Quantifying the distribution and dynamics of forage fish using a size-based ecosystem model

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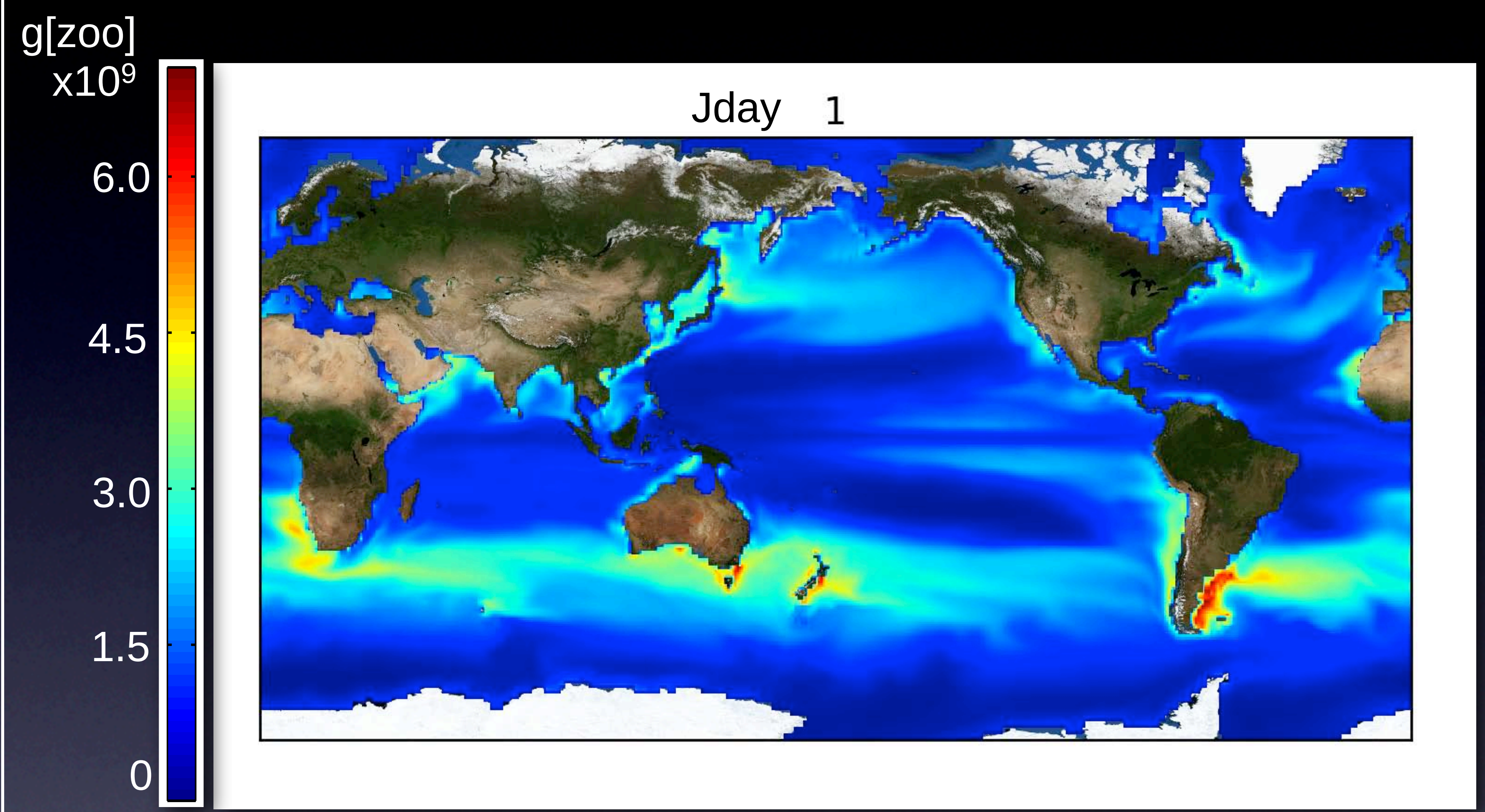
PICES meeting, May 2012

Earth System Models



Large zooplankton daily climatology
Charles Stock, John Dunne, Jasmine John

COBALT (Carbon, Ocean Biogeochemistry and Lower Trophics)

1 deg horizontal, 50 vertical layers

Climatology
1948 - present hindcast

Large Zoo (2-20 mm ESD)
Med Zoo (200-2000 mum ESD)
Small Zoo (<200 mum ESD)

Zooplankton mass and loss terms to higher predators

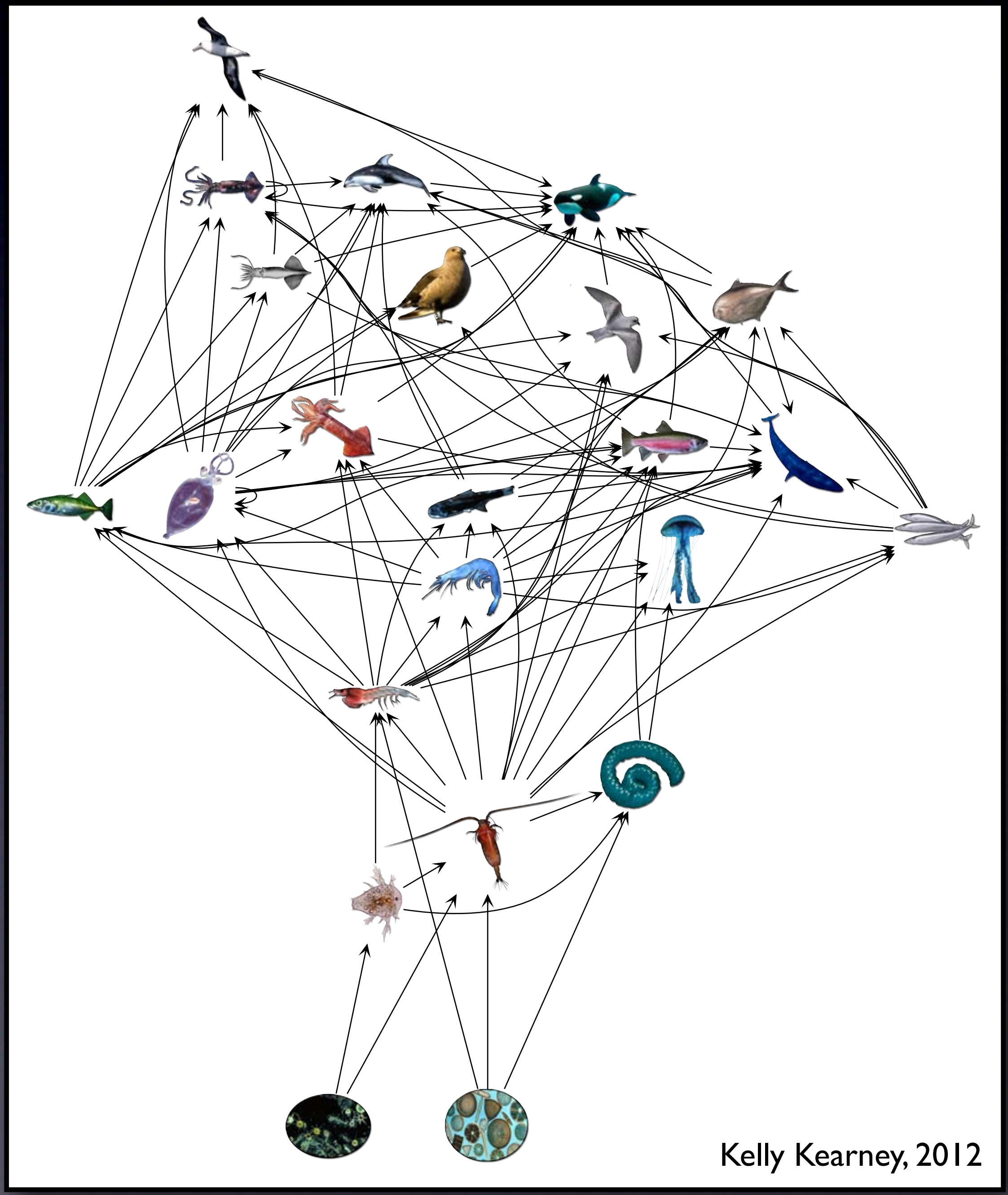
Goal:

- use the earth system model output (i.e. zoo) to estimate the abundance and distribution of high trophic pelagic species

- over global spatial scales and long time scales

Upper Trophic Level Models

- NEMURO.fish, Ecosim/Ecopath/Ecospace, Osmose, Apecosm...
  - Fisheries models (specific to certain species, a specific place)

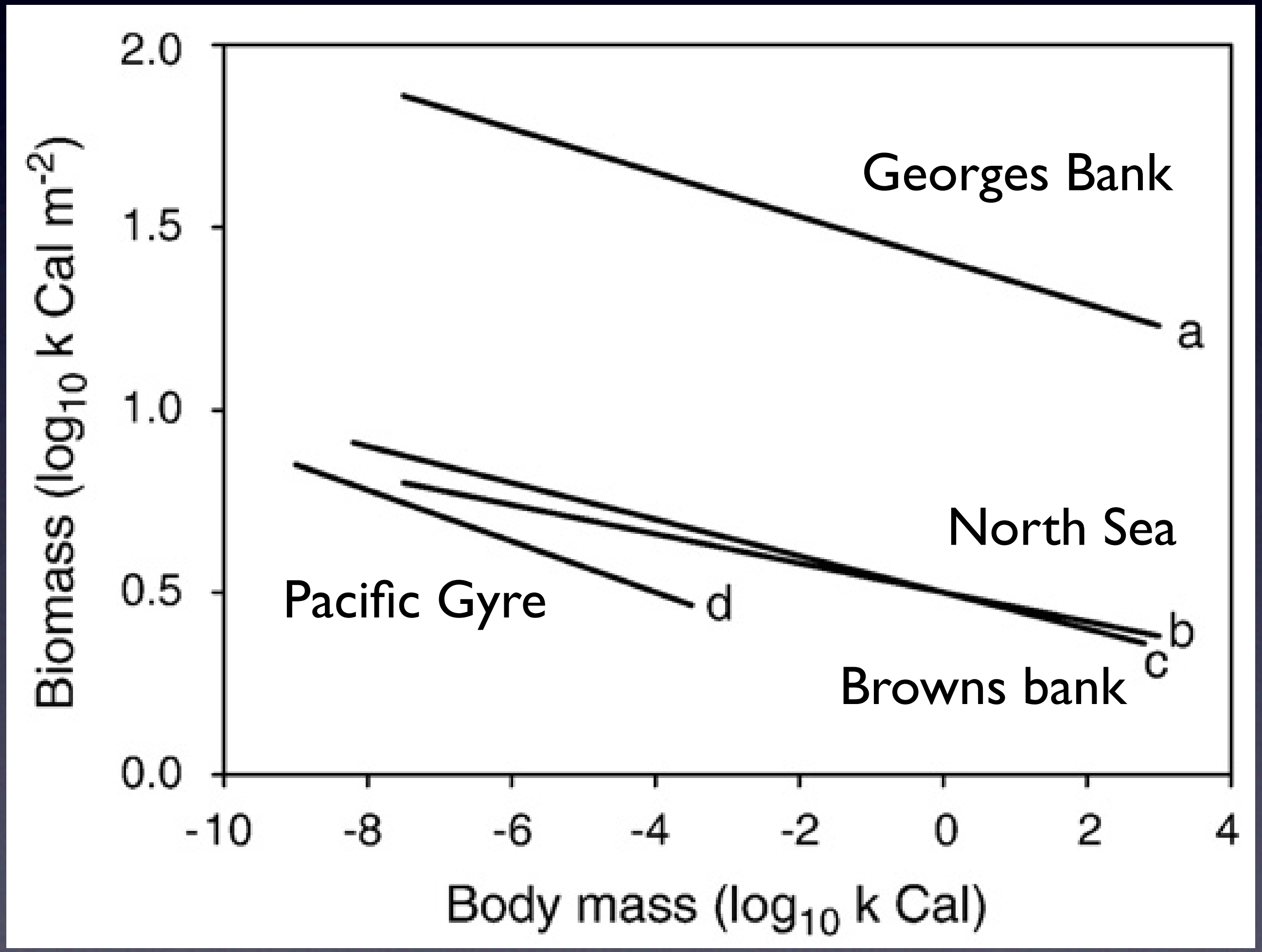


Appropriate for understanding specific systems and interactions

but...

Upper Trophic Level Models

- An alternative
  - general across species, across different systems
  - an ecological model based on size



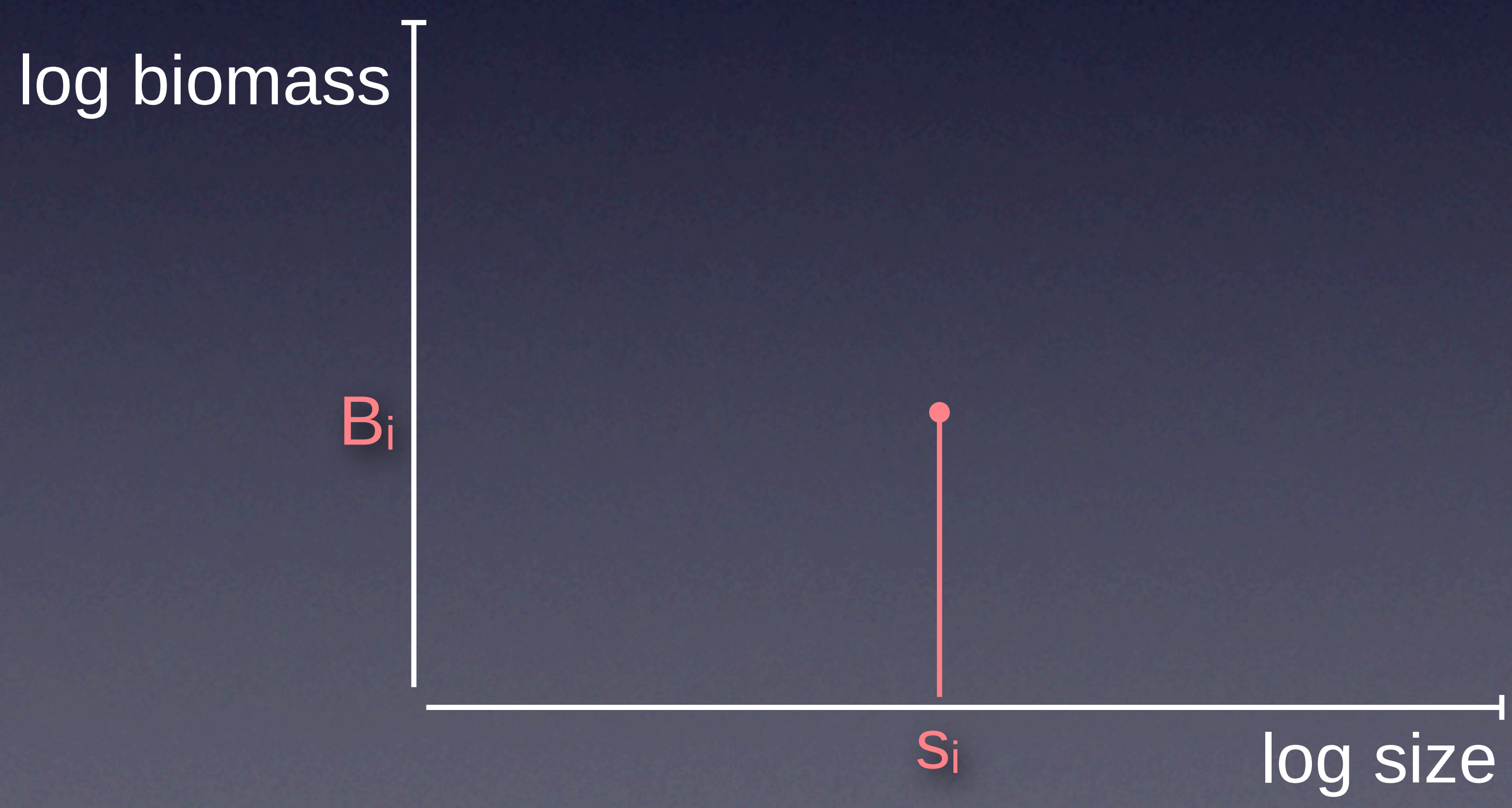
Jennings & Brander 2010,
originally from Boudreau & Dickie 1992

A general feature of marine systems around the globe

Size spectra

- Goal: reproduce marine size spectra
- Challenge: build the simplest model...

$$\frac{dB_i}{dt} =$$



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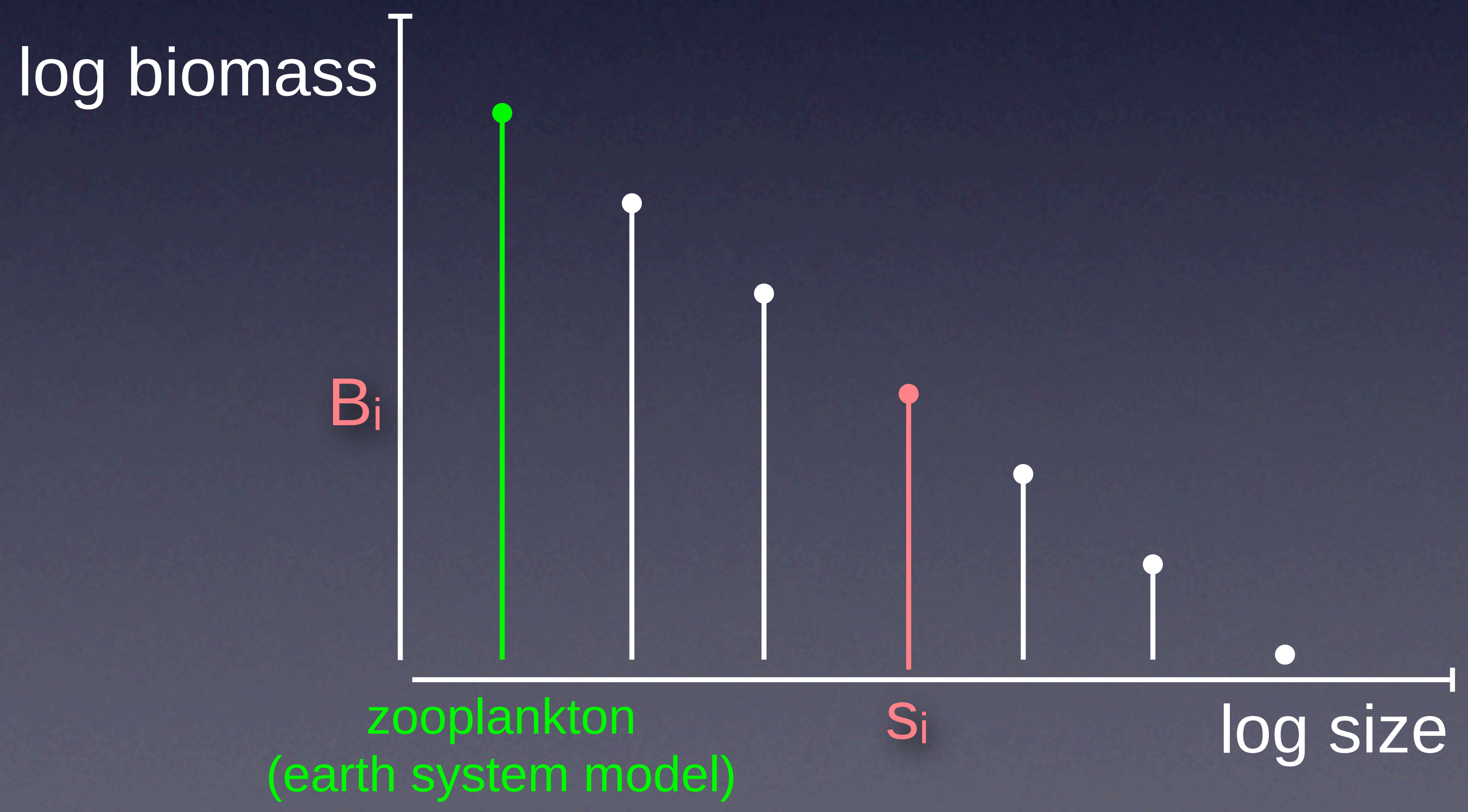

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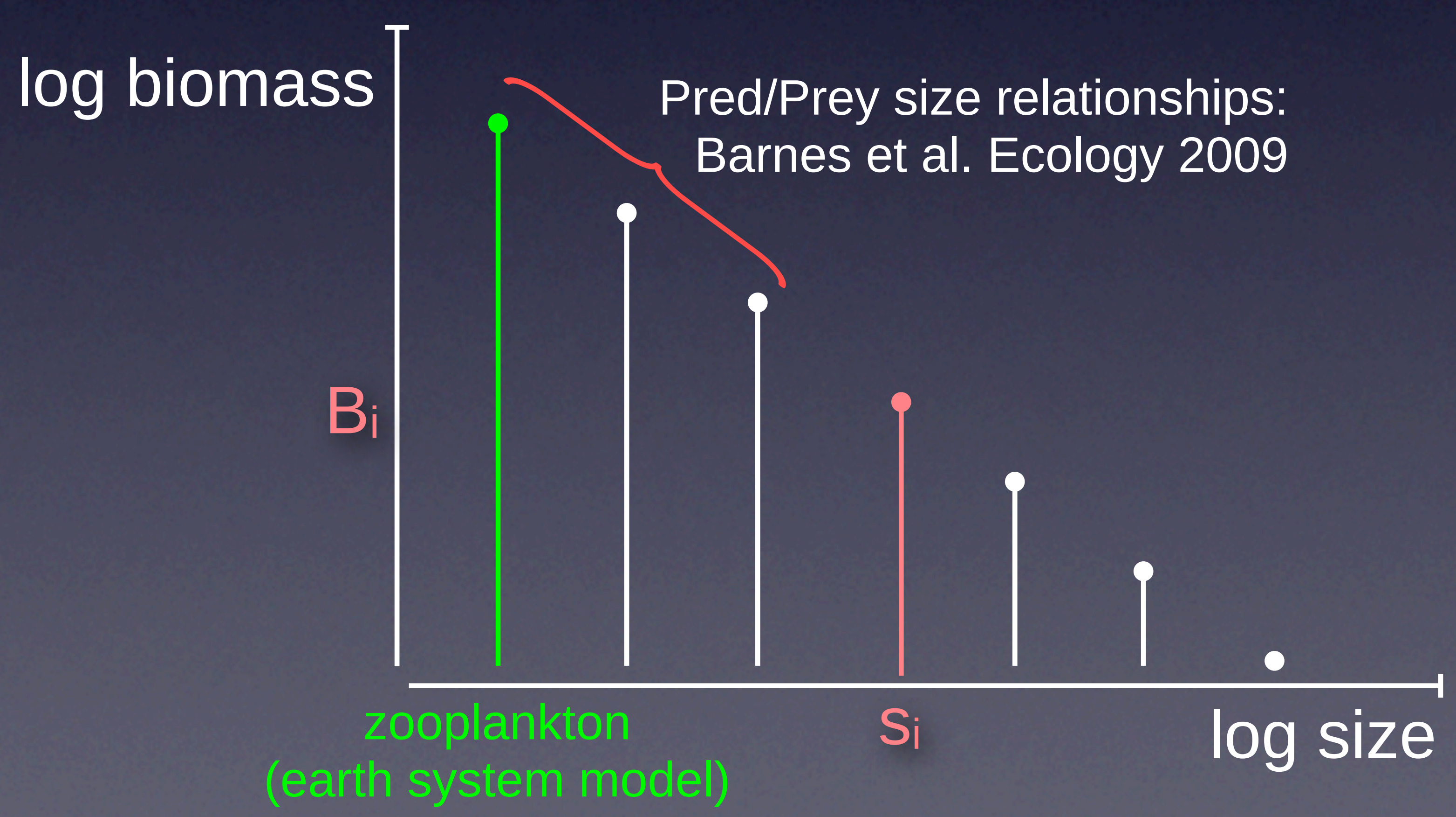

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Nemuro.Fish

A bioenergetics-based population dynamics model of Pacific herring (*Clupea harengus pallasi*) coupled to a lower trophic level nutrient–phytoplankton–zooplankton model: Description, calibration, and sensitivity analysis

Bernard A. Megrey[a,*], *Kenneth A. Rose*[b], *Robert A. Klumb*[c], *Douglas E. Hay*[d], *Francisco E. Werner*[e], *David L. Eslinger*[f], *S. Lan Smith*[g]

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Other theoretical eco/evo research

Ecology Letters, (2012) doi: 10.1111/j.1461-0248.2012.01777.x

LETTER

Mechanistic theory and modelling of complex food-web dynamics in Lake Constance

Alice Boit,[1]* Neo D. Martinez,[2] Richard J. Williams[3,4] and Ursula Gaedke[1]

Abstract
Mechanistic understanding of consumer-resource dynamics is critical to predicting the effects of global change on ecosystem structure, function and services. Such understanding is severely limited by mechanistic models' inability to reproduce the dynamics of multiple populations interacting in the field. We surpass this limitation here by extending general consumer-resource network theory to the complex dynamics of a specific ecosystem

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Discrete size classes: versus Continuous size classes

McKendrick-Von Foerster Equation

Size spectra

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Discrete size classes:

I swim $\left\{ \quad -J_i\left(\frac{\partial B_j}{\partial x}\right) \right.$

Mass flux by taxis (follow the gradient of prey)

VOL. 151, NO. 2 THE AMERICAN NATURALIST FEBRUARY 1998

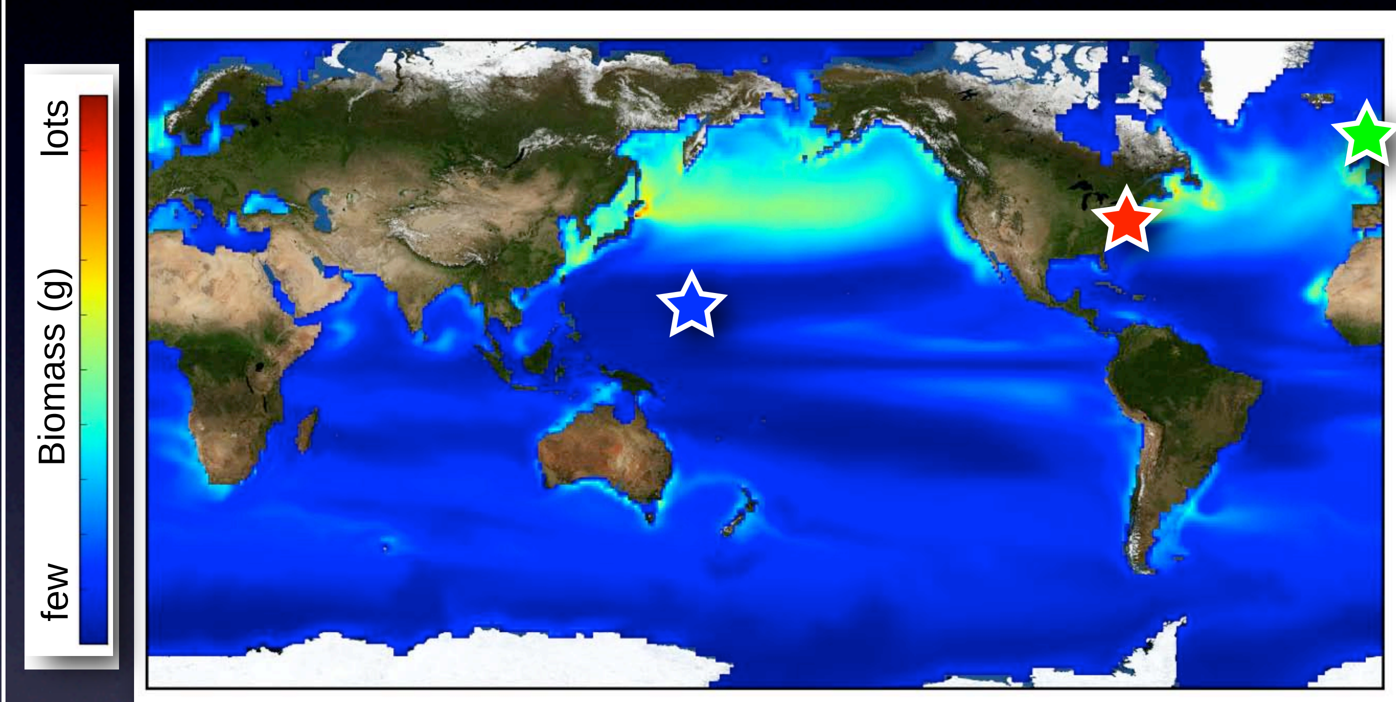
Using Spatially Explicit Models to Characterize Foraging Performance in Heterogeneous Landscapes

Daniel Grünbaum*

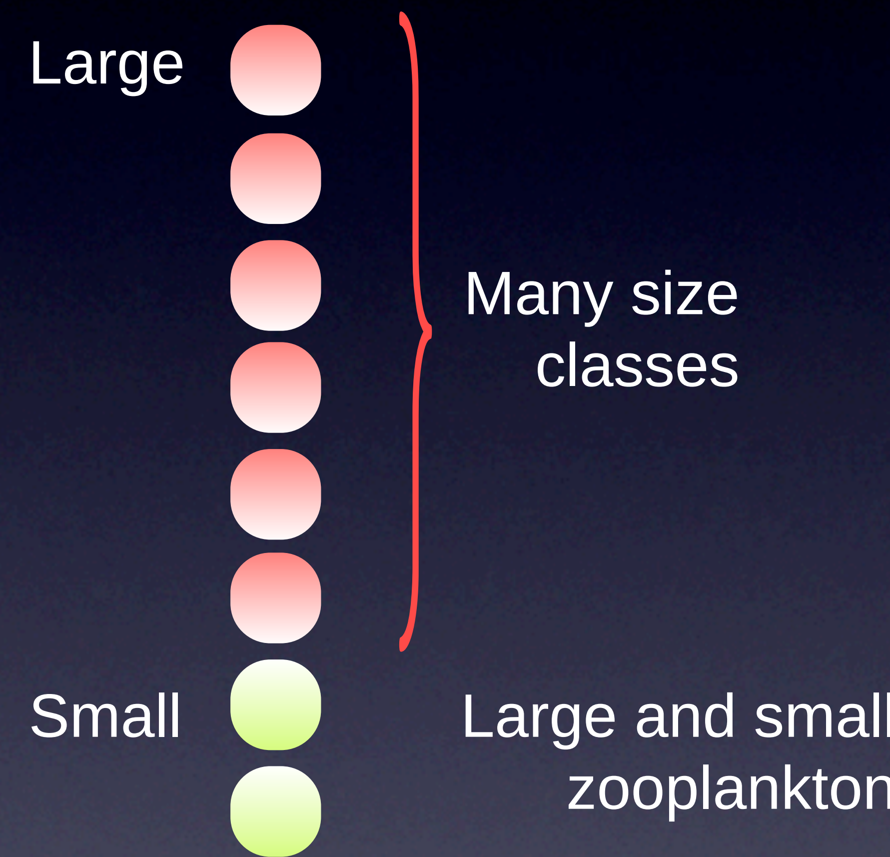
Global distribution of Biomass...

- ... based on size

  - use zooplankton climatology (i.e. daily averages looped over a year)



- 2 dimensional
- integrate top 200m of zooplankton
- pelagic
- offline size-based model



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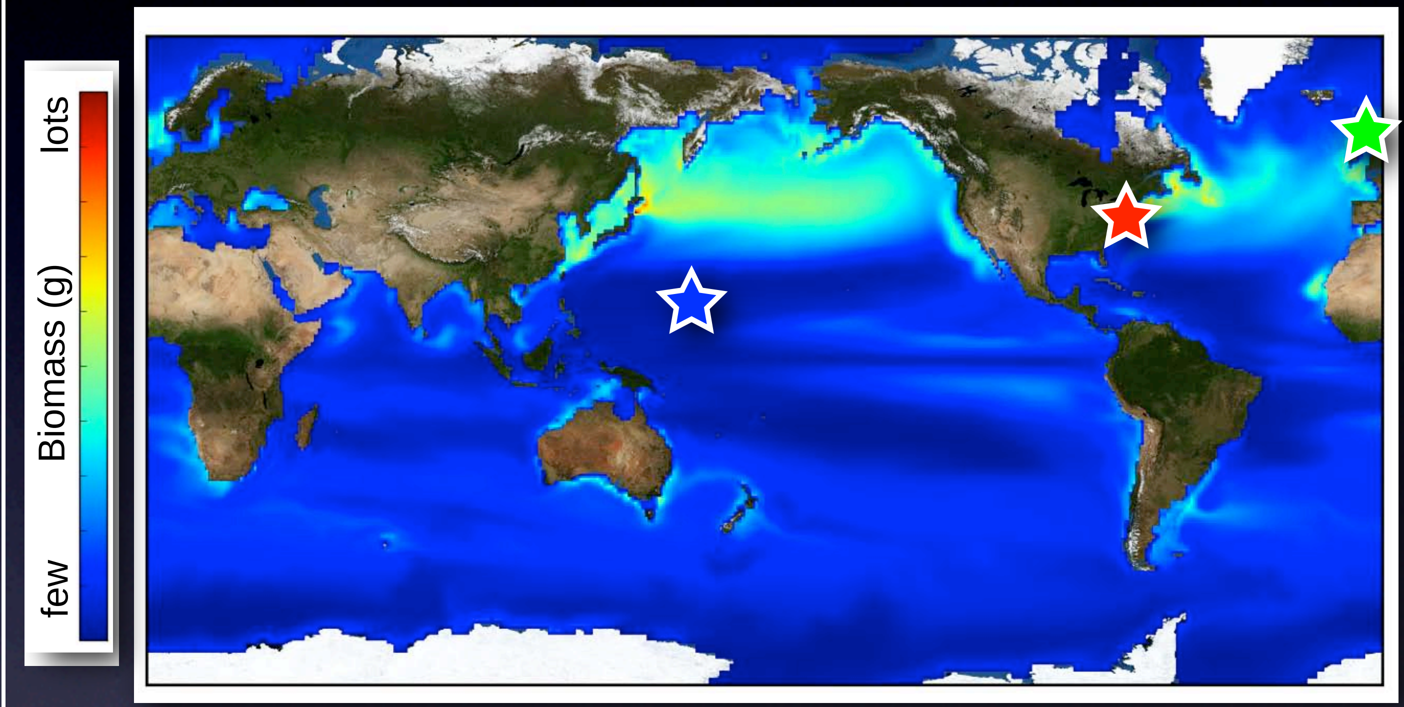

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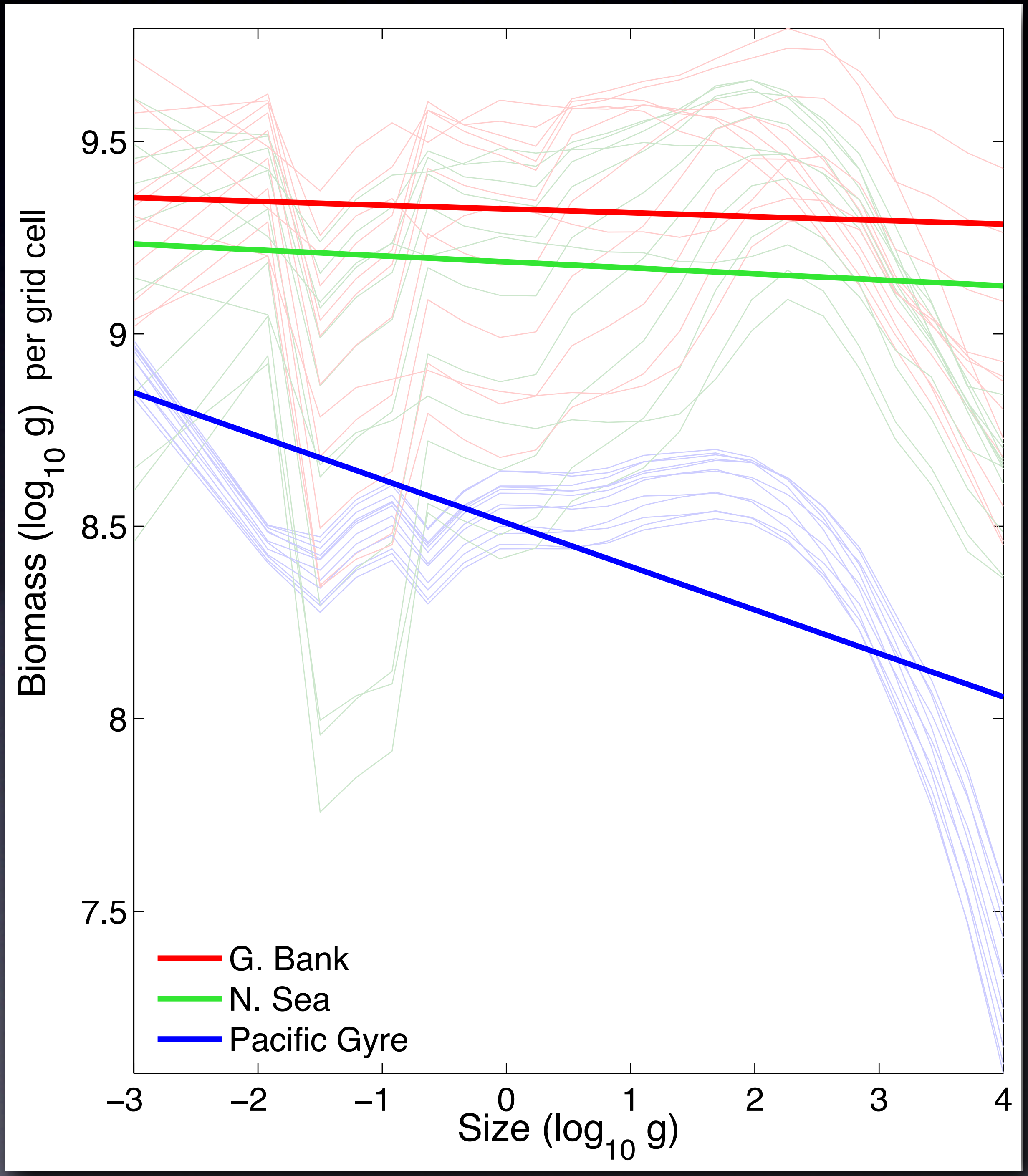

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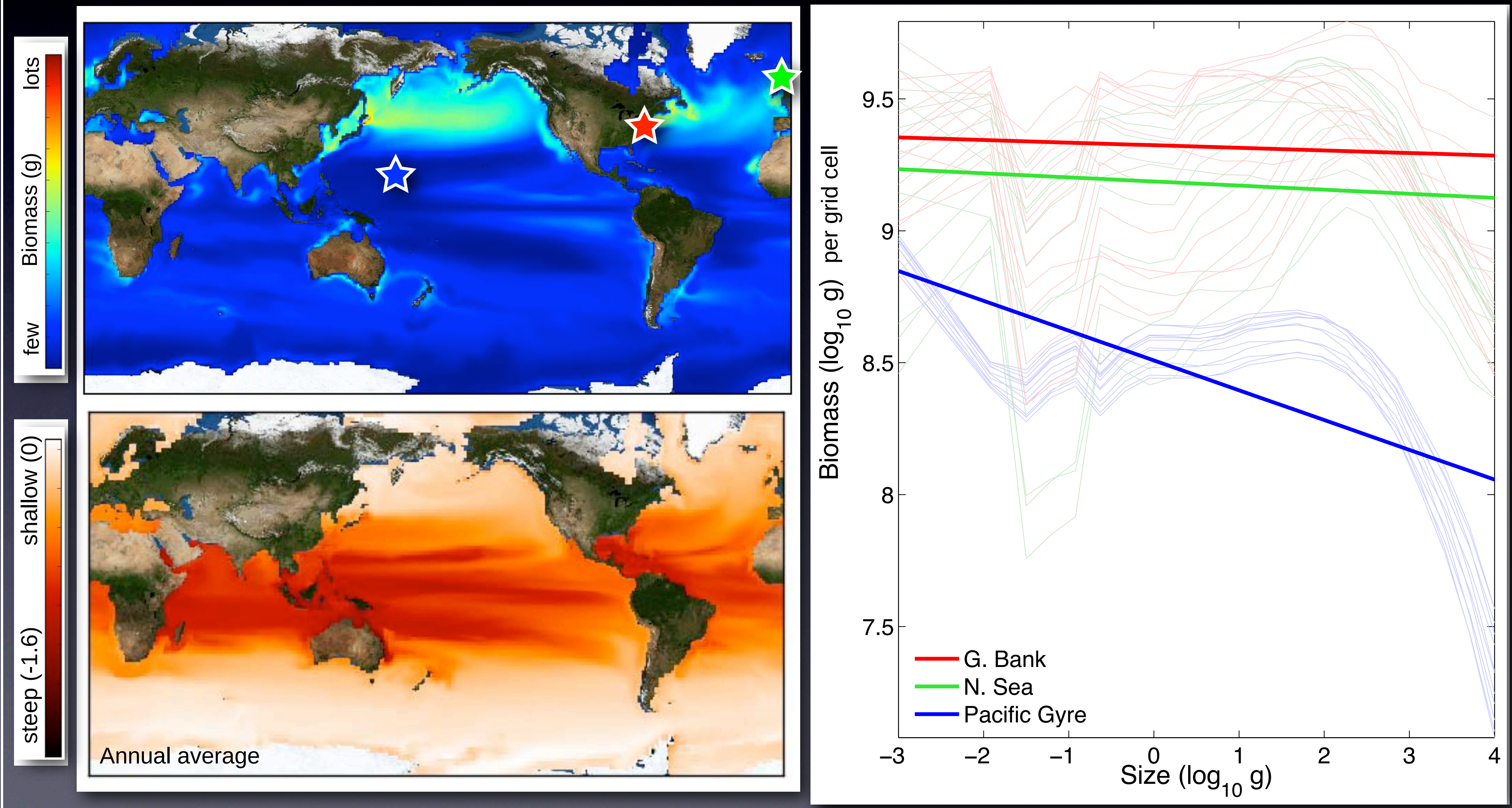

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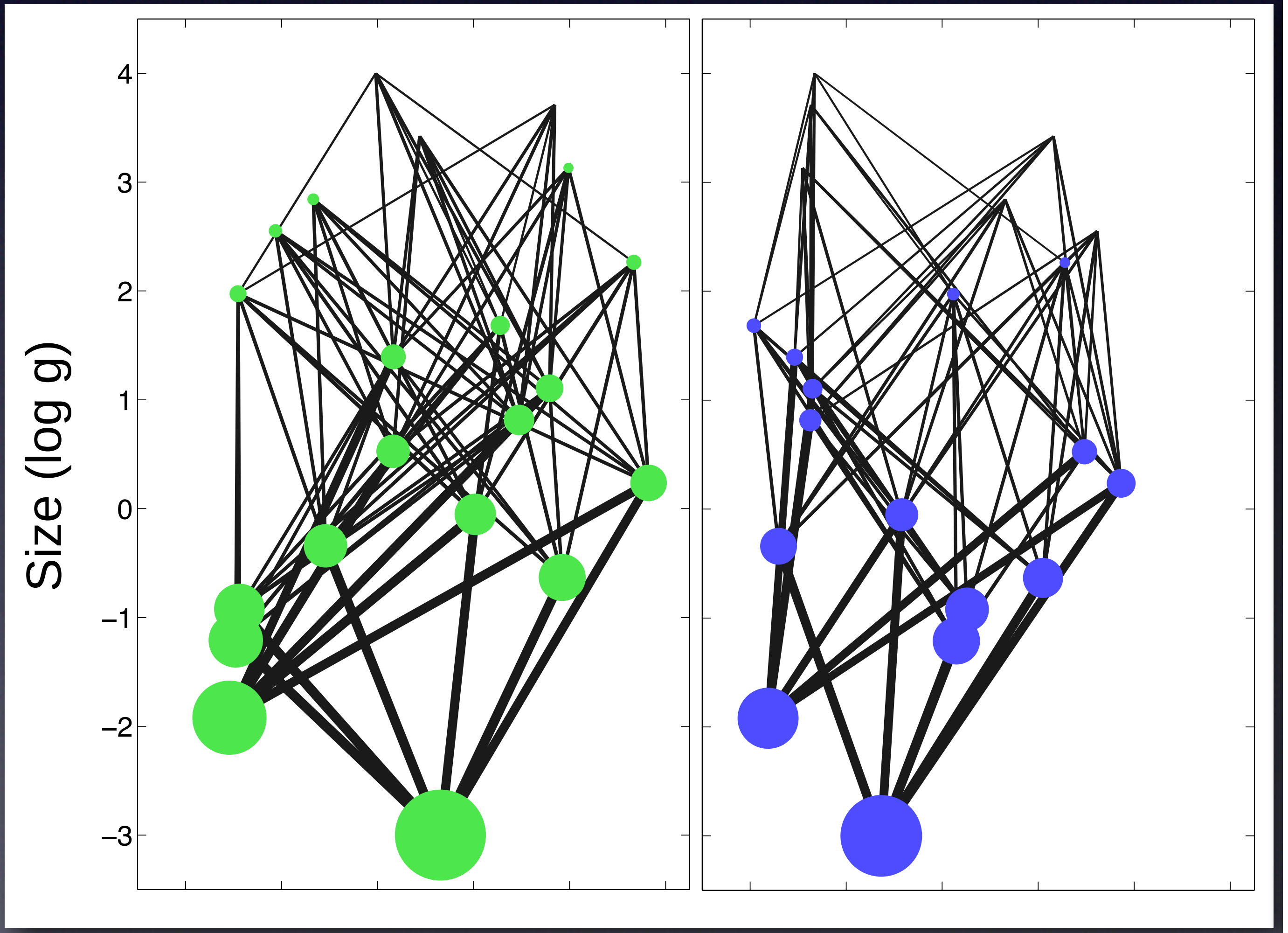
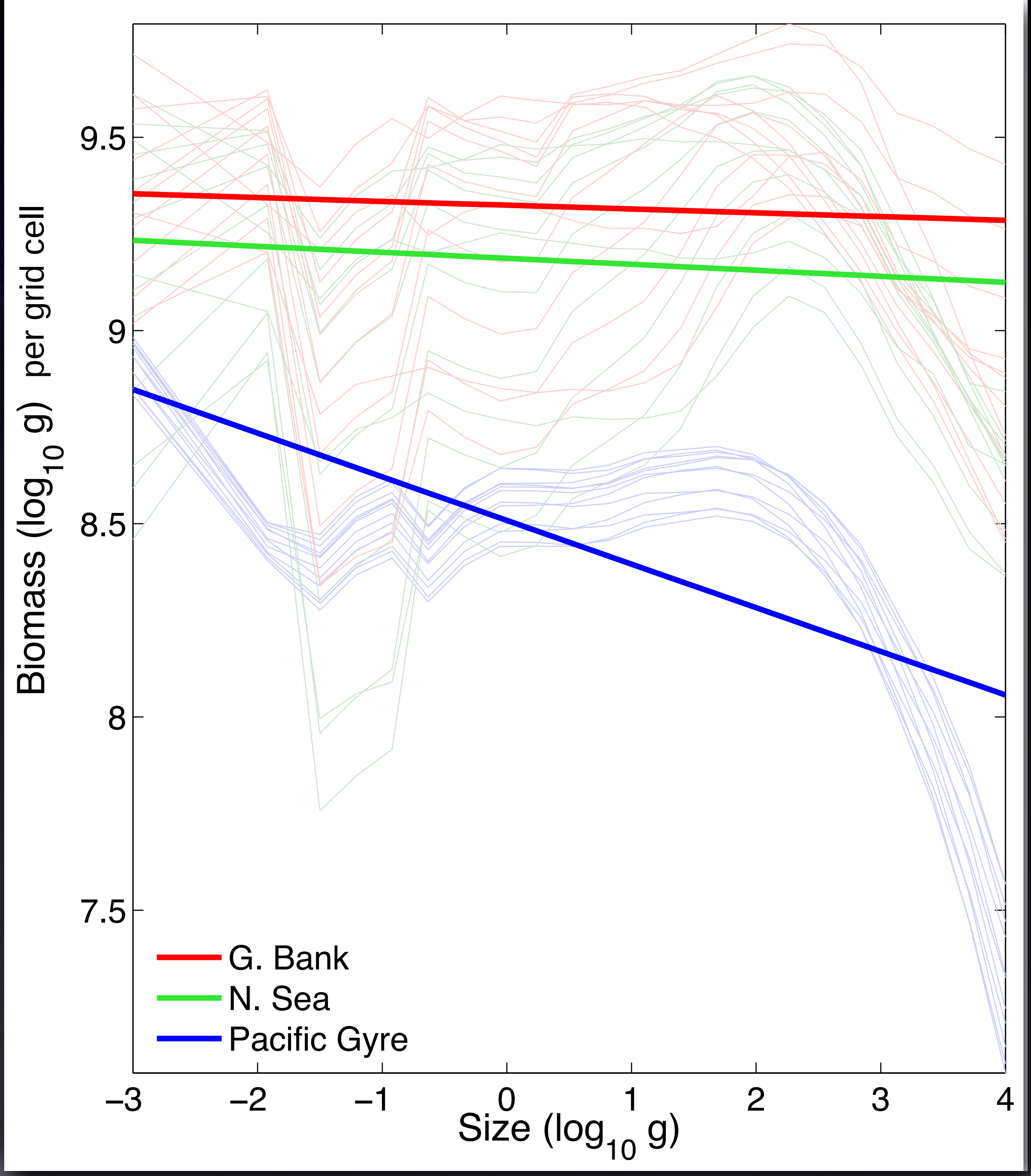
Consumption kernel

$$\frac{dB_i}{dt} = B_i \boxed{C_{ij}} - B_i M - B_j C_{ji}$$

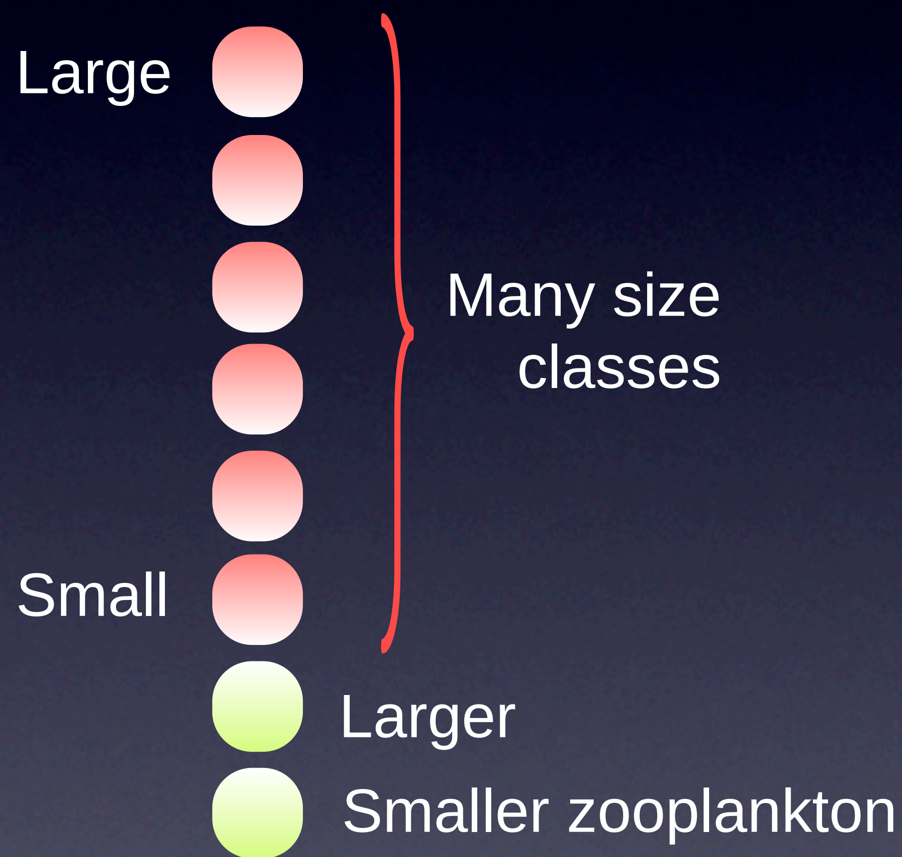




Forage Fish Dynamics

- General model

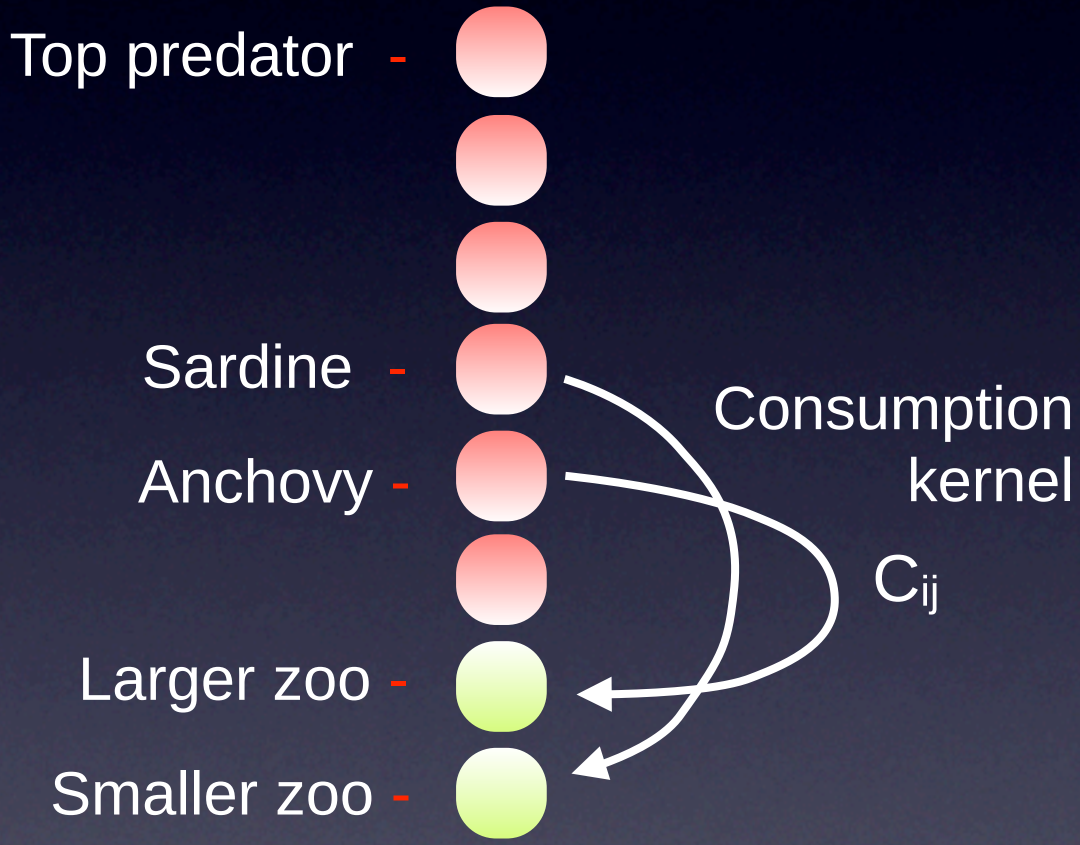
  - produced global size spectra



Forage Fish Dynamics

- Now focus on particular size classes

  - sardine, anchovy, sprat... etc



~ 30% of global fisheries production

~ 10-20% of landings consumed directly

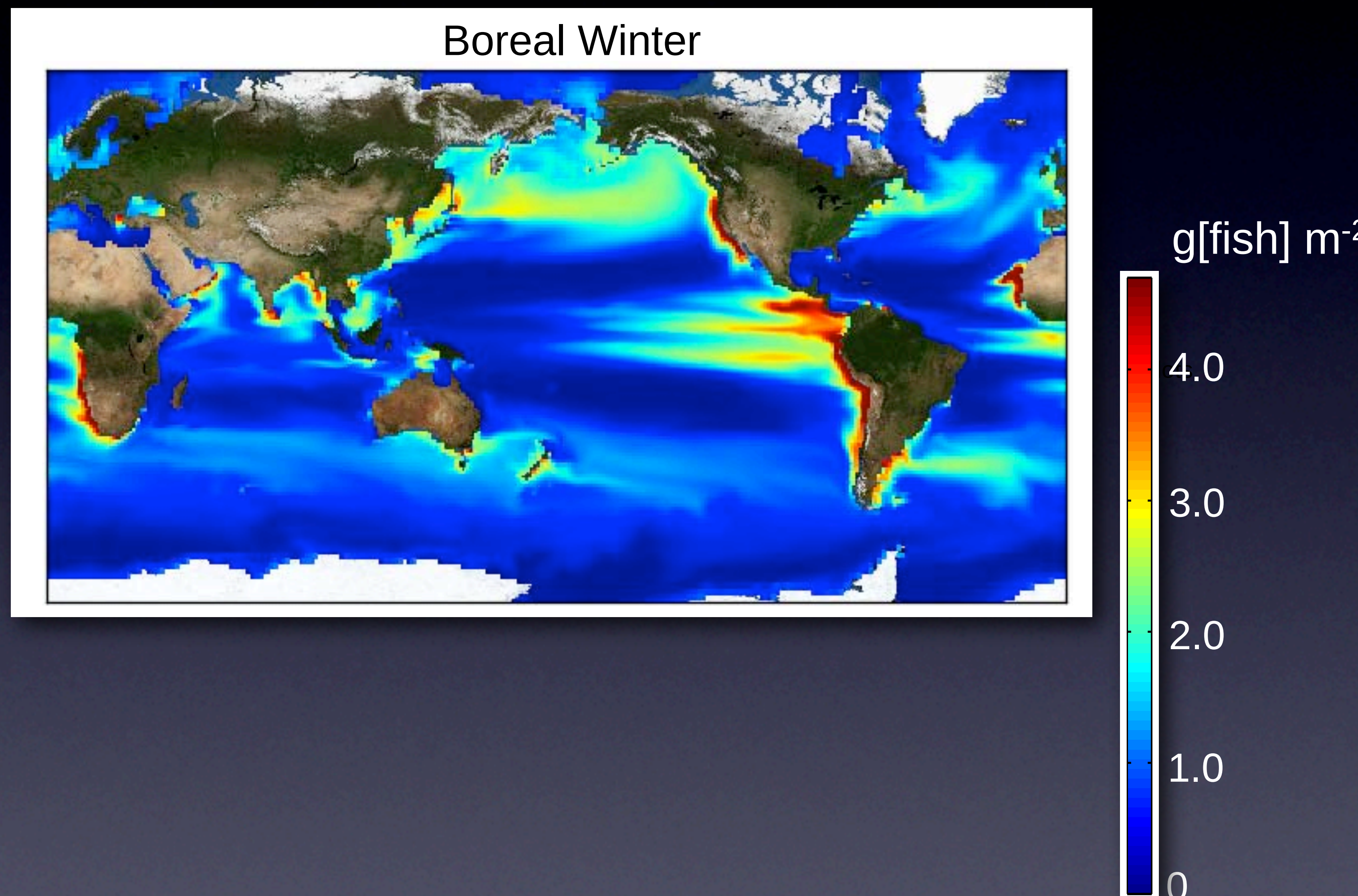
- important for global food security

- Peruvian anchovy contributes ~ 50% of global landings in fishmeal

Dynamics of Forage Fish

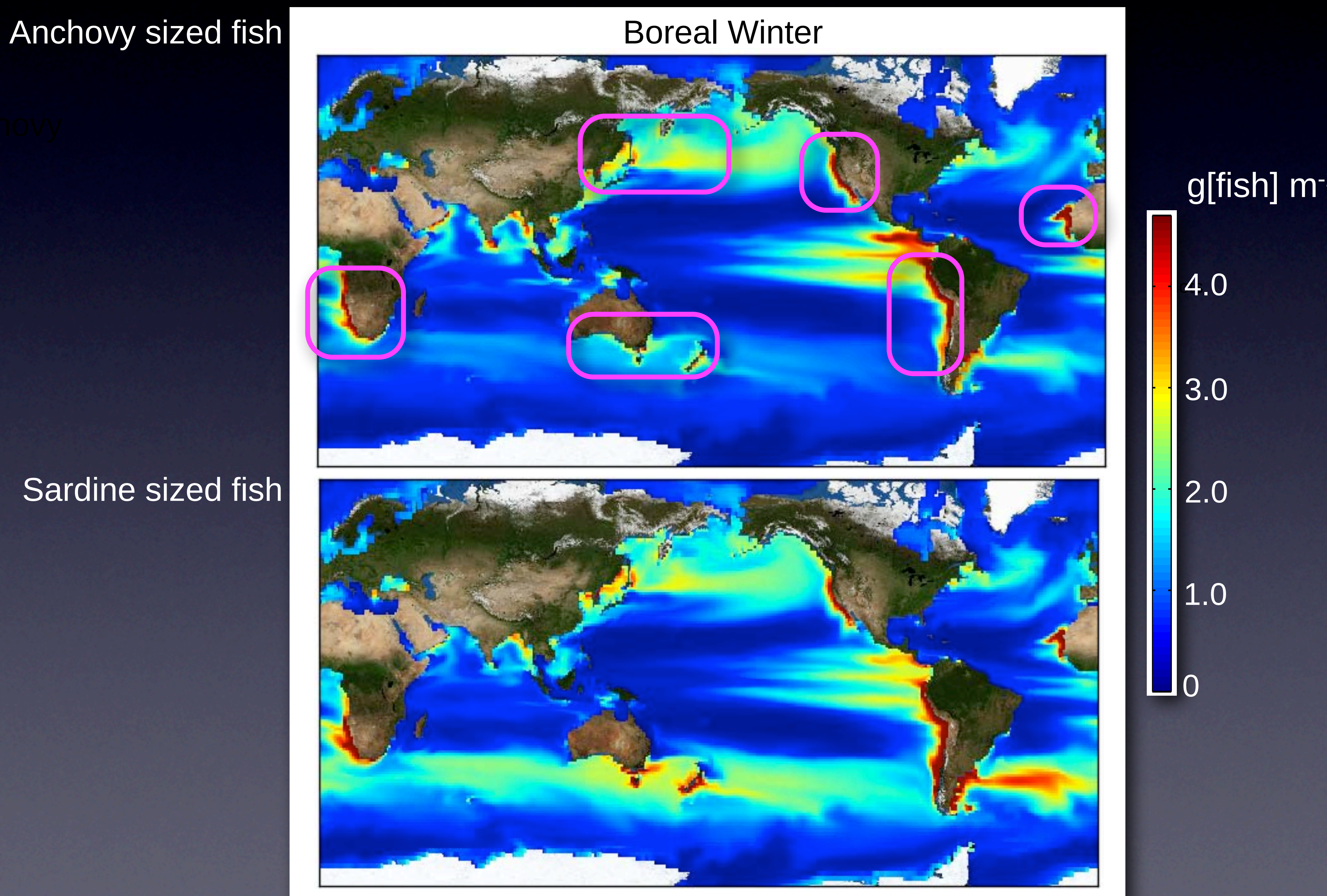
- Abundance and distribution of forage fish

Anchovy sized fish



Dynamics of Forage Fish

- Global locations of major forage fish fisheries



Its still highly experimental

Summary

- A size-based ecosystem model

  - from small to large

  - general, mechanistic (pred/prey, allometric), spatial (movement)

  - captures general features of fish production (distribution, size spectra)

Summary

- Questions we want to address...

  - how will (did) size spectra change in the future (past)?

  - how much biomass is there in the pelagic ocean (intercept and slope)?

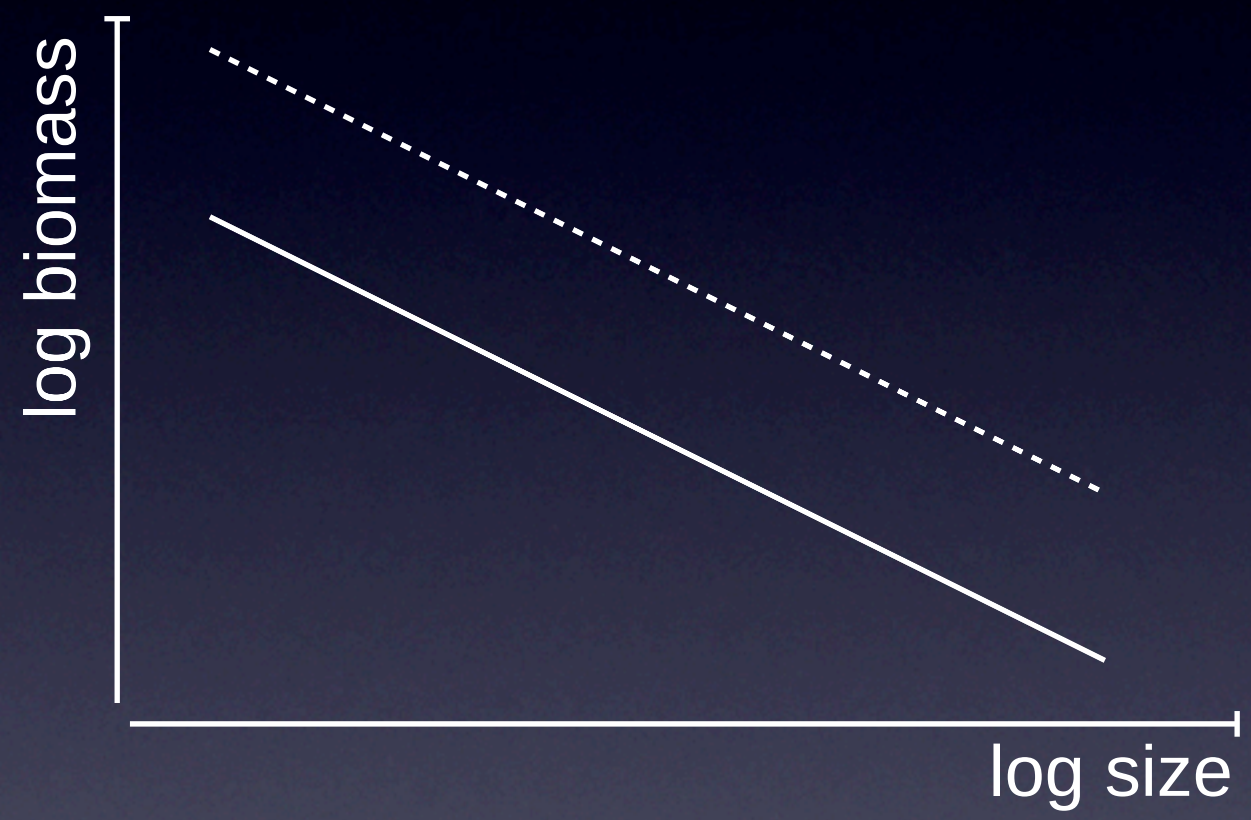
  - explore regional dynamics

  - compare dynamics between regions

Summary

- Future directions

  - parameterize with data (i.e. slope and magnitude of size spectra)



Summary

- Future directions

  - parameterize with data (i.e. slope and magnitude of size spectra)

  - fishing

  - 3D; vertical migration, mesopelagics

  - different traits (go beyond size)

Nippon Foundation - Nereus Fellowship

Princeton University - Atmospheric and Oceanic Sciences Program

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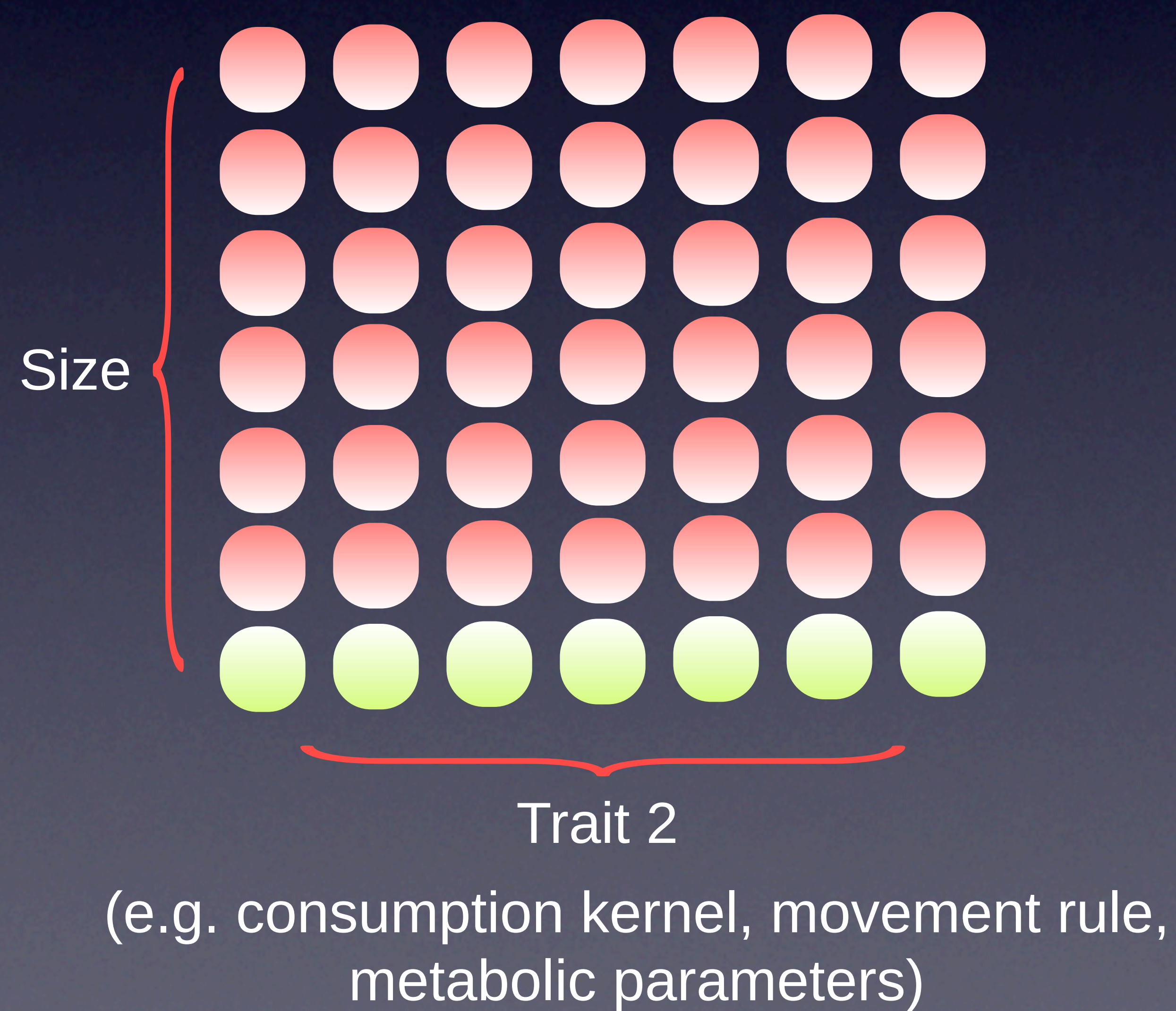
Thank You

Summary

- Future directions
  - parameterize with data (i.e. slope and magnitude of size spectra)
  - fishing
  - ontogeny (production into larval pool)
  - different traits
    - large competition



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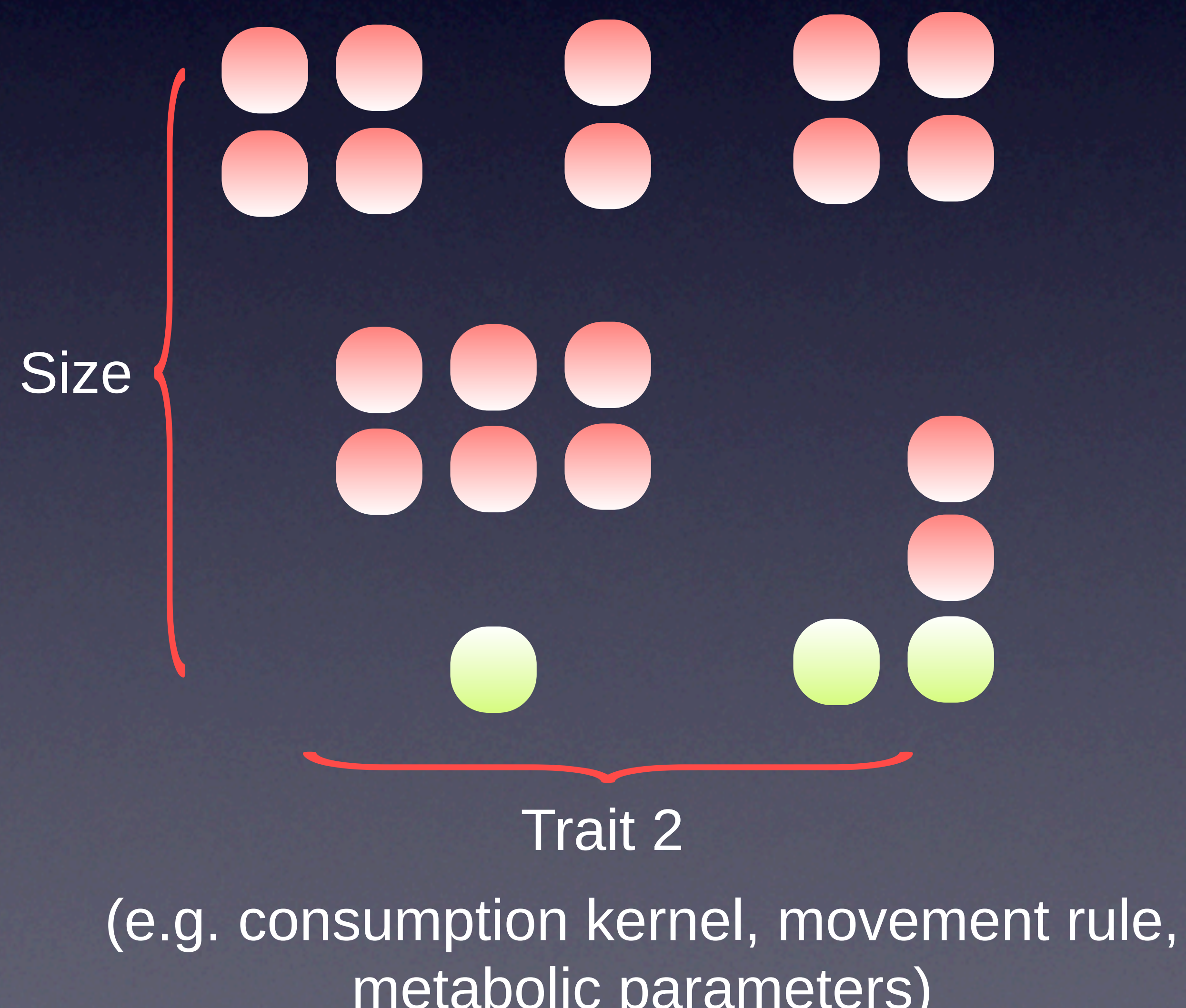
    - the environment selects



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  - different traits

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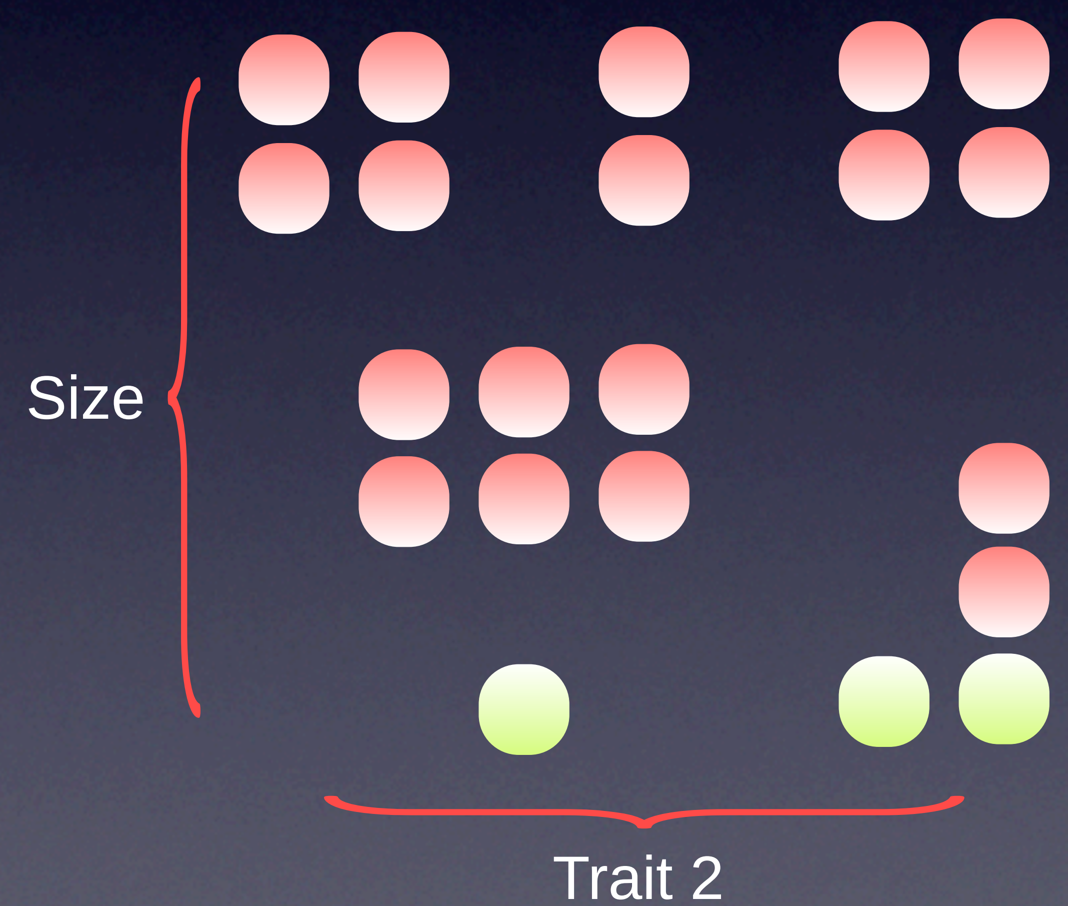
    - the environment selects

    - Follows, Bruggeman

  - Future projections



(e.g. consumption kernel, movement rule, metabolic parameters)