Projected Climate Impacts on the Pelagic Ecosystem Size Structure and Catches in the North Pacific Over the 21st Century

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NOAA GFDL Earth System Model 2.1 (*ESM2.1 A2 NPZ*)

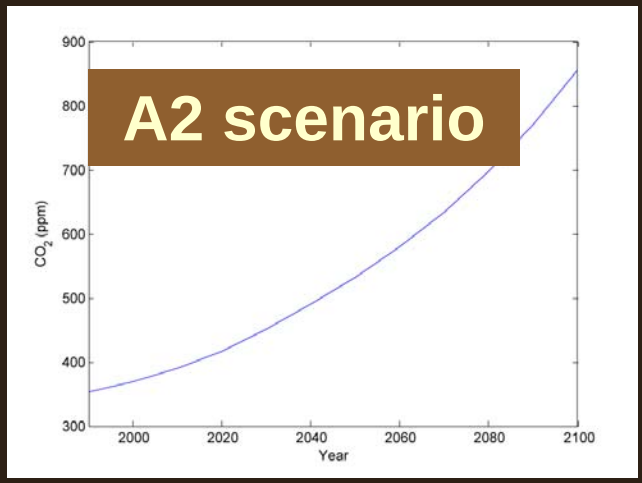
CM 2.1 (Atmos., Land, Ice)

Coupled Climate

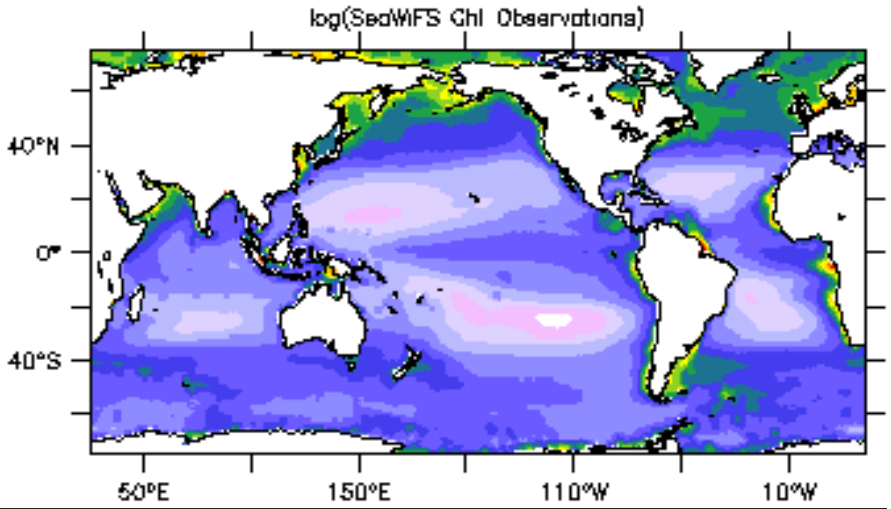
Biogeochemical

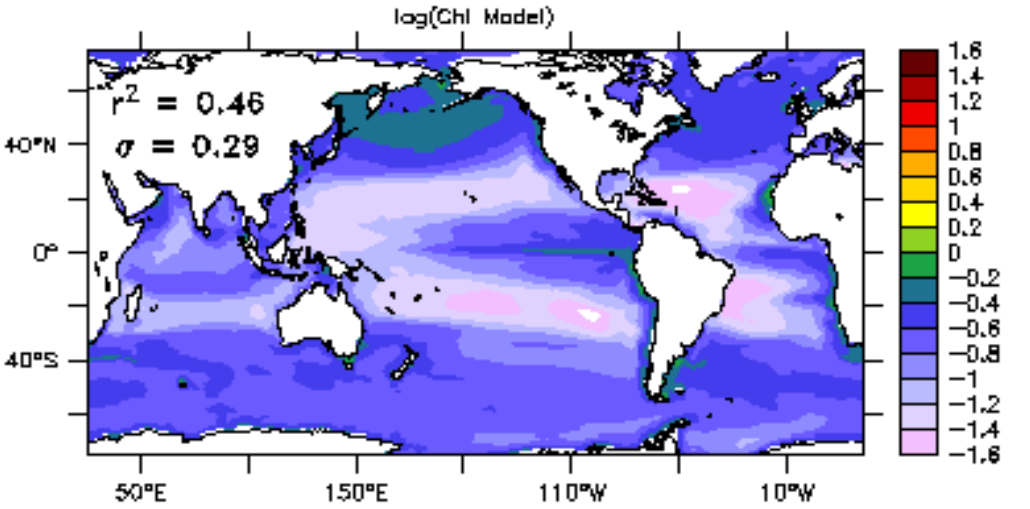
Tracers of Phytoplankton with Allometric Zooplankton (TOPAZ)*

Major nutrients + 4 phytoplankton groups



1° x 1° north of 30°N, with latitudinal resolution increasing to 0.33° at equator





Projected Climate Changes for N Pacific over the 21st Century

Basin-wide warming

Tropical easterlies weaken

Westerlies and polar easterlies weaken and shift poleward

Reduced wind-stress curl

Weakened vertical velocities and increased stratification

Nutrient redistribution

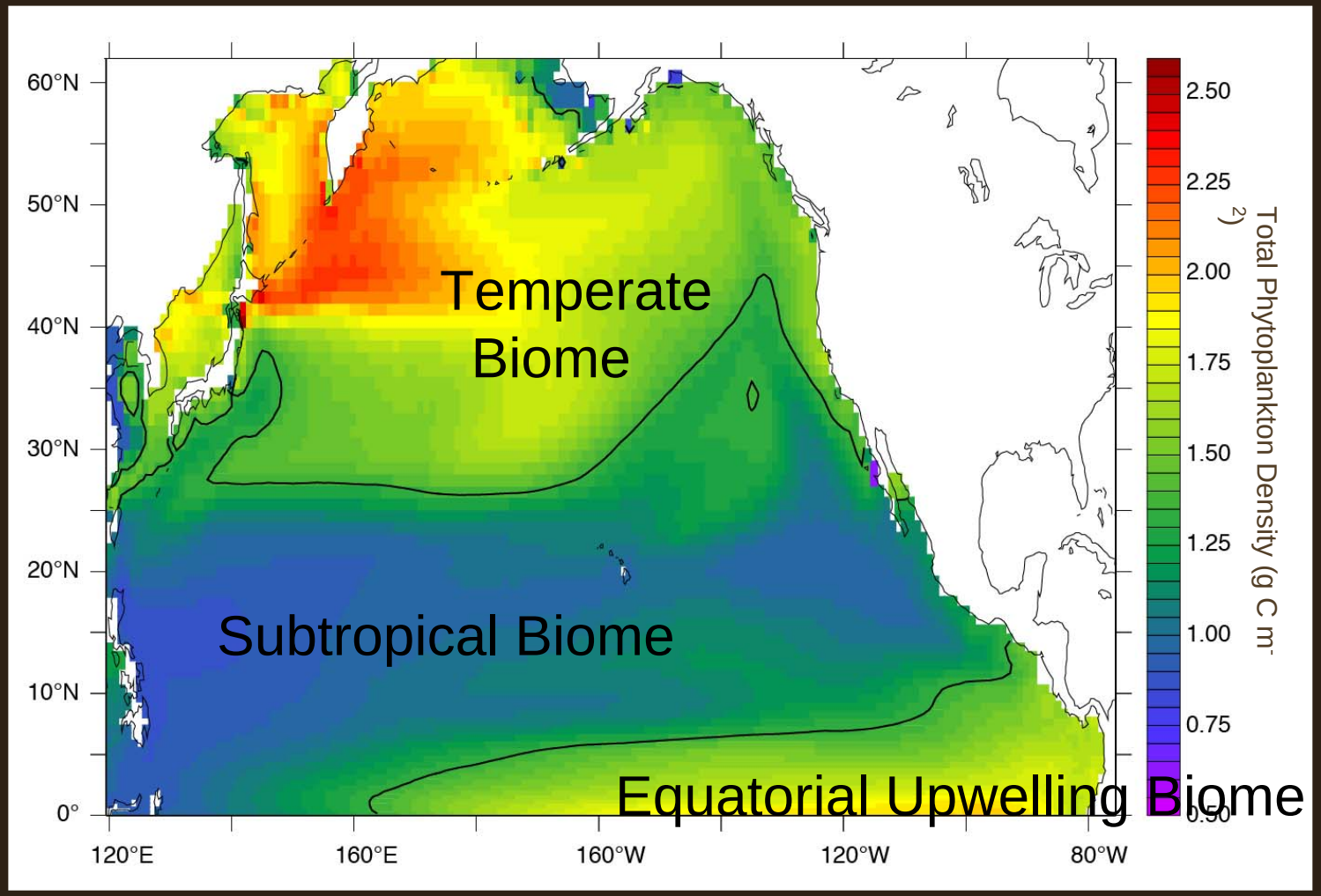
Rykaczewski and Dunne 2010, Sarmiento *et al*. 2004, Vecchi *et al*. 2006, Yin 2005

Extending climate model results to higher trophic levels – 2 approaches

- Using climate model output to define dynamic biomes and then examine spatial and temporal changes in model-derived biomes in response to climate change

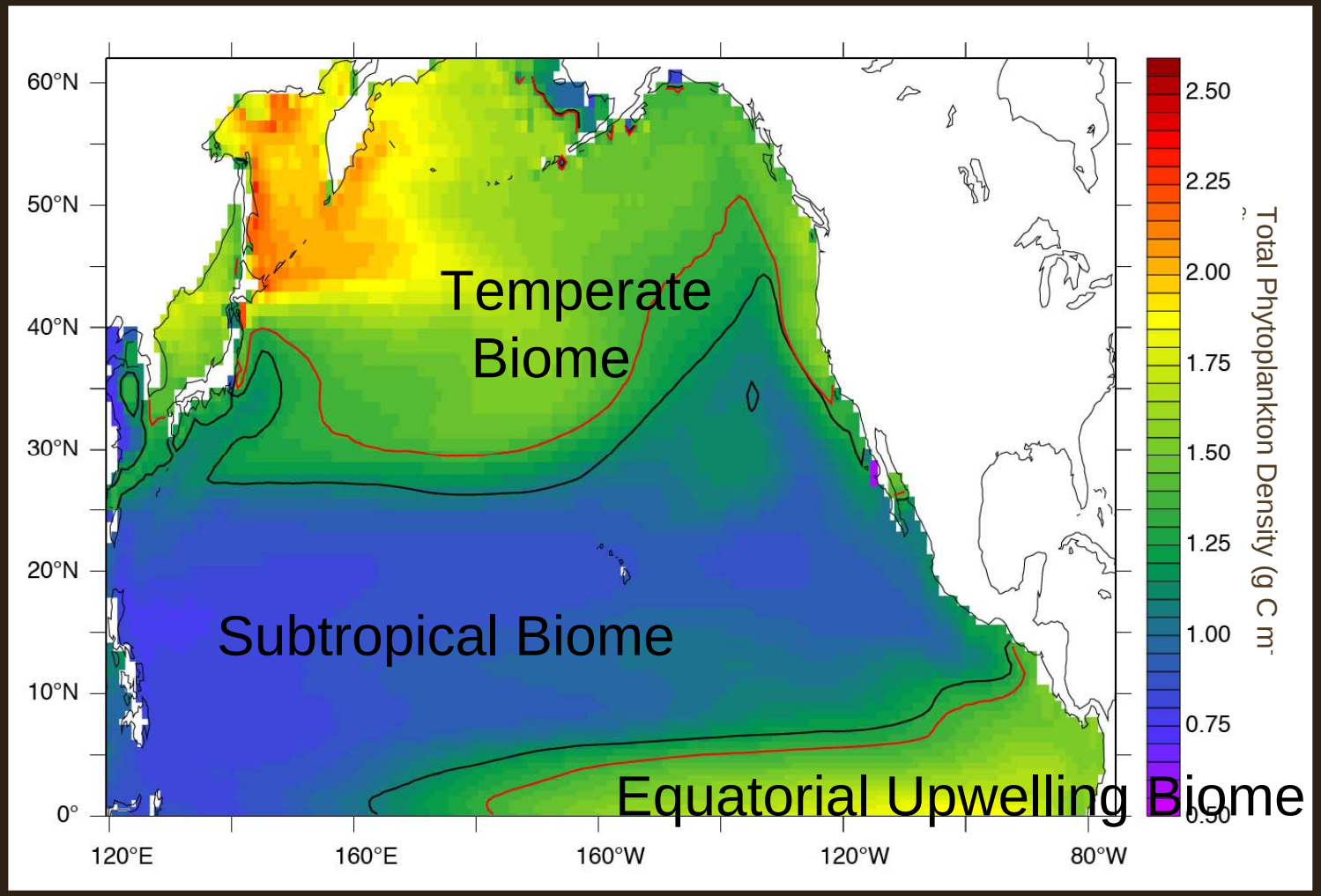
- Using climate model output to drive a size-based ecosystem model at specific locations

20-year Mean Total Phytoplankton Density 2001 – 2020



Polovina *et al*. (2011)

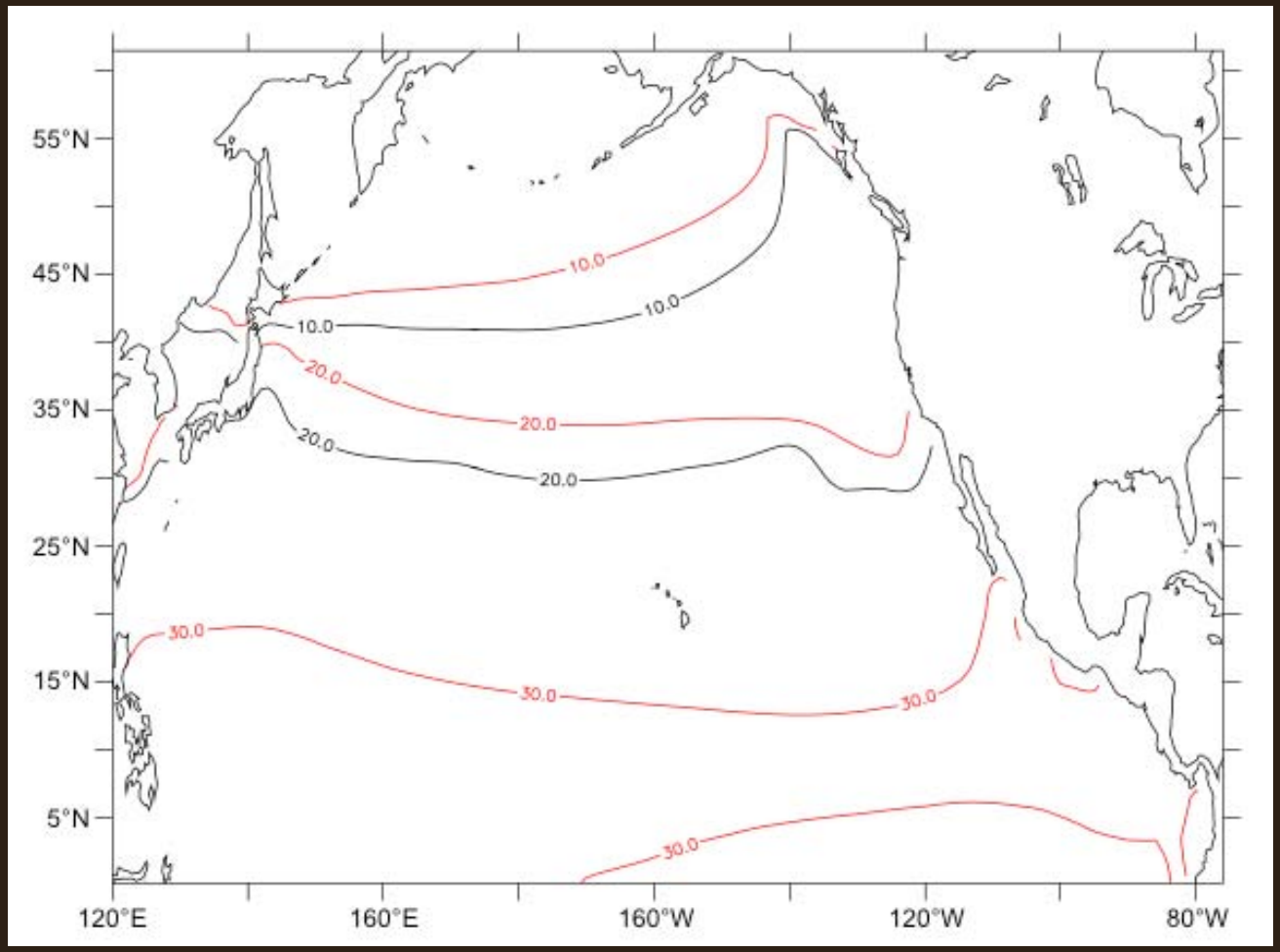
20-year Mean Total Phytoplankton Density 2081 – 2100



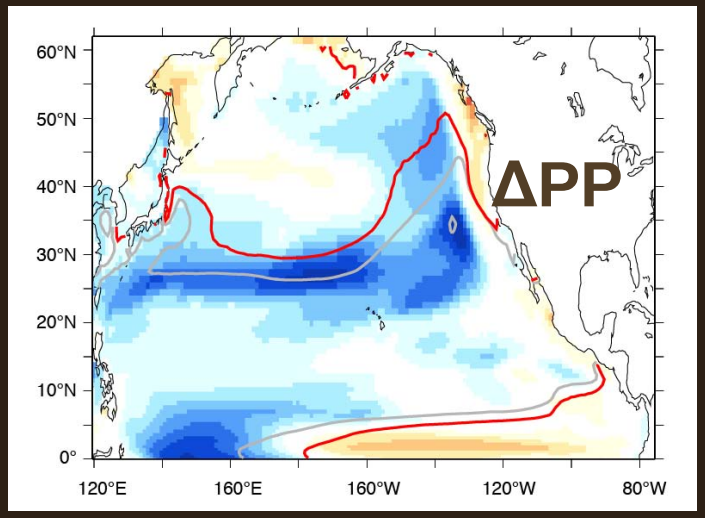
Polovina *et al*. (2011)

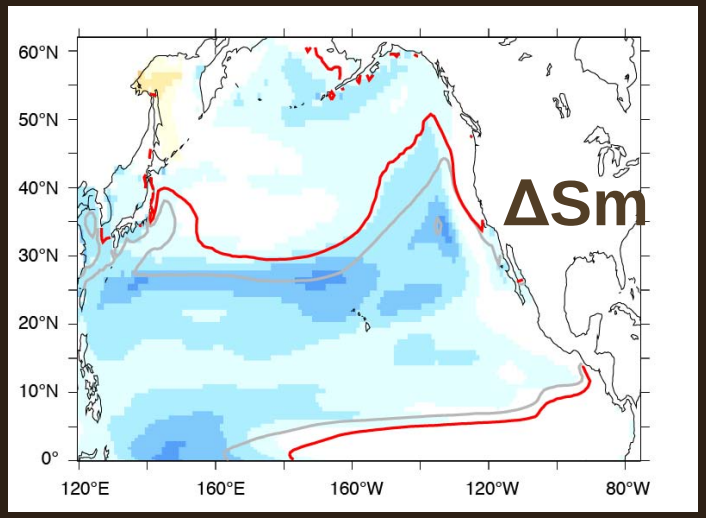
Impacts of increasing SST

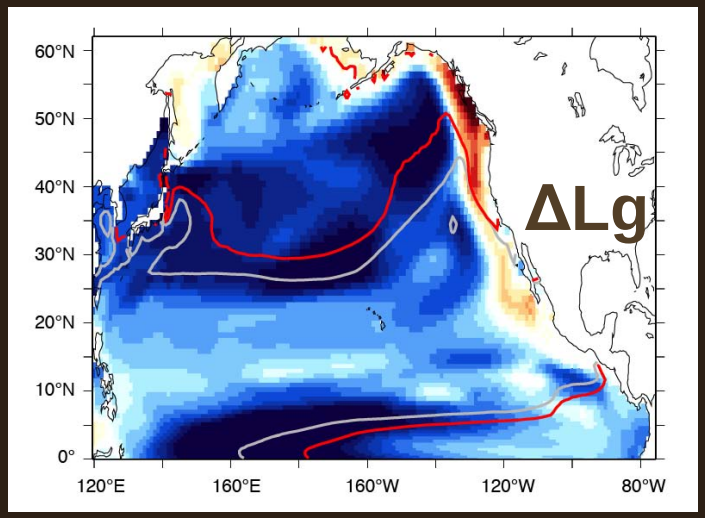
Mean SST at the Beginning and End of the 21st Century

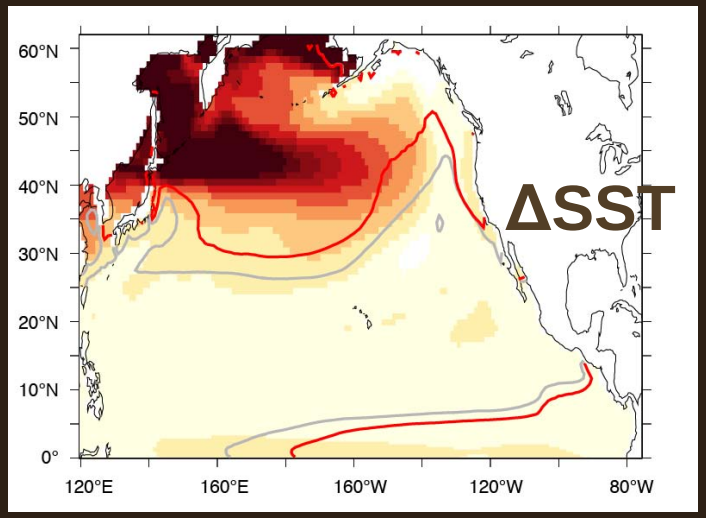


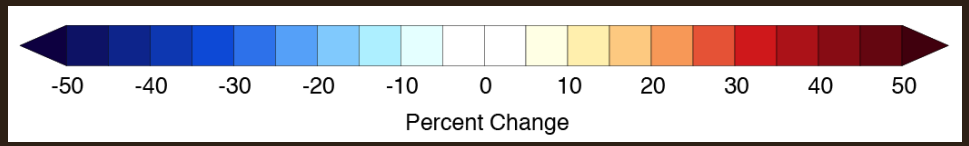
Change Over the 21st Century





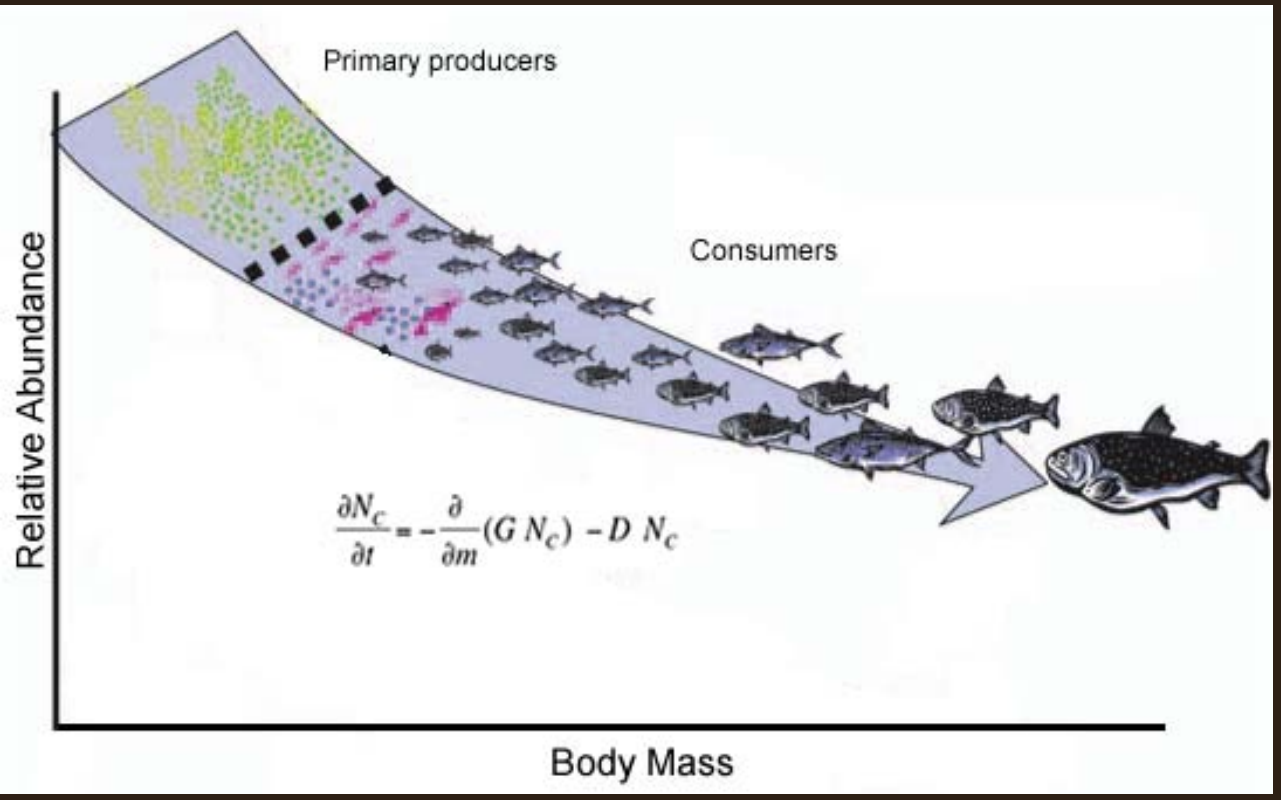






Gnanadesikan *et al.* 2006

Size-based model



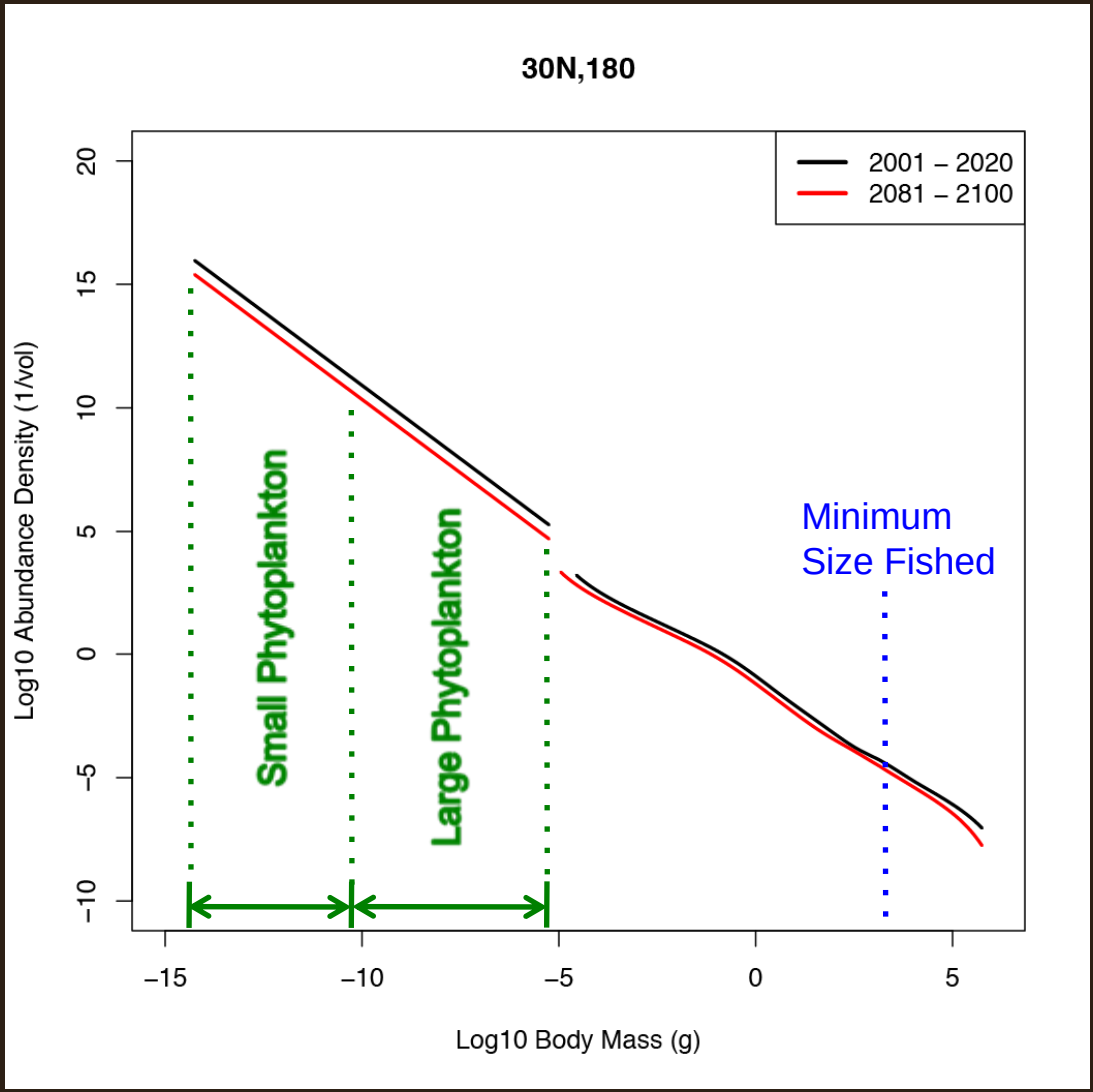
Assumes size-based predation, and size-specific growth and mortality are functions of food availability and SST

Input: monthly plankton size spectrum and SST

Output: monthly population size spectrum

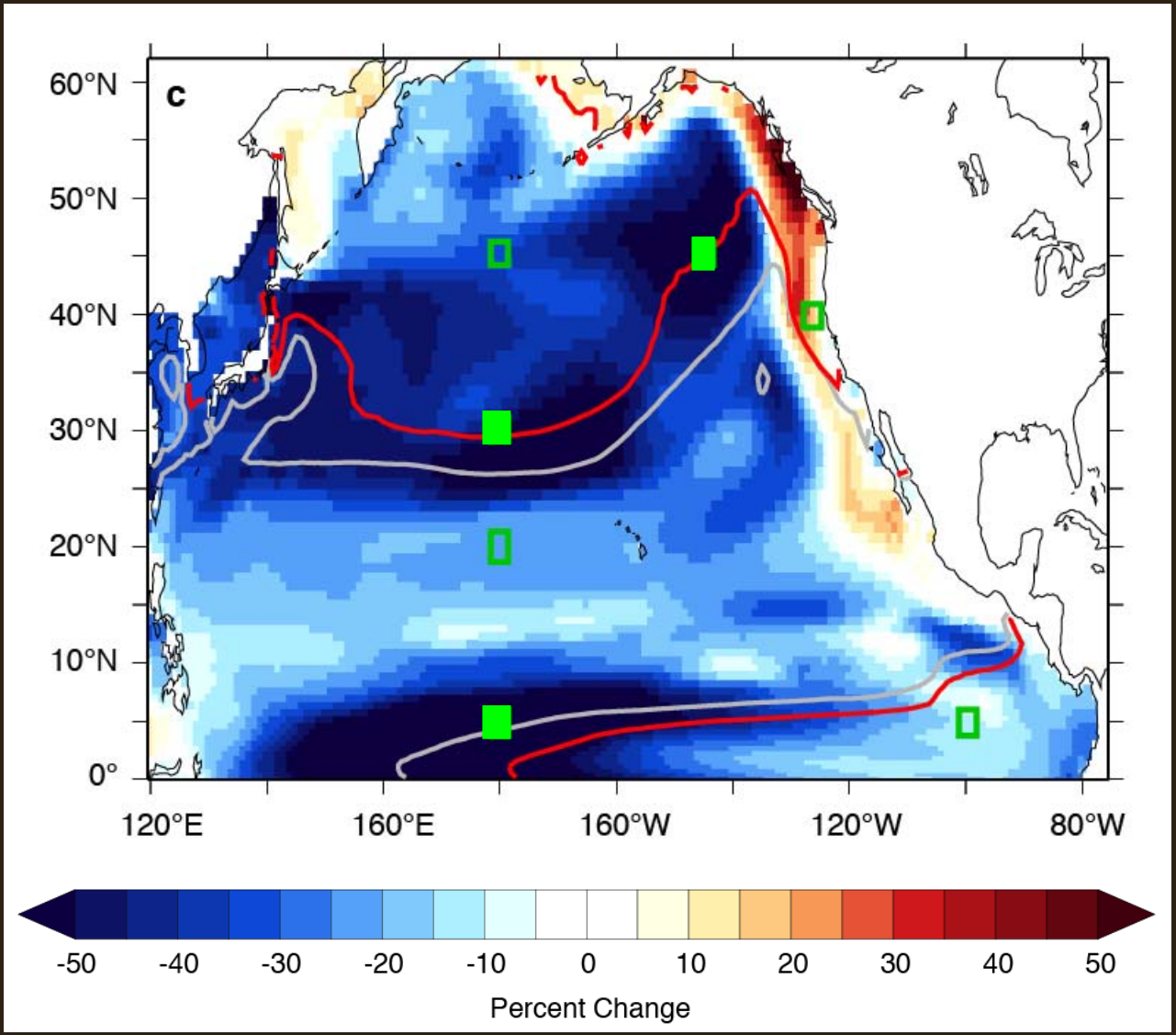
Jennings et al. 2008, *Proc. R. Soc. B;* Blanchard et al. 2009 *J Anim Ecol*; Blanchard et al. 2010 *Theor. Ecol.*

Size Spectra



Barnes *et al*. 2010, Benoit and Rochet 2004, Blanchard *et al*. 2009, Jennings *et al*. 2008, Stock and Dunne 2010

Areas of Interest

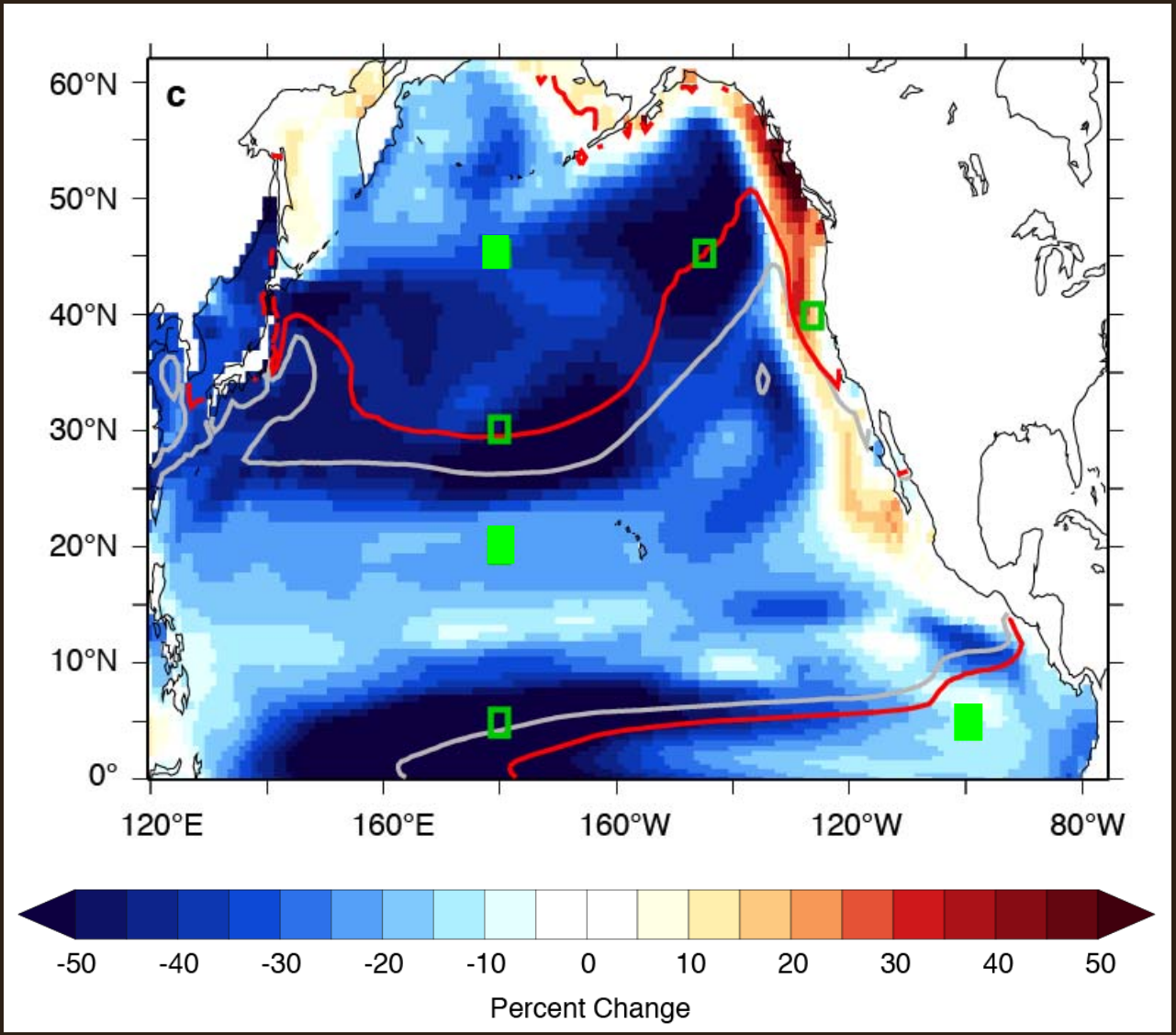


Biome Boundaries

Biome Interiors

California Current

Areas of Interest



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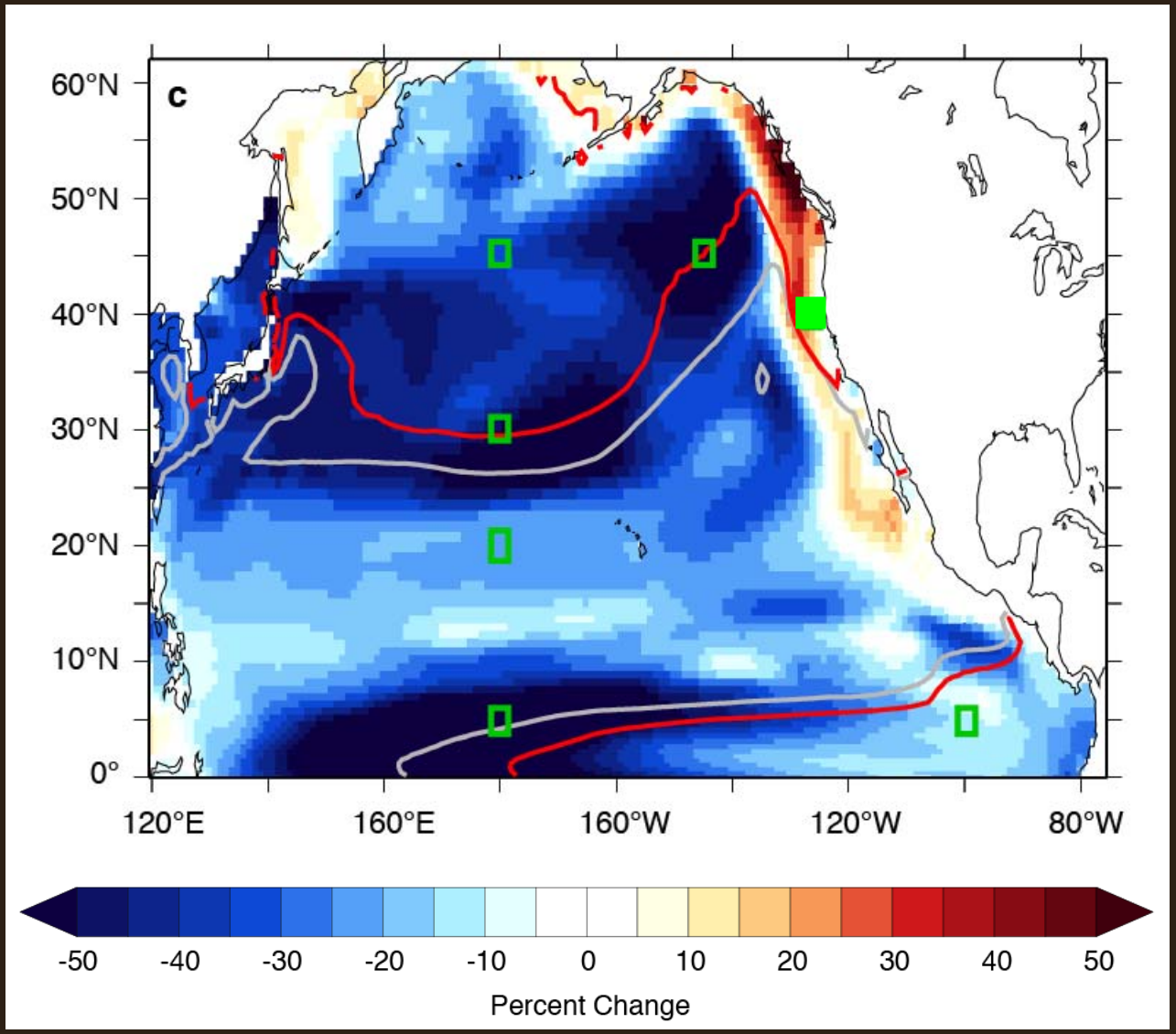
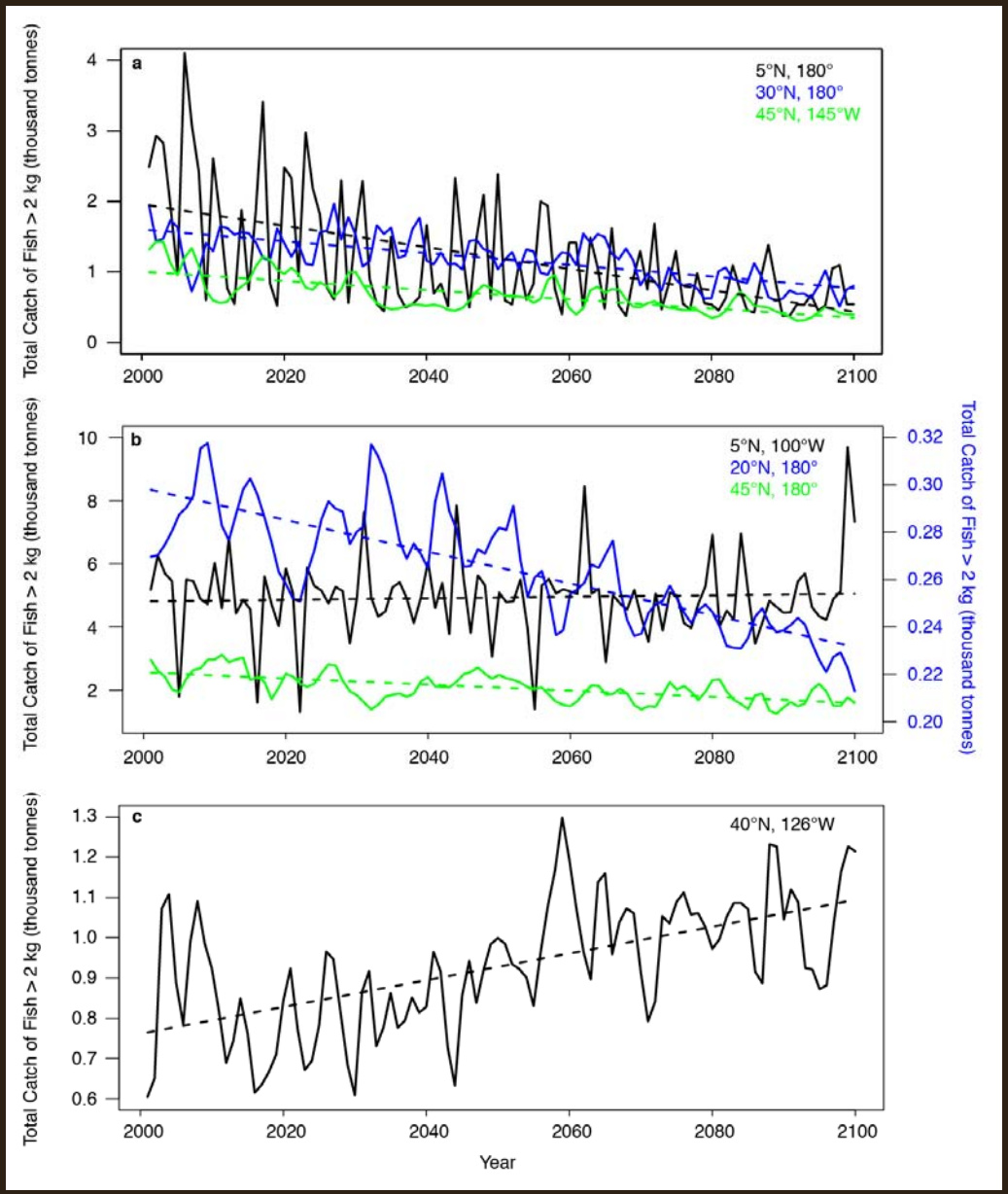


Biome Boundaries

Biome Interiors

California Current

Projected Catch of Fish > 2 kg, F=0.2

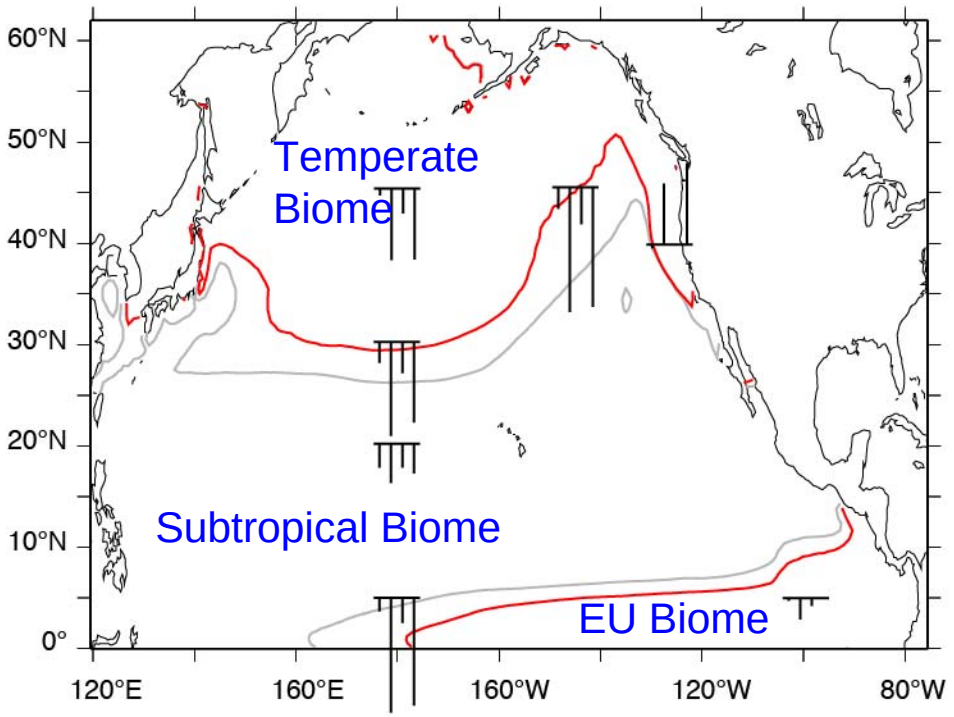


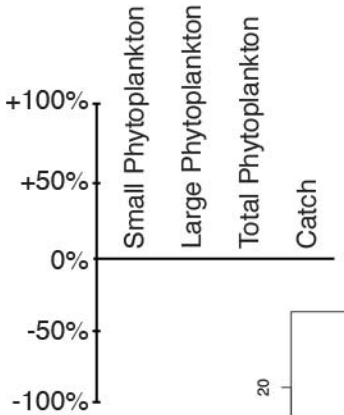
Biome Boundary Regions
decline 52 – 77%

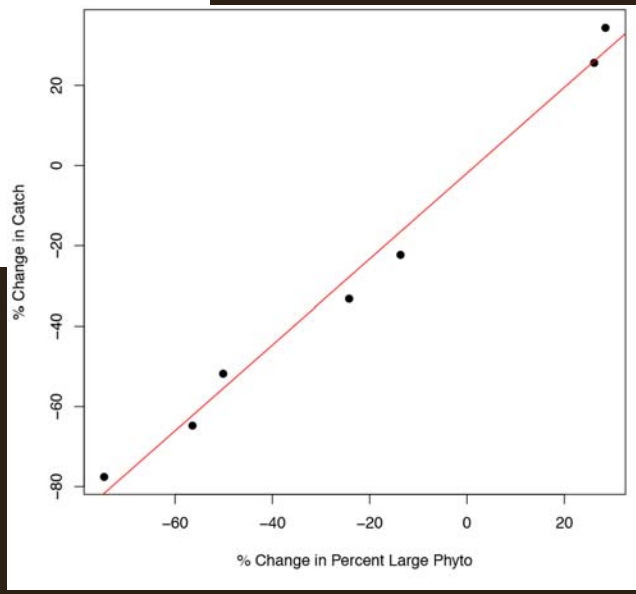
Biome Interior Regions
decline 0 – 38%

California Current Region
increase 43%

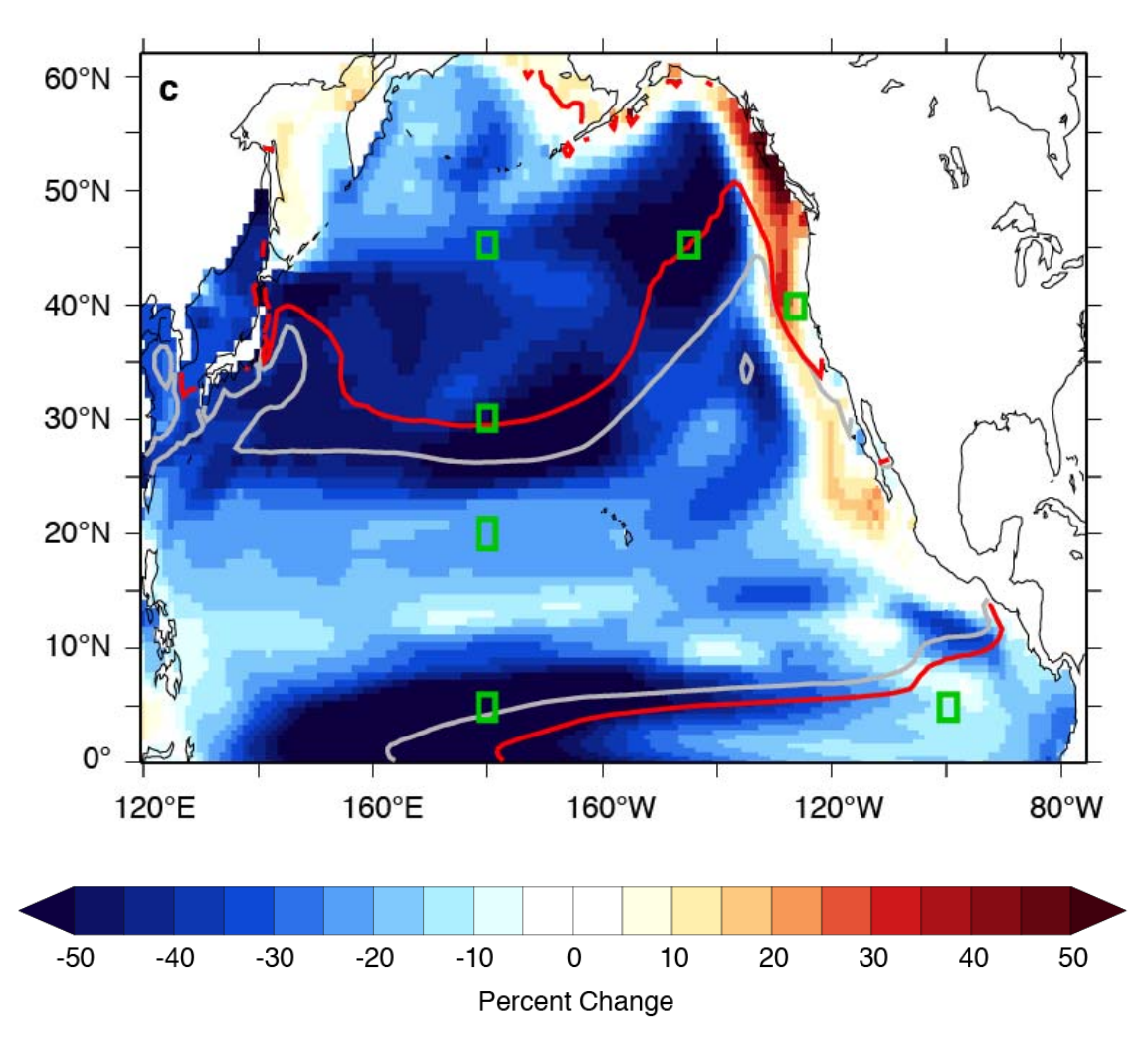
Correlation between Size Composition and Catch







Additional Implications



- Biome boundary regions may see earliest and greatest impacts and hence are ideal areas for monitoring phytoplankton size structure

- Transition Zone for used foraging and migration

- Possible eastward redistribution of skipjack and yellowfin, and bigeye tuna

- Results present come from only one climate model. Need to consider output from several climate models

Summary

- Over 21st century a change in wind field and increased ocean warming will increase oceanic vertical stratification and redistribute nutrients.
- For much of oceanic North Pacific fish density and catch declines, with greatest declines (50-80%) near the boundary of the expanding subtropical gyre.
- However, in the California Current, nutrient upwelling increases resulting in an increase in fish density and catch.
- Changes in density of large phytoplankton is a dominant biological response to climate change which alters the length of food chains and hence fish yields.
- Size-based model couples well with climate model to assess high tropic impacts from climate change.