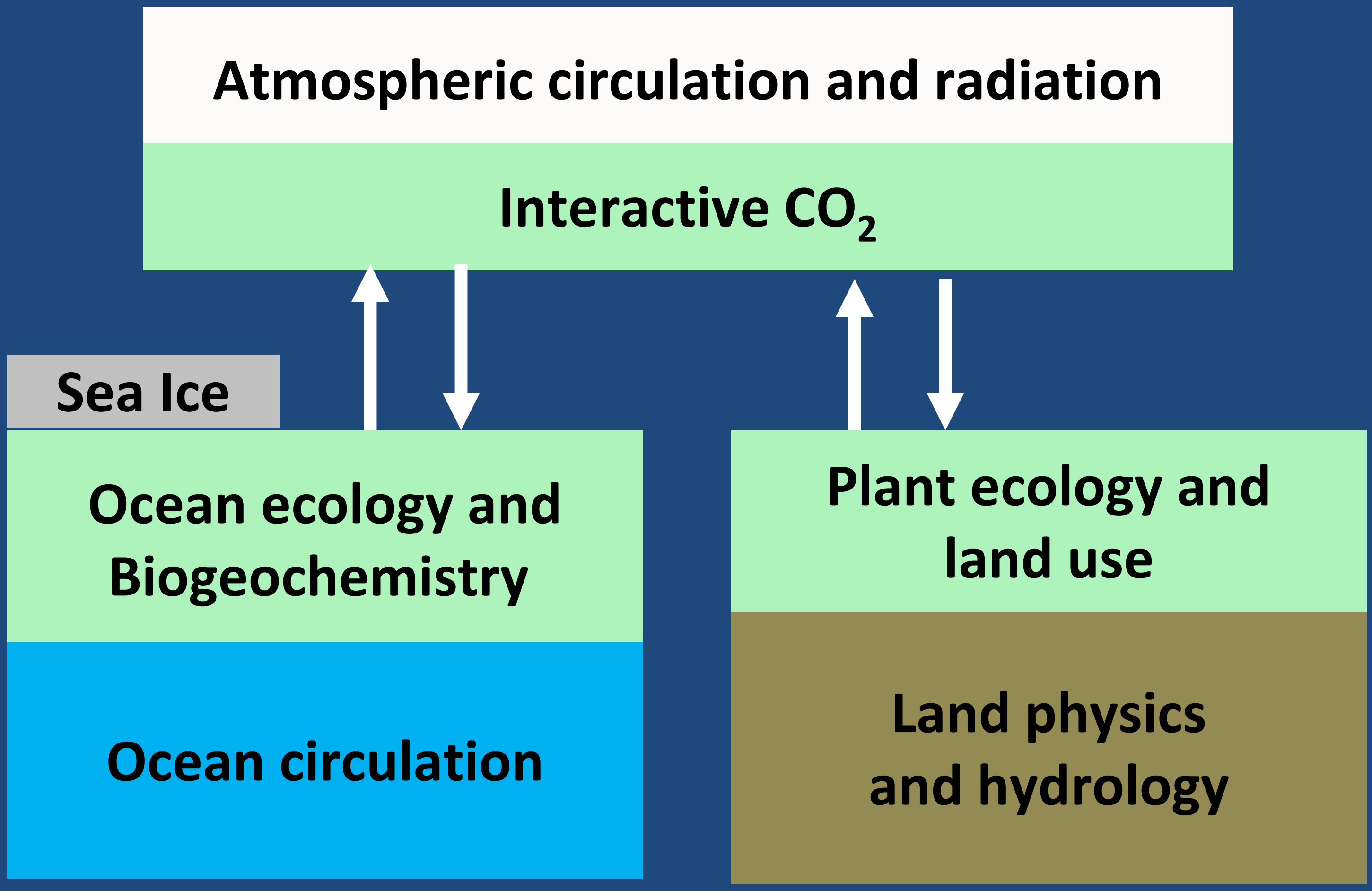
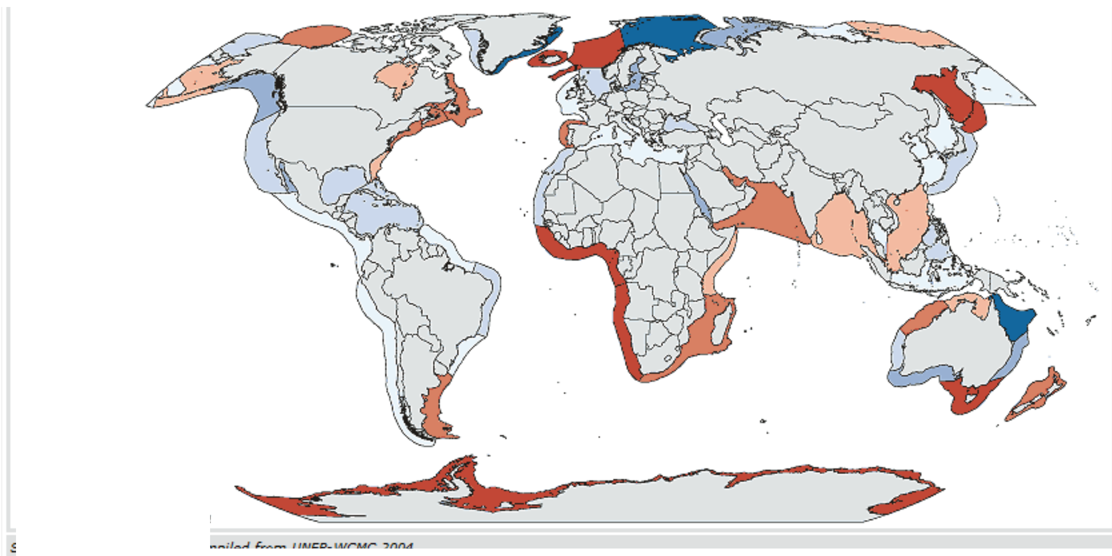
Earth System Models: adding the biosphere to global climate simulations



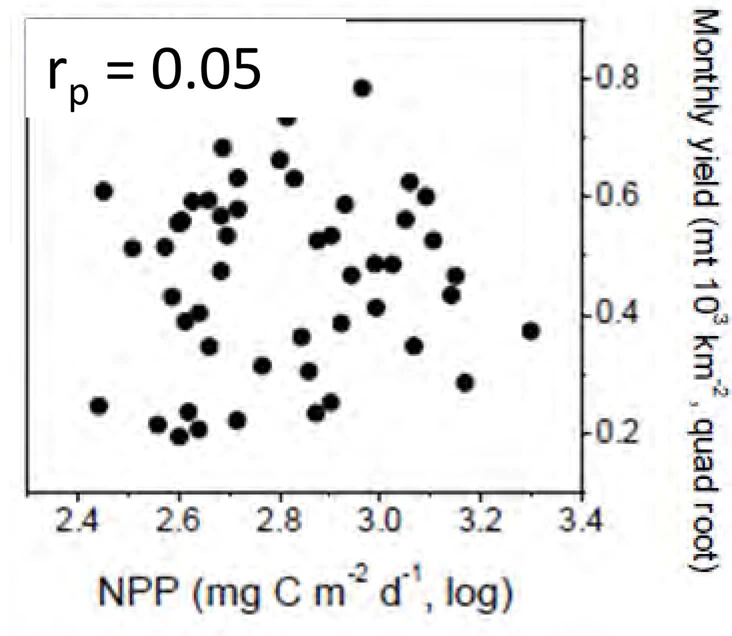
- ESMs emphasize computationally-efficient resolution of broad-scale carbon and nutrient fluxes

- This often results in coarse resolution and validation of planktonic food web dynamics, which:
  - Limits the mechanistic resolution of biogeochemical processes
  - Limits the utility of ESMs for assessing the impact of climate on living marine resources

Primary production is a poor indicator of global-scale fisheries yields



Large Marine Ecosystems



Primary production is undoubtedly linked to fisheries production, but the relationship is complex!

Friedland et al., 2012, PLoS-ONE 7(1)

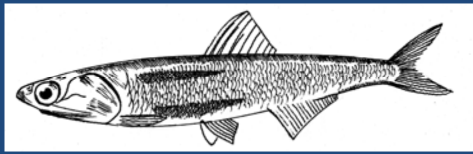
The COBALT (Carbon, Ocean Biogeochemistry and Lower Trophics) model objectives:

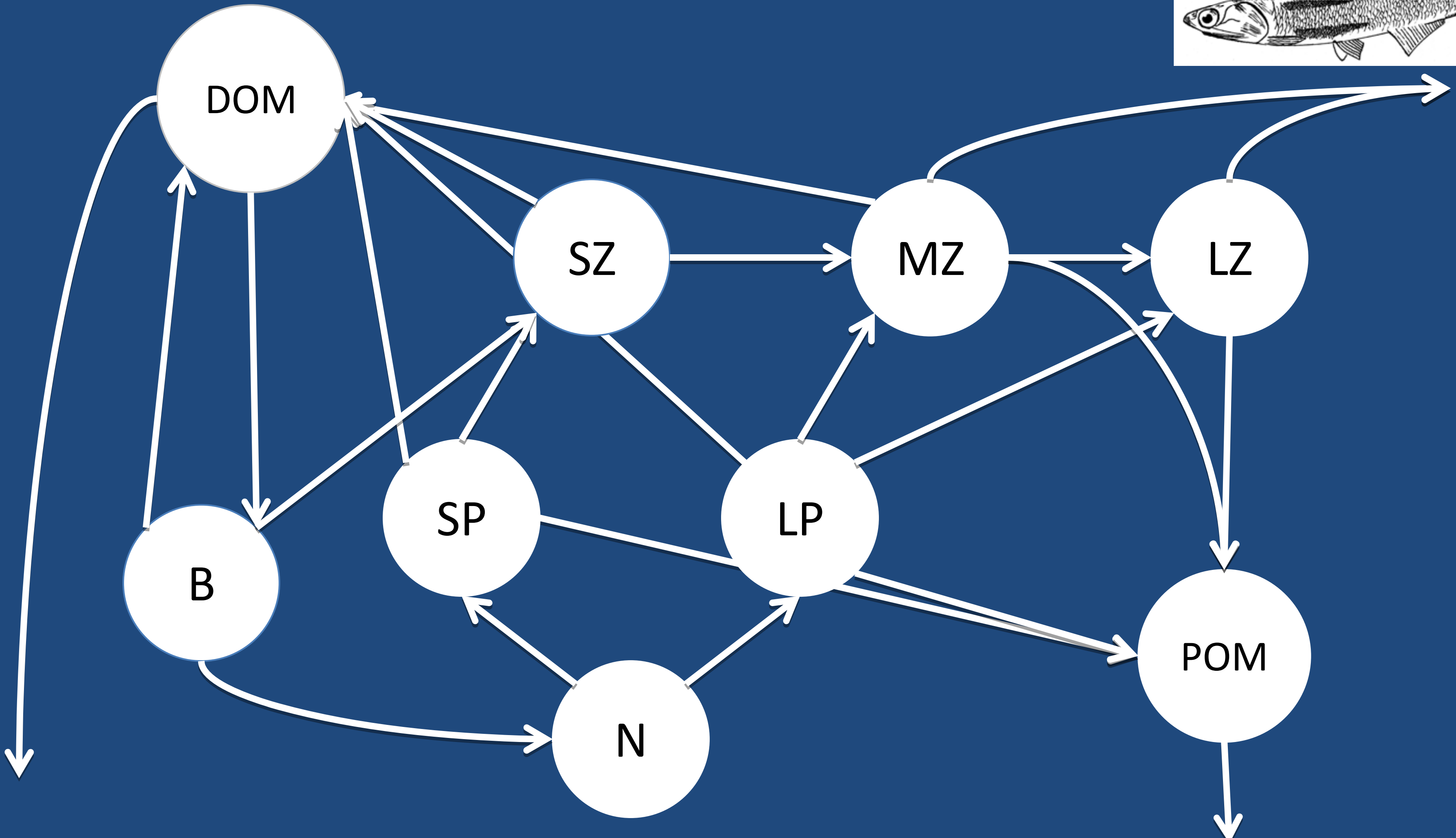
- Capture interactions between climate and the ocean’s global nutrient and carbon cycles with a more highly-resolved, mechanistic representation of the planktonic ecosystem

- Capture the impact of climate on broad-scale patterns in the flow of energy through the planktonic foodweb to fisheries and other living marine resources.

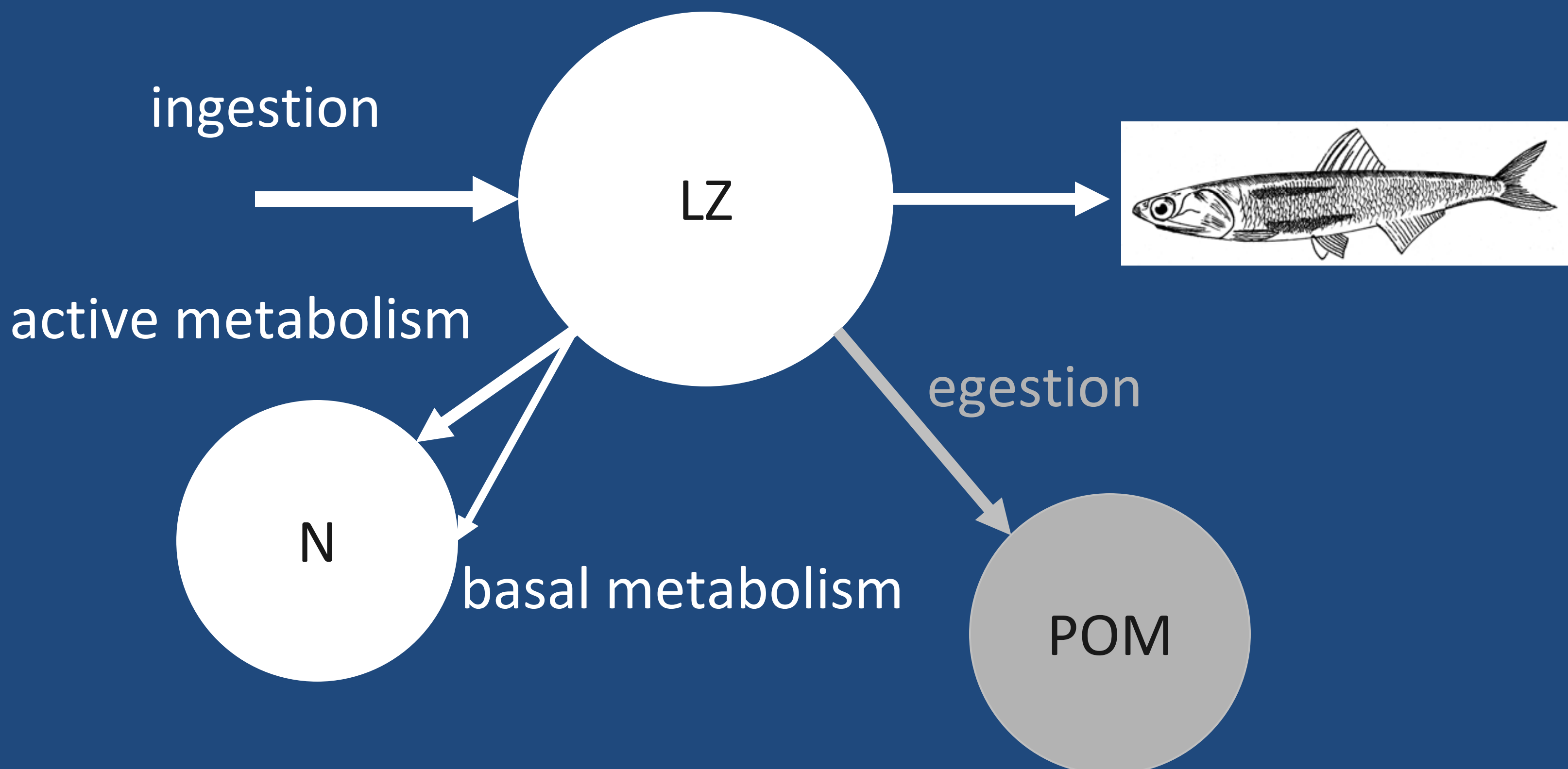
Stock et al., in preparation

Planktonic food web structure (simplified)





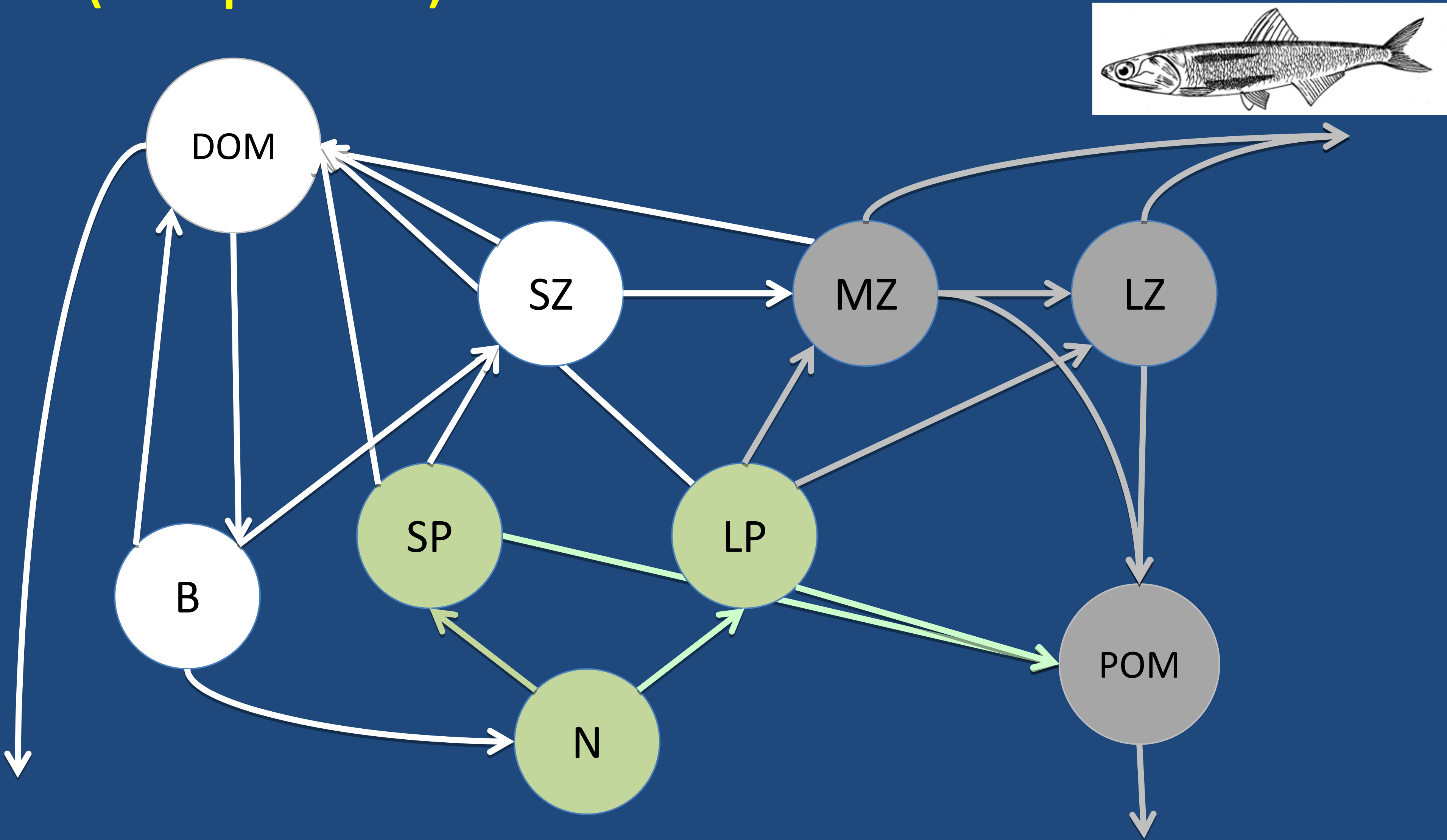
Simple representation of consumer bioenergetics



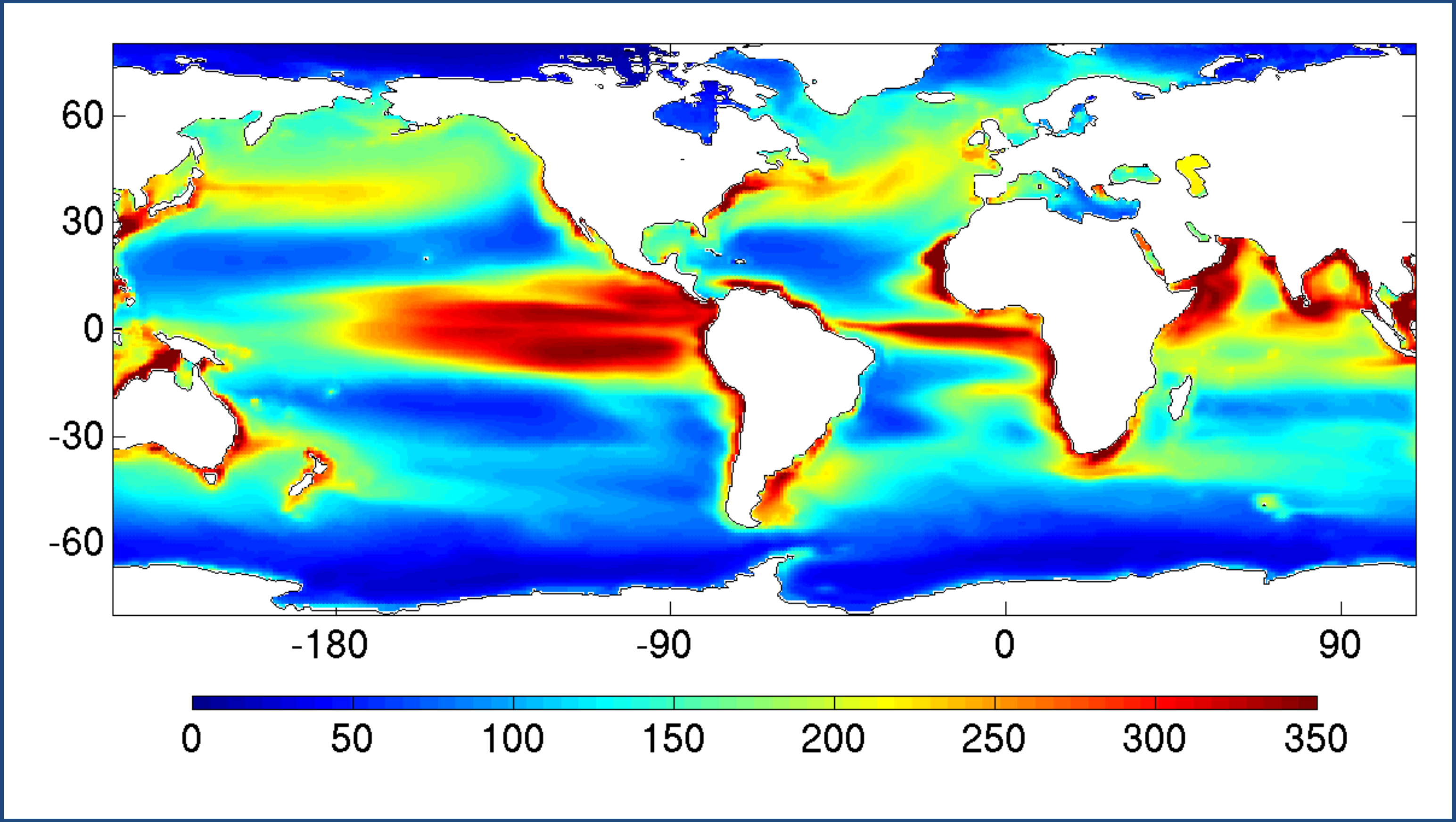
Over-arching aspects of the parameterization of food web dynamics

- Rely as much as possible on empirical and theoretical constraints (e.g., allometric relationships)
- Enlist a pragmatic approach for calibrating particularly uncertain parameters to broad-scale emergent patterns (Stock and Dunne, 2010)

Planktonic food web structure (simplified)



Primary production (g C yr^{-1}; total = 55.7 Pg C yr^{-1})
(CORE-forced hindcast; 100 year spin-up; last 20 years)



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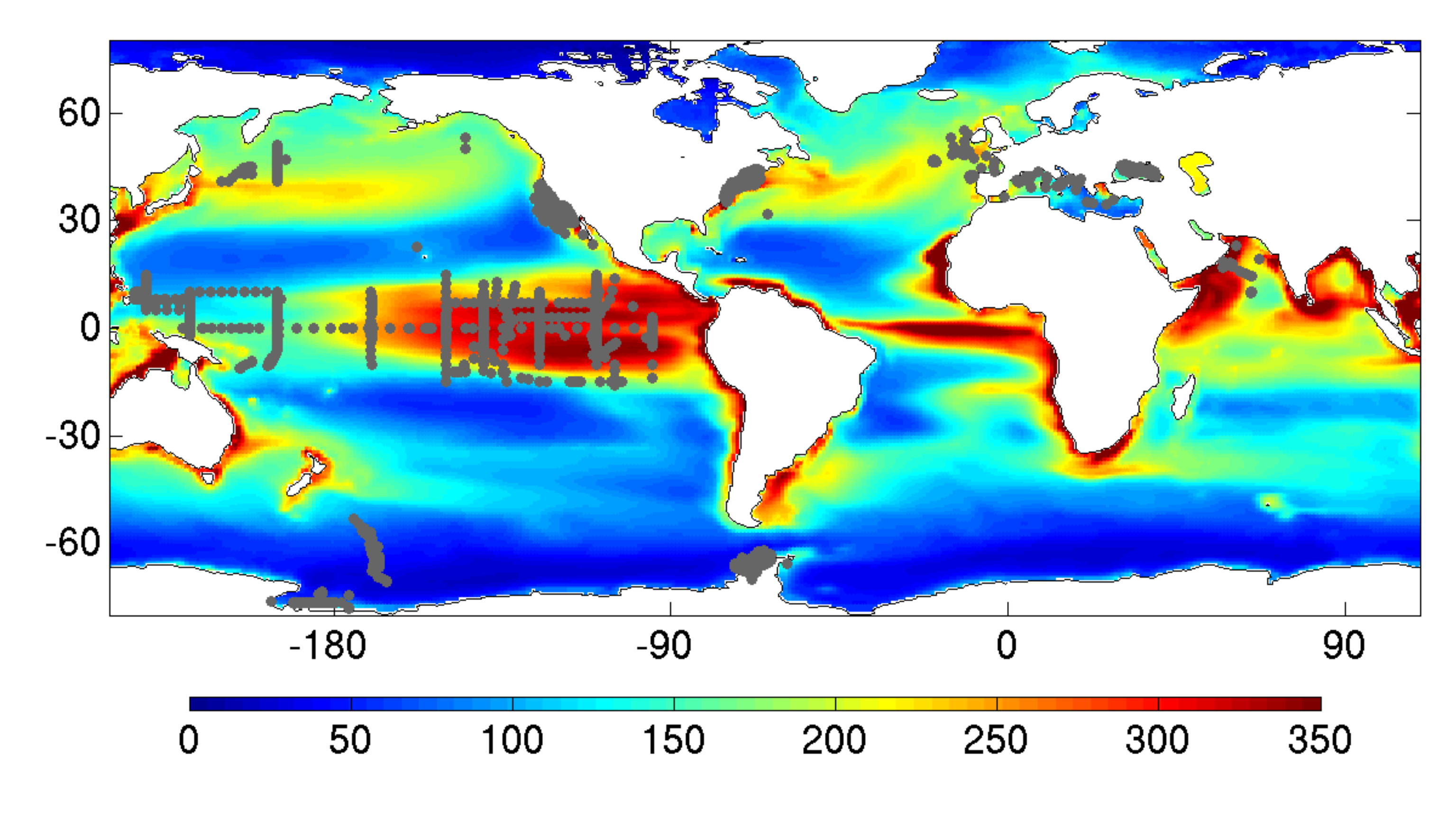
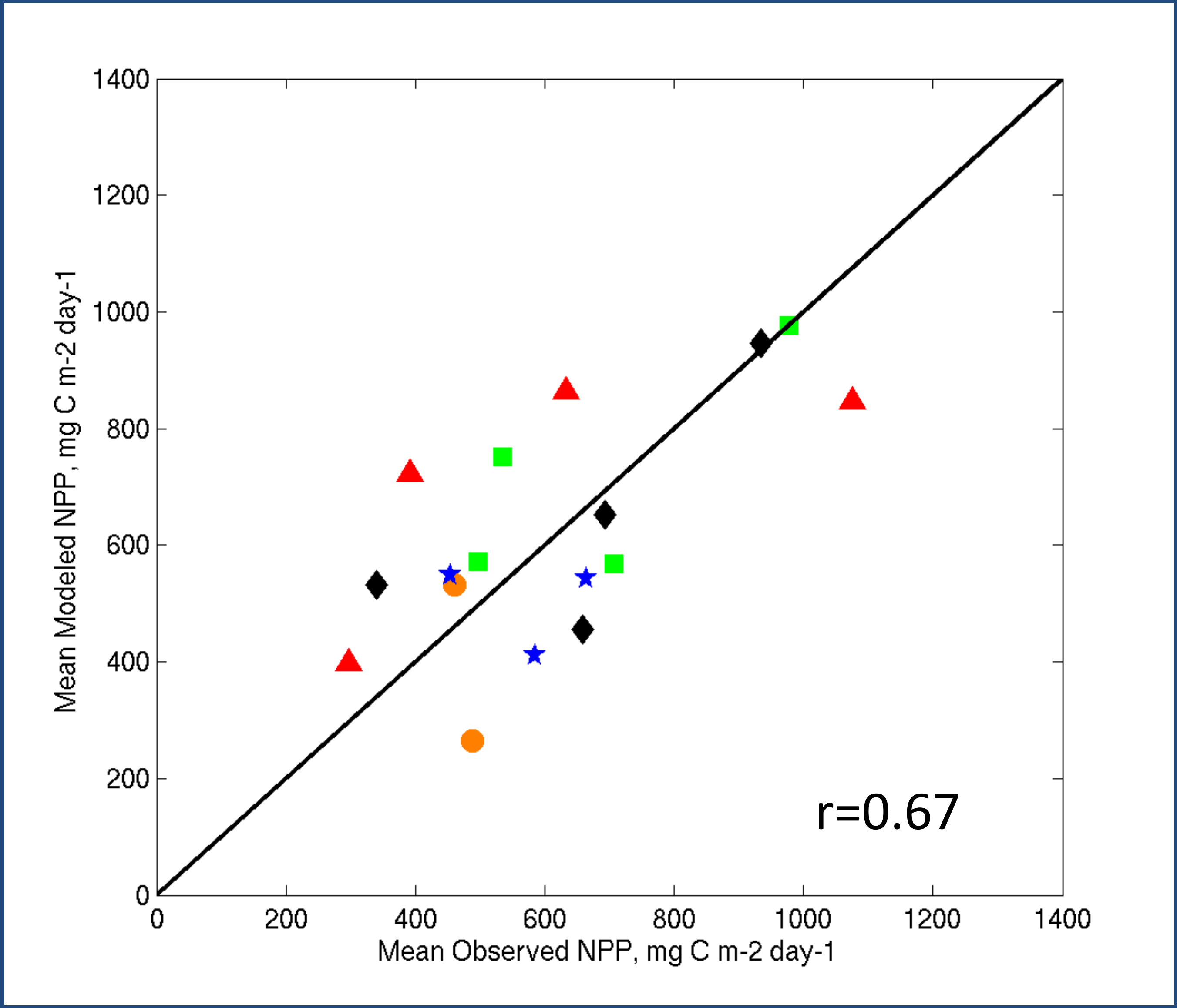
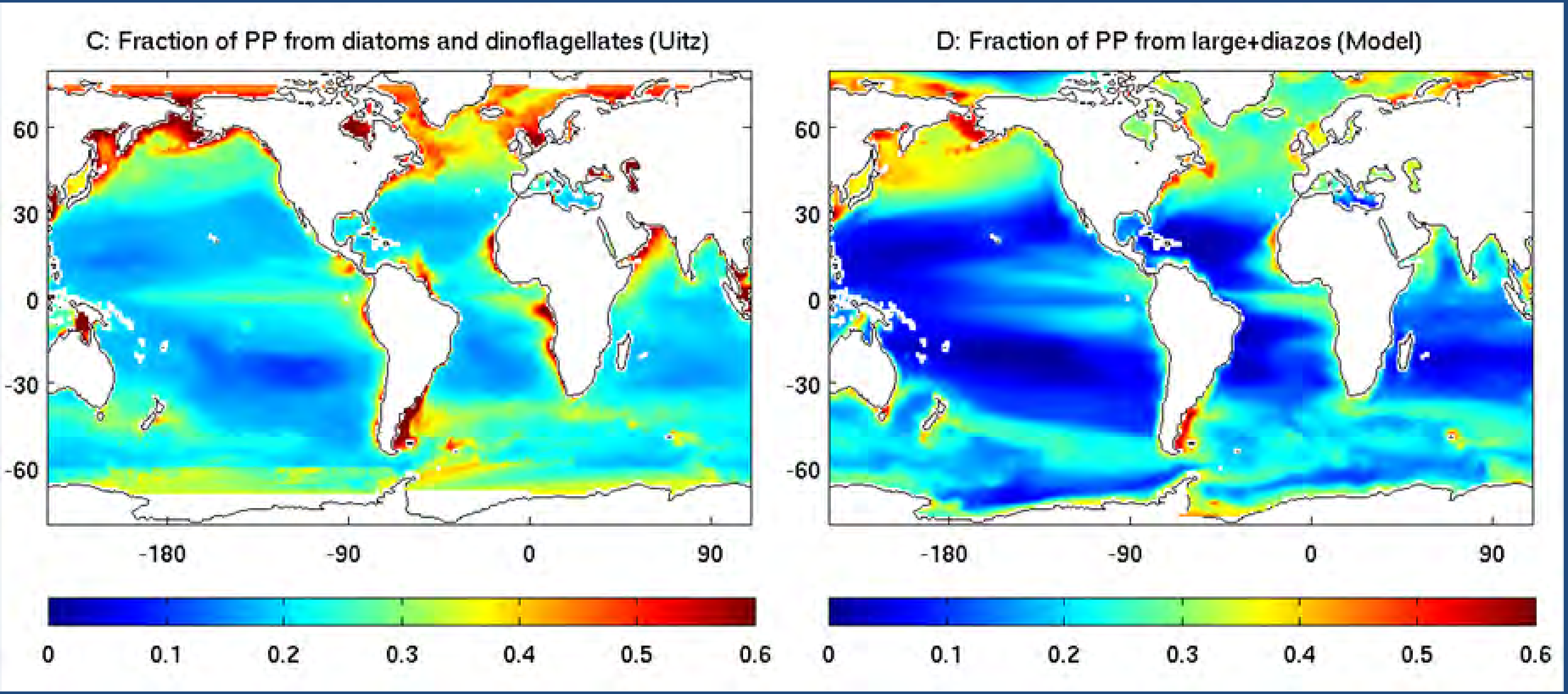


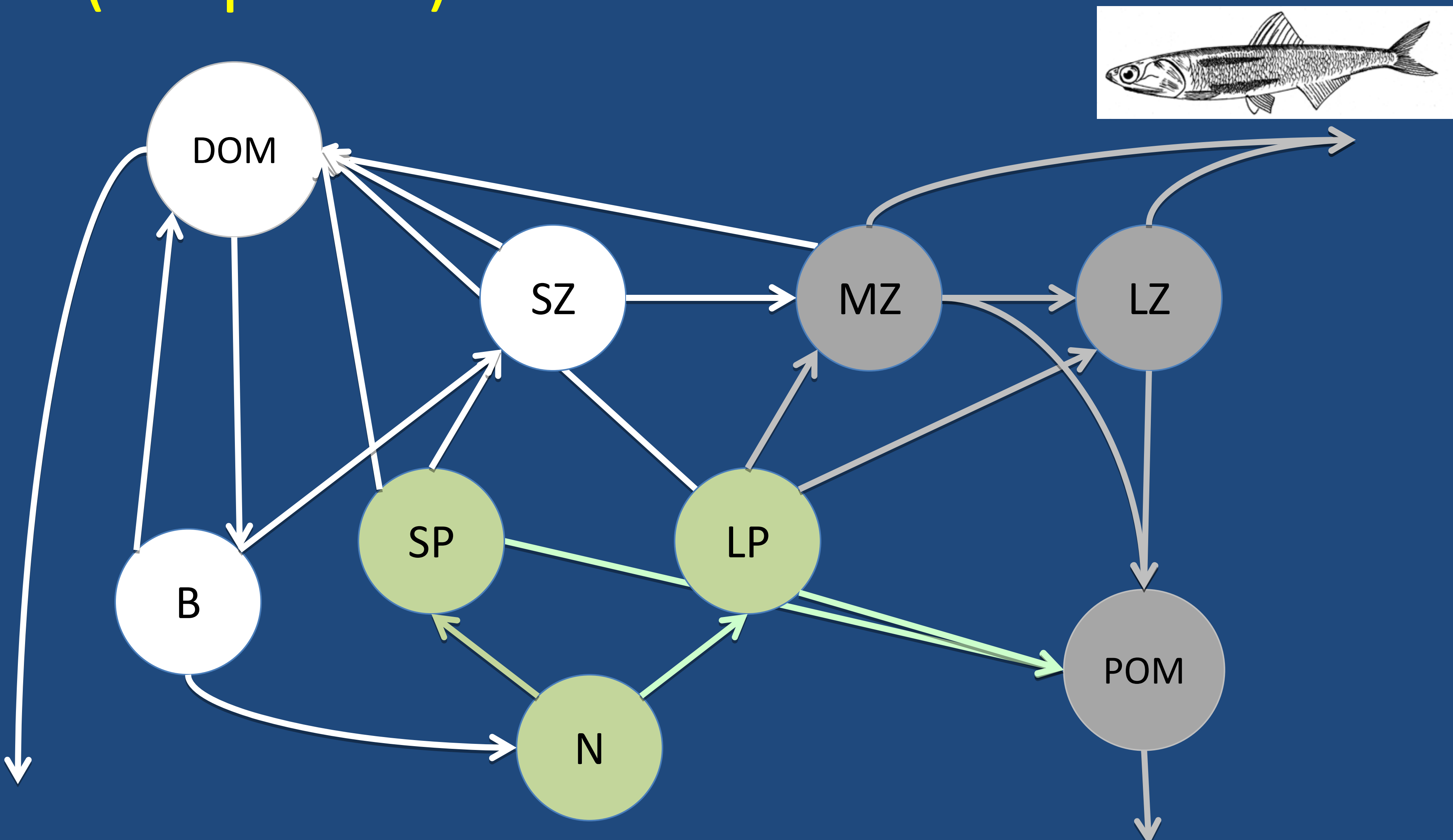
COBALT captures observed differences in mean productivity across different ocean provinces



Fraction of primary production from large phytoplankton



Planktonic food web structure (simplified)

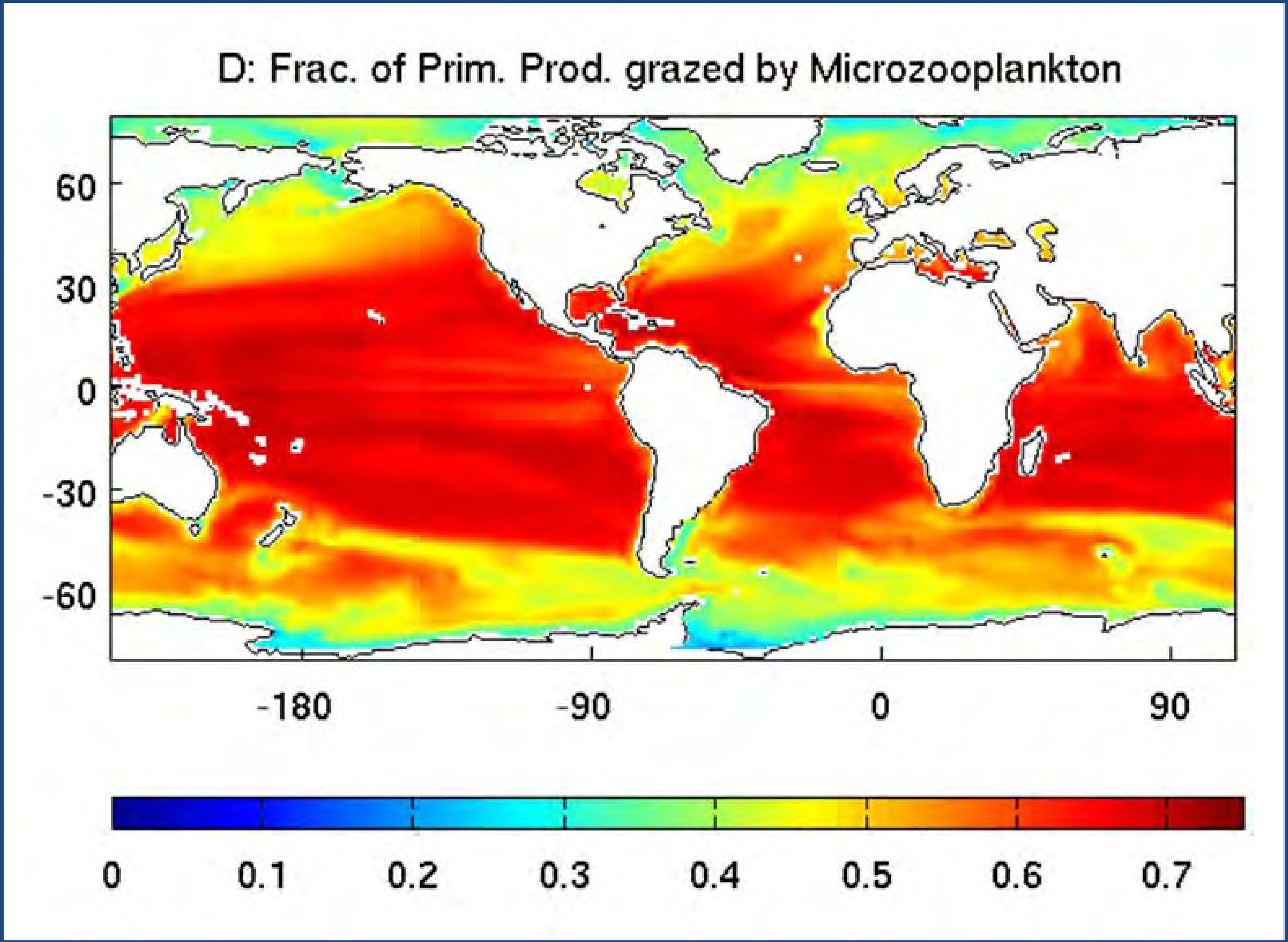


Fraction of primary production consumed by microzooplankton

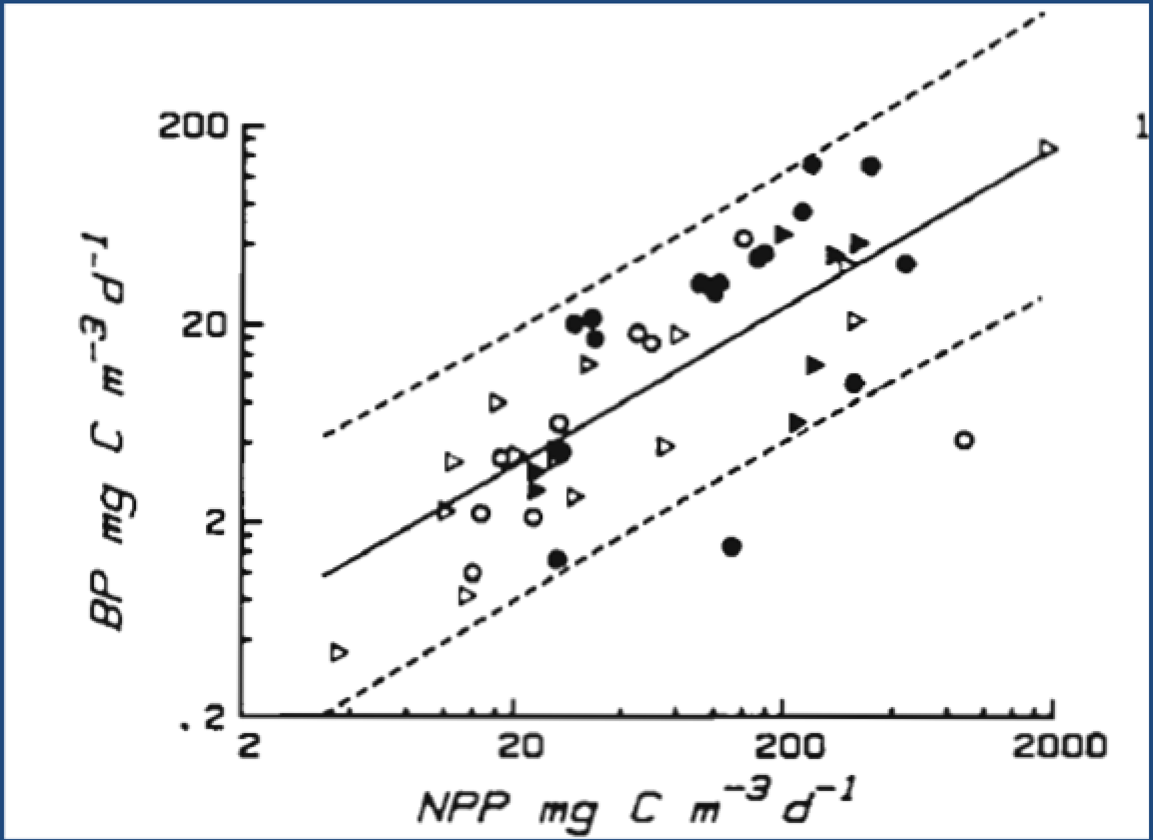
- Tropical/Subtropical: 74.5 (2.0)
- Temperate: 60.8 (1.8)
- Polar: 59.2 (3.3)

Calbet and Landry, L&O, 2004

Modeled microzooplankton grazing



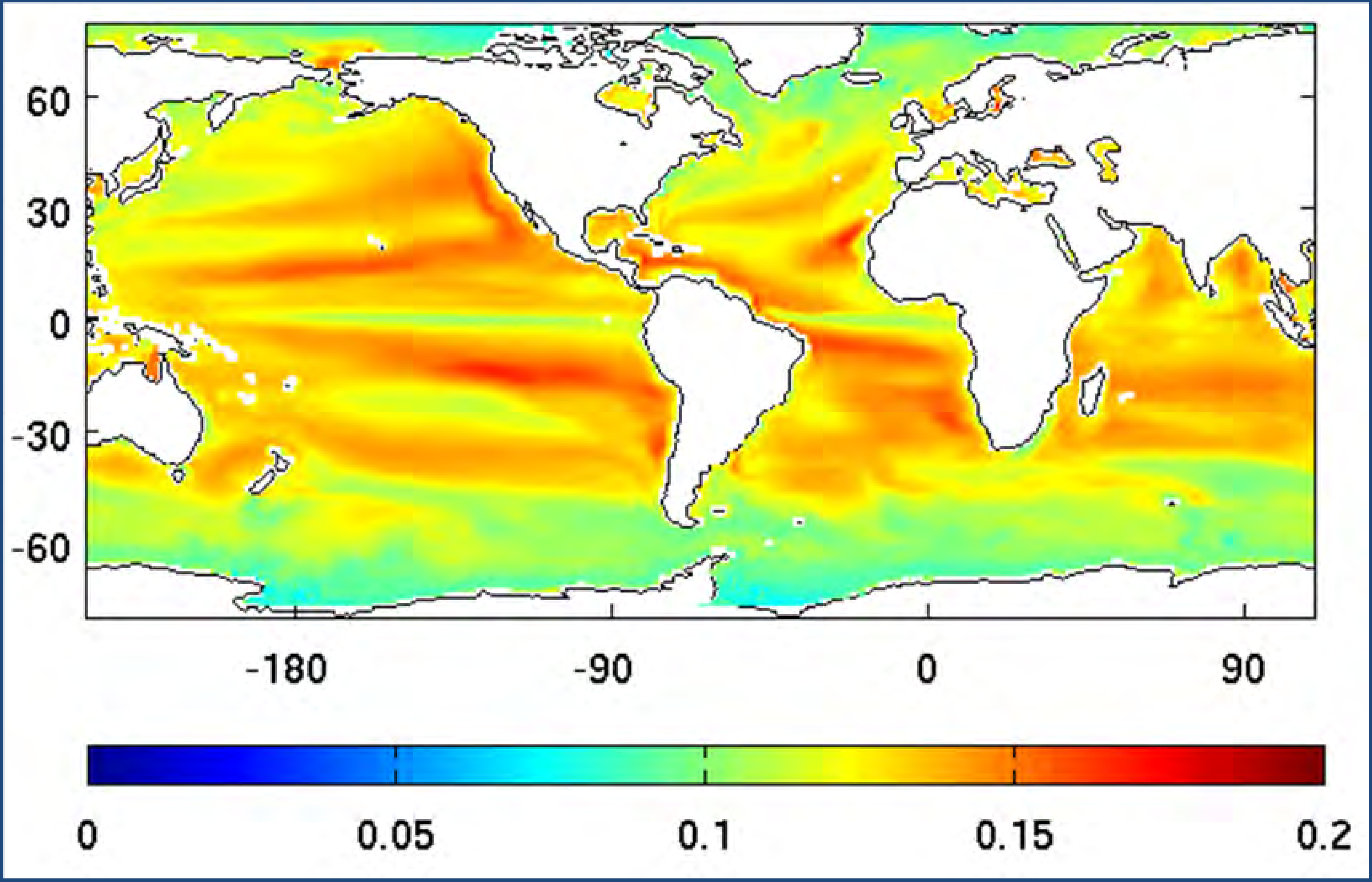
Bacterial production scales with primary production



Cole et al., 1988. Limnol. & Oceanogr., 43, 1-10

- Bacterial Prod. ~ 20% of NPP over range of coastal and estuarine systems
- Ratio may be lower (~10-20%) in oceanic systems, and very low in Southern Ocean (Ducklow, 1999)

Bacterial Production/Primary Production

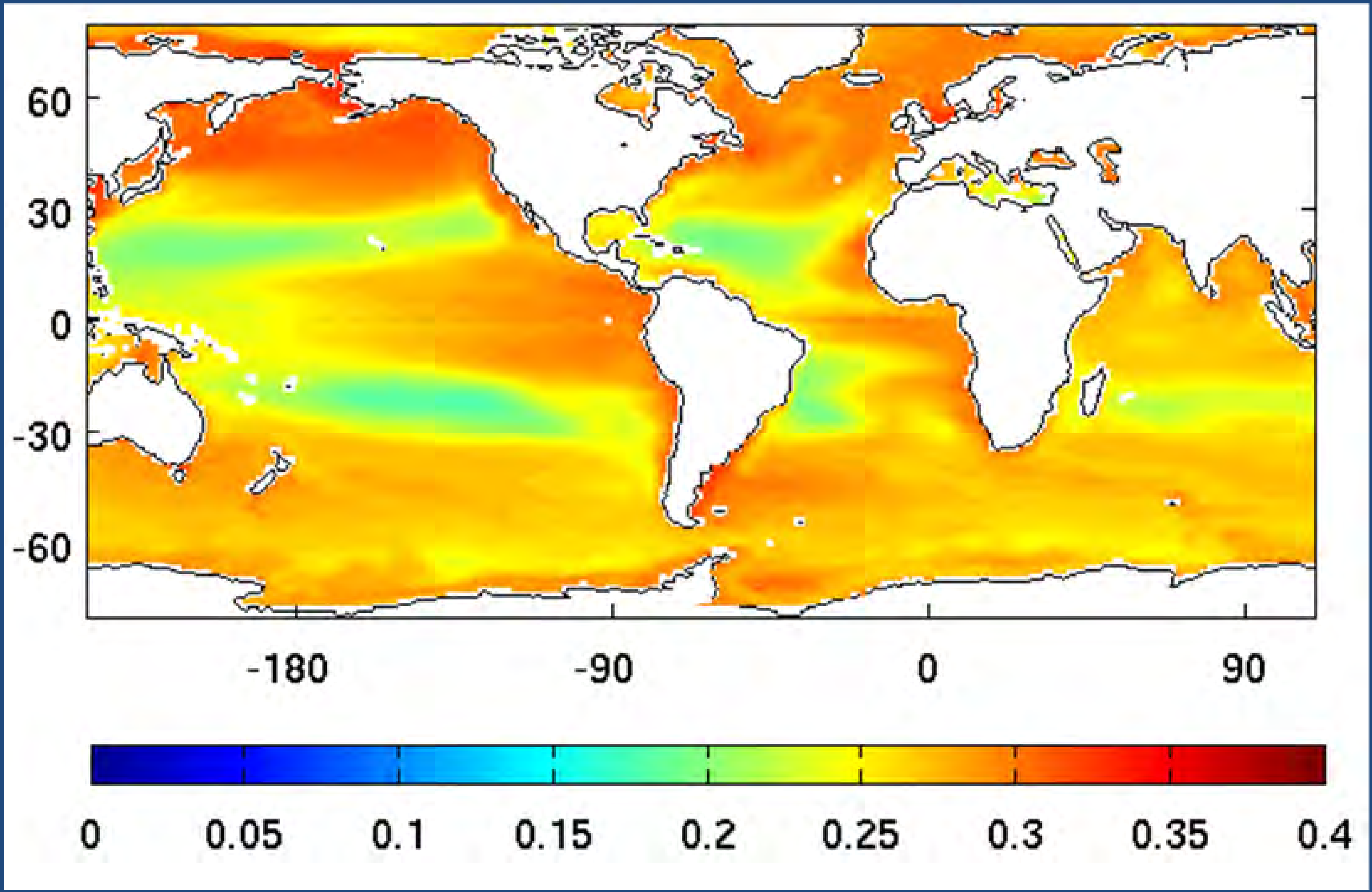


Bacterial growth efficiency increases from open-ocean to coastal system

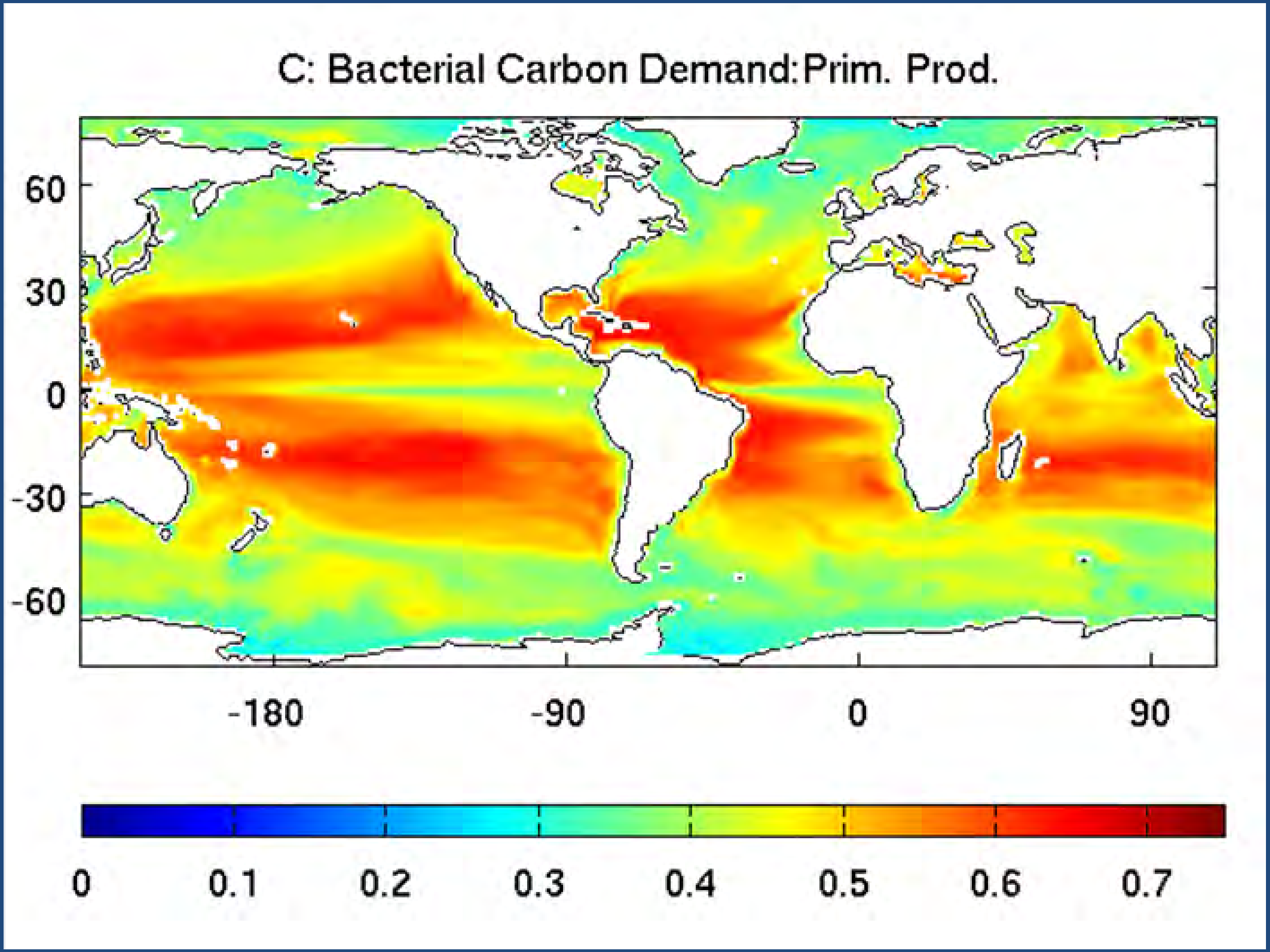
- Open ocean systems: 0.15 (0.12)
- Coastal systems: 0.27 (0.18)
- Estuarine systems: 0.37 (0.15)

Del Giorgio and Cole, 2000, in
Microbial Ecology of the Oceans (Kirchman ed.)

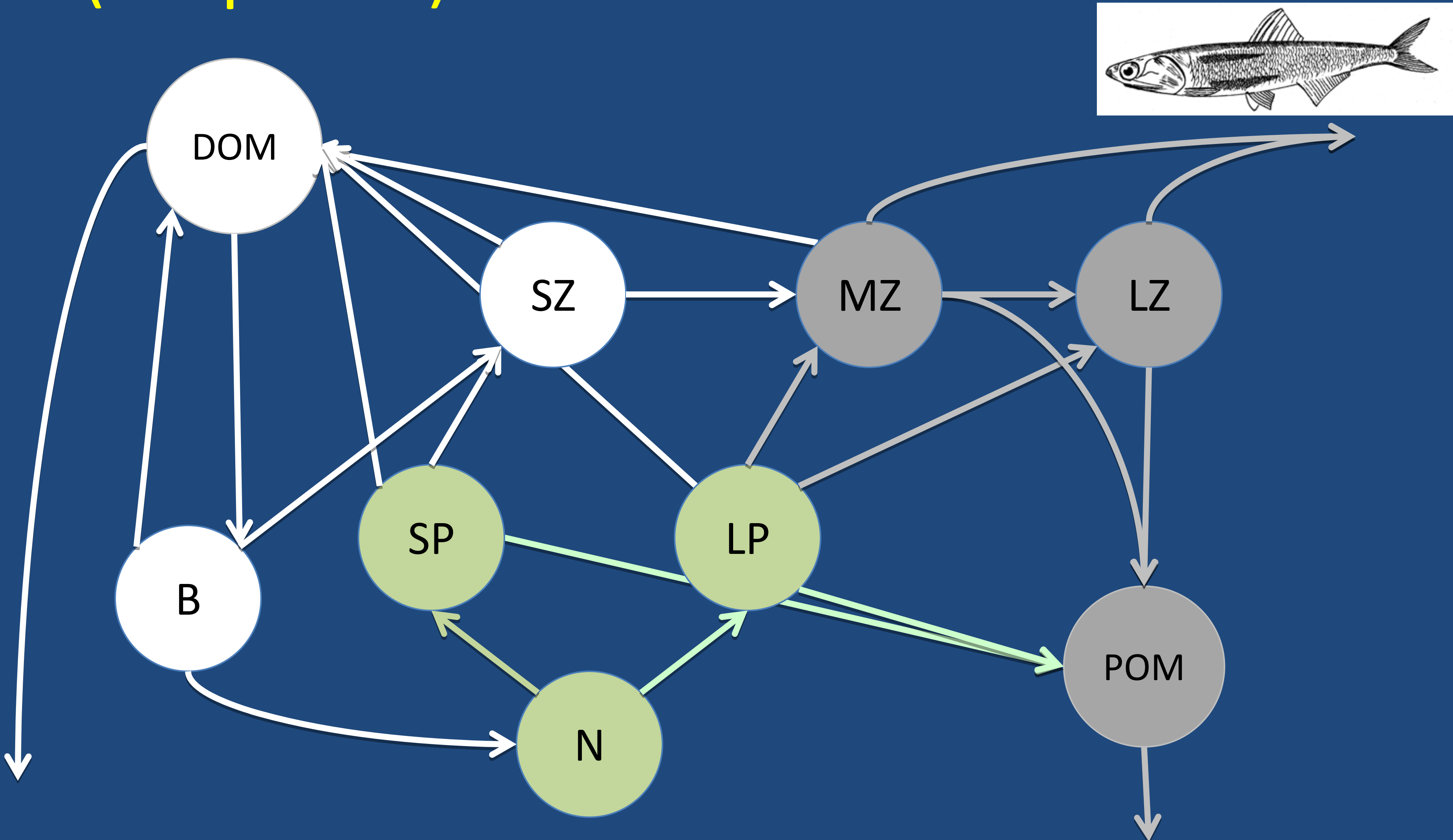
Modeled BGE exhibits cross-system trend similar to that observed



Bacterial carbon demand/NPP

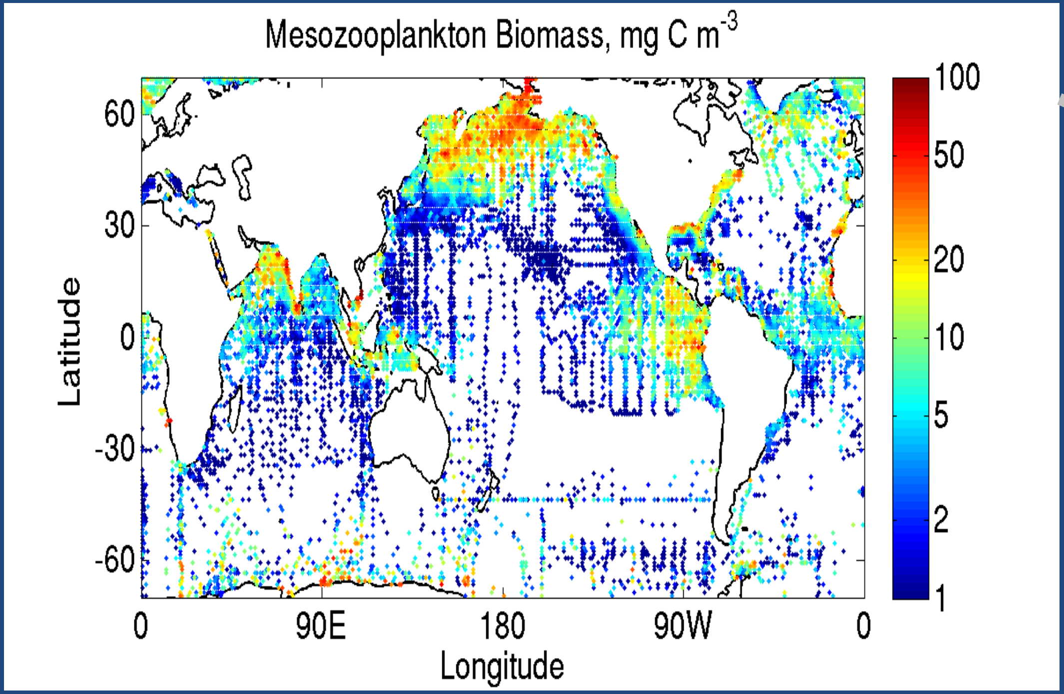


Planktonic food web structure (simplified)



Global estimates of ratio of mesozooplankton production to primary production

mesozooplankton biomass (mg C m^{-3})

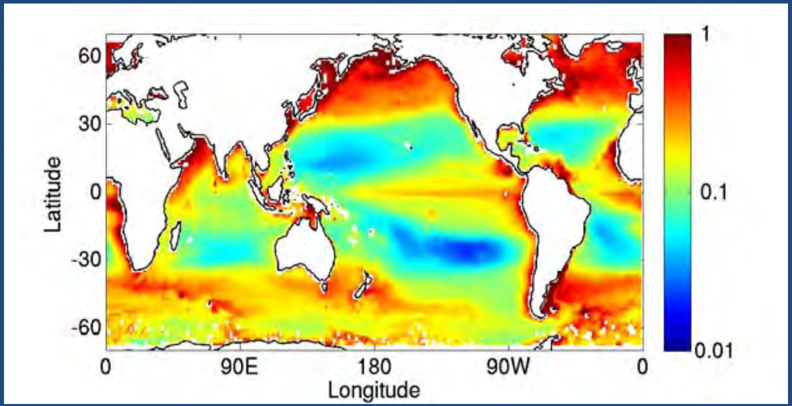


$$mzp = \mu_{LZ} \times (MZ + LZ)$$

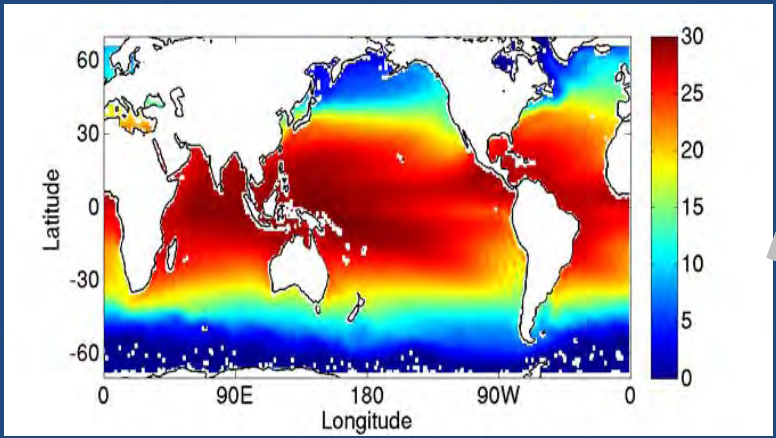
Global average from many net tows
NOAA/NMFS COPEPOD database (O'Brien, 2005)

Global estimates of ratio of mesozooplankton production to primary production

chlorophyll



SST



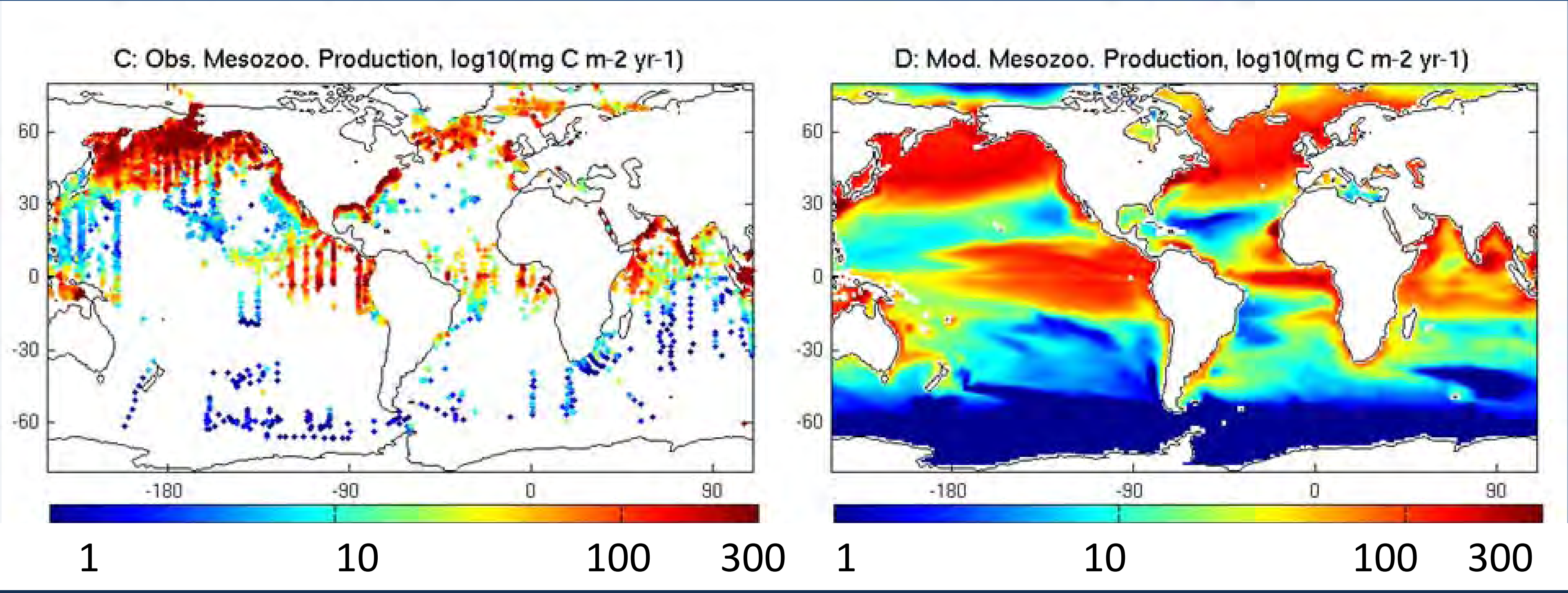
$$\mu_{LZ} = f(chl, sst, W = 25\mu g C)$$

$$mzp = \mu_{LZ} \times (MZ + LZ)$$

Hirst and Bunker, 2003

Mesozooplankton production (mg C m^{-2} day^{-1})

Independent Estimates | Model

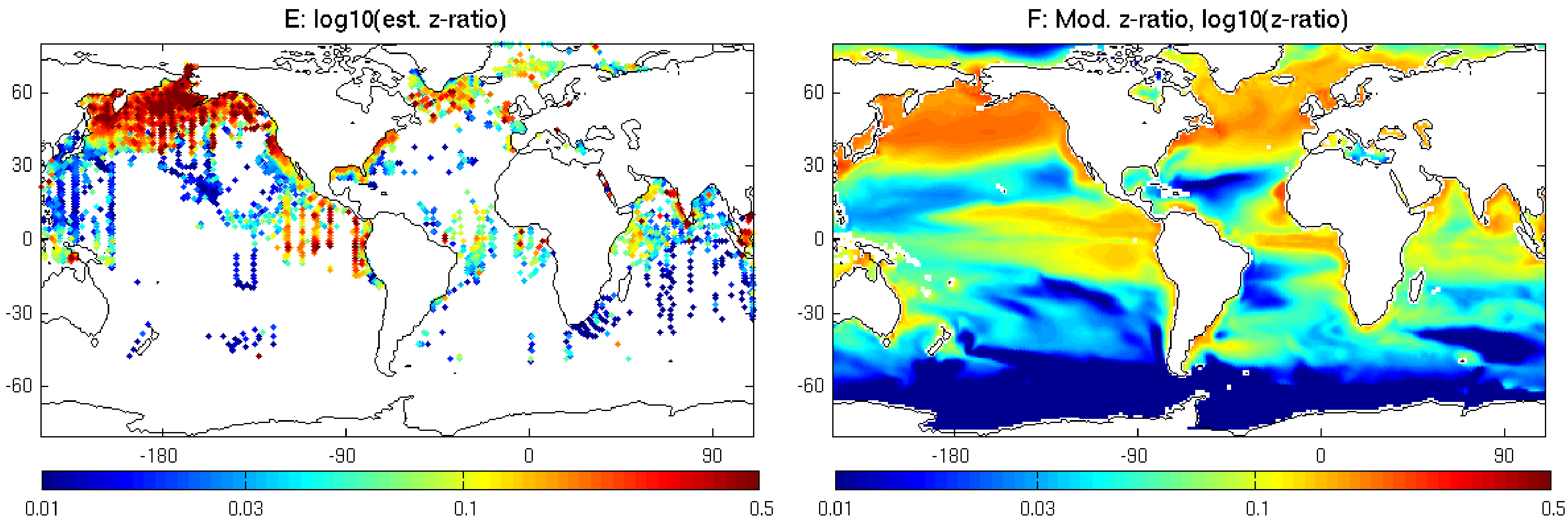


Correlation = 0.74, bias = 0.25

Summer ratio of mesozooplankton production to primary production

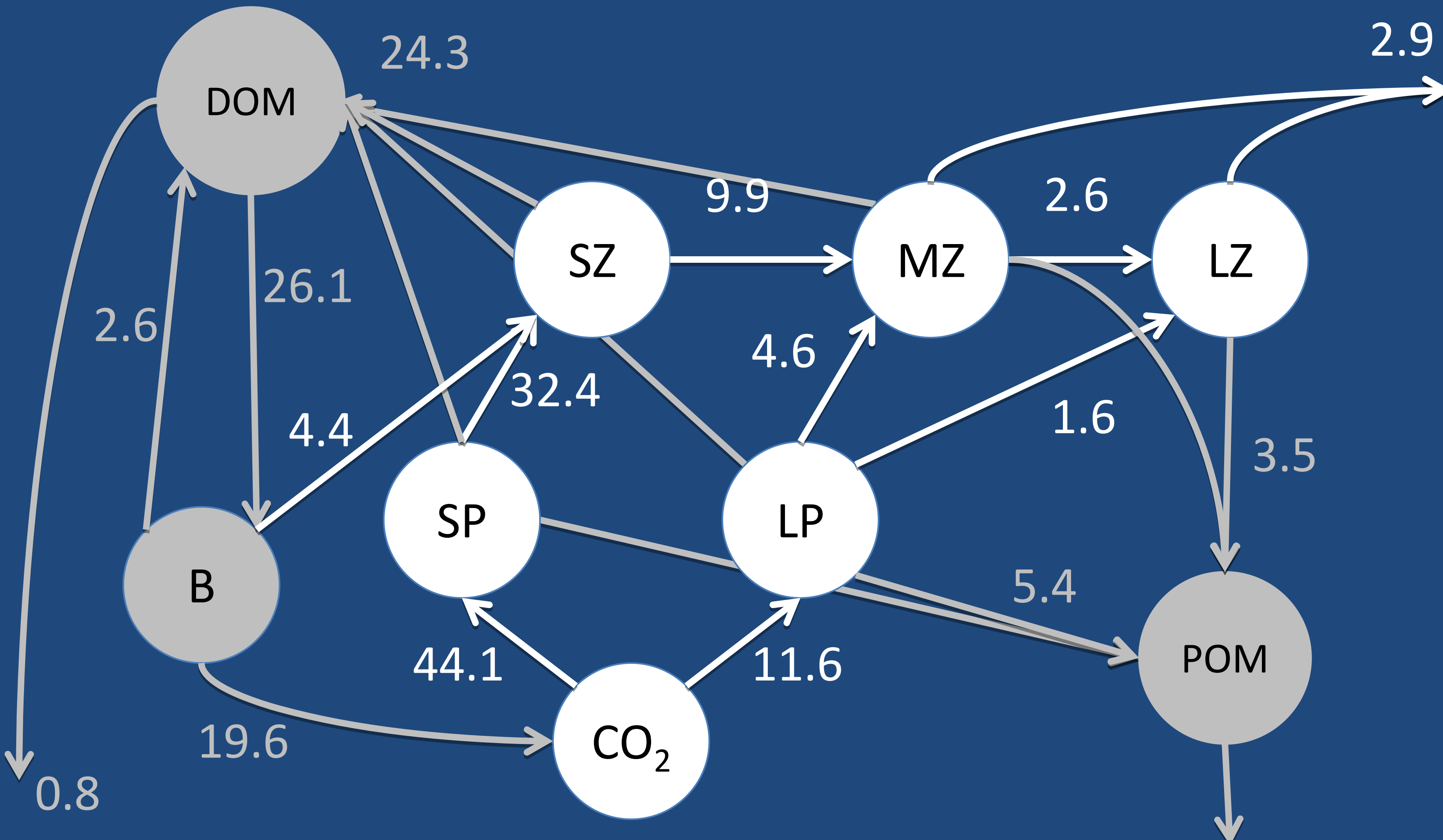
Independent Estimates

Model



See also: Stock and Dunne, 2010

Internally consistent estimates of global energy flow through the planktonic ecosystem



Conclusions

- Need to look beyond primary production to understand global marine resources and mechanistically resolve biogeochemical processes
- COBALT captures emergent global-scale energy flow patterns throughout the planktonic food web
- This offers internally consistent global energy flow estimates
- Intended as a robust baseline for linking biogeochemical and ecosystem interests