Connecting Climate and Marine Ecosystems

Presented by

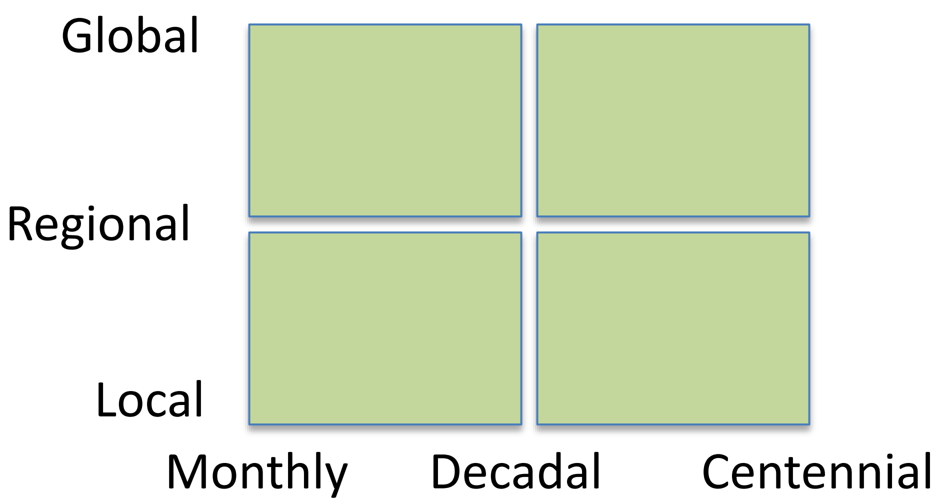
Charles Stock

Geophysical Fluid Dynamics Laboratory Review

May 20 – May 22, 2014

Objectives

Robust, quantitative predictions and projections of climate-ecosystem Interactions across spatial and temporal scales



In support of NOAA NGSP Goals:

- Climate Adaptation and Mitigation
- Healthy Oceans
- Resilient Coastal communities and economies

Accomplishments

- Led comprehensive synthesis on the use of IPCC-class climate models to assess climate impacts on living marine resources (Stock et al., Prog. in Oceanogr., 2011; 120, 1-28)
- Led or co-authored 30 published studies to assess climate impacts on living marine ecosystems
- Advanced marine ecosystems models within ESMs, yielding new insights into marine resource sensitivity to climate change
- Developing innovative marine ecosystem applications for new GFDL climate predictions and projections

Interdisciplinary collaborative efforts essential for meeting our objective

Negative impacts on endangered leatherback turtles

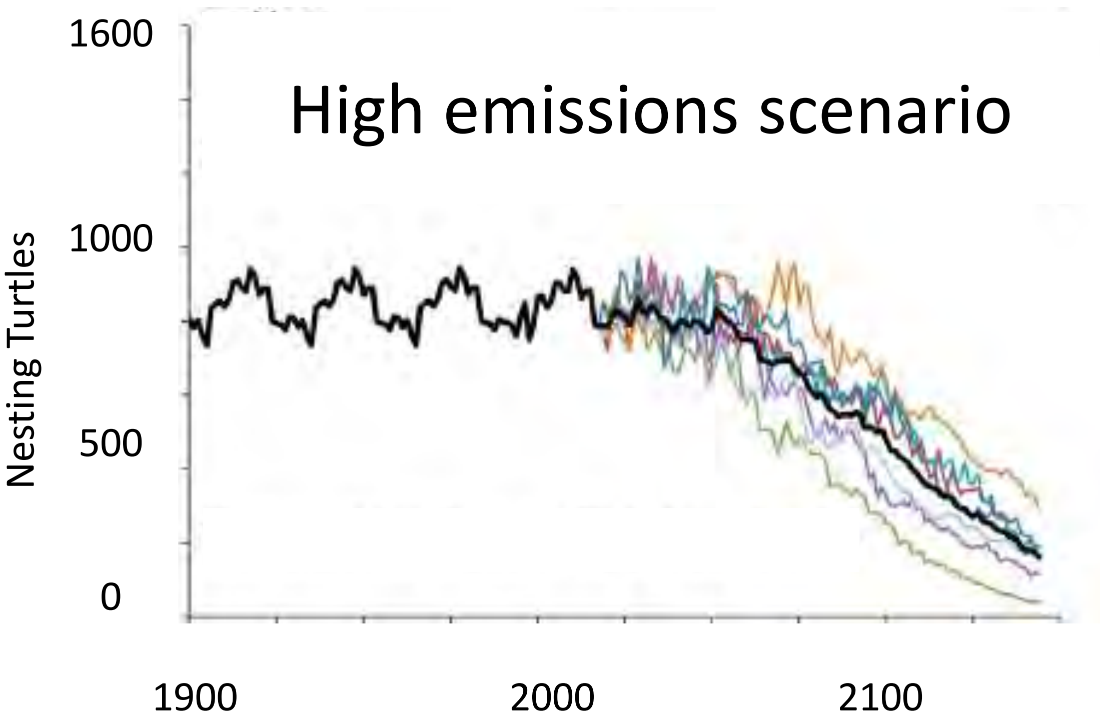
- Hatch and emergence success depend on temperature and precipitation

- Sex ratio depends on precipitation levels

- Returns to land for nesting depend on ocean productivity (cold, La-Nina conditions indicate more productive ecosystem)

Saba, V. S., C. A. Stock, et al., 2012: Projected response of an endangered marine turtle population to climate change. *Nature Climate Change*. 2, 814-820.

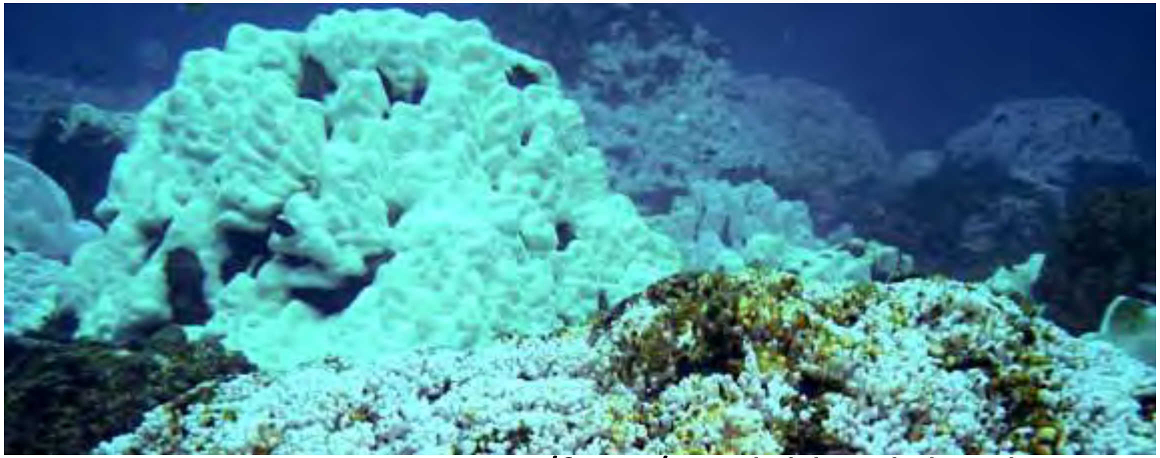
Negative impacts on endangered leatherback turtles



- Project declining numbers due to lower hatching/emergence with increasing temperature
- Nesting further north unlikely due to extremely dry conditions in sub-tropics
- Potential to maintain population through irrigation and shading if projected impacts begin to manifest.

Saba, V. S., C. A. Stock, et al., 2012: Projected response of an endangered marine turtle population to climate change. *Nature Climate Change*. 2, 814-820.

Adaptation & climate change impacts on coral reefs



Oceanservice.noaa.gov/facts/coral_bleach.html

- Stressed corals, including those exposed to warming, may expel symbiotic algae that provide much of coral's nutrition.
- > 1 degree heating month above maximum monthly mean temp in a span of 3 months = likely bleaching

Logan, C.A., J. P. Dunne, et al., 2014: Incorporating adaptive responses into future projections of coral bleaching. *Global Change Biology*. 20, 125-139.

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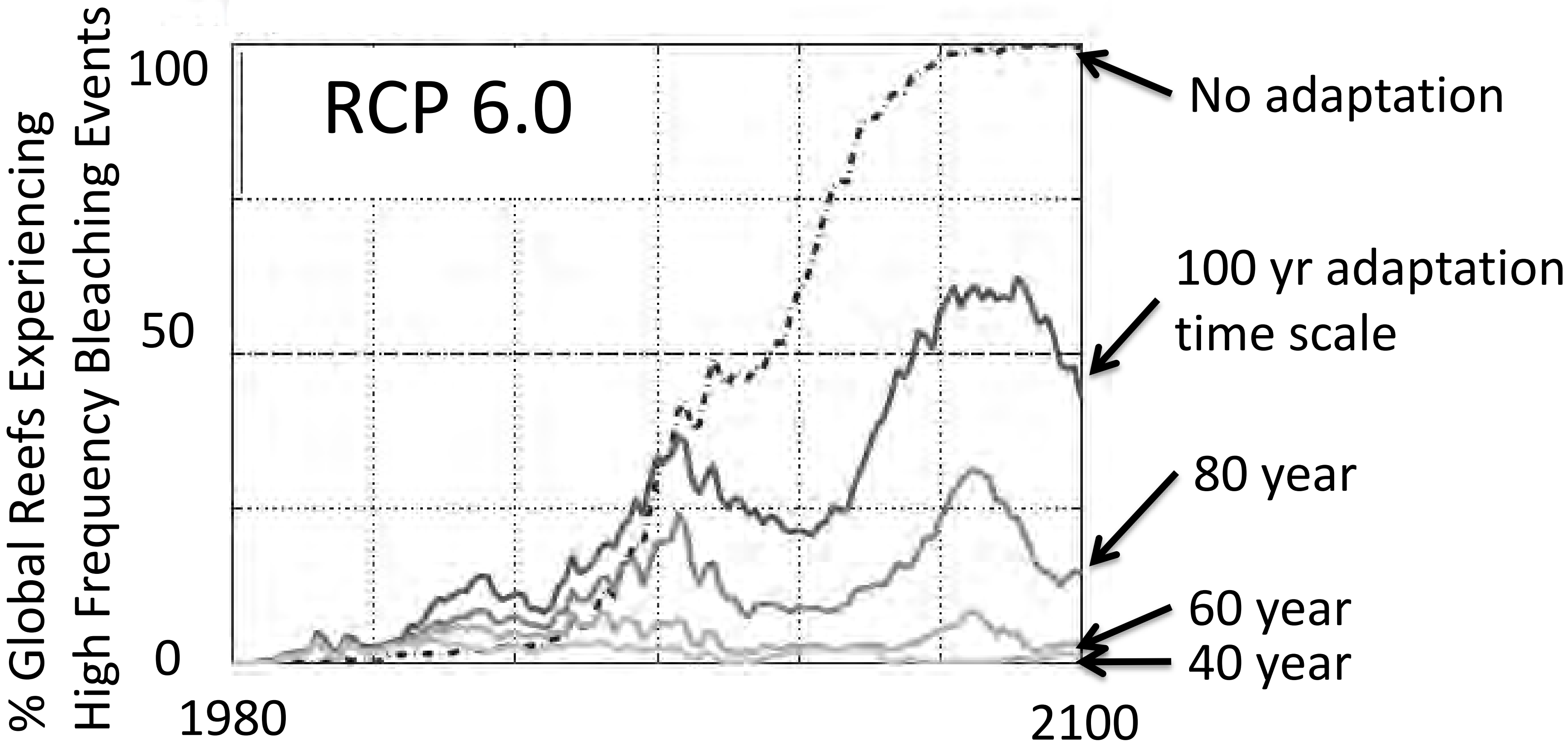

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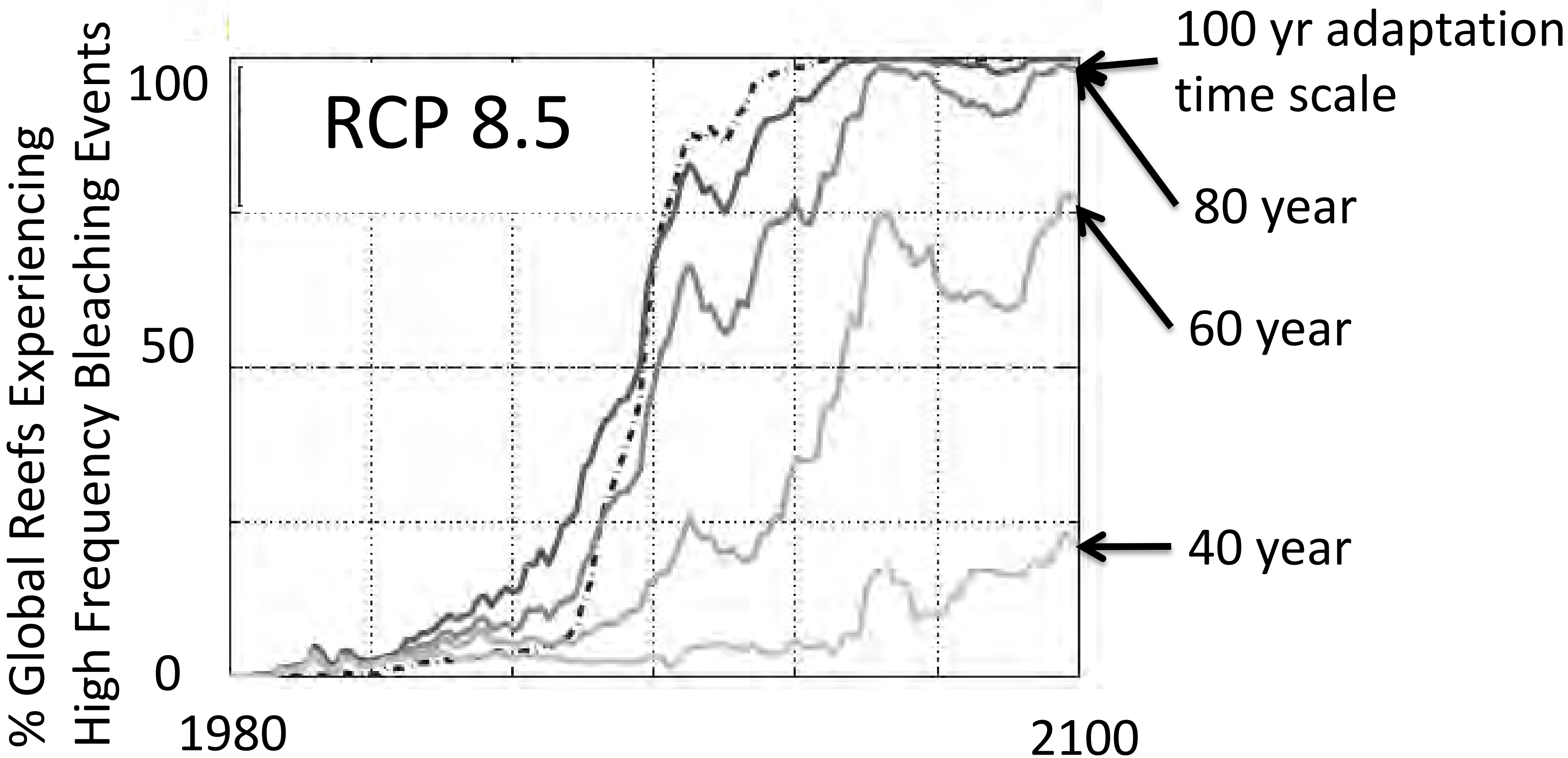
Adaptation & climate change impacts on coral reefs



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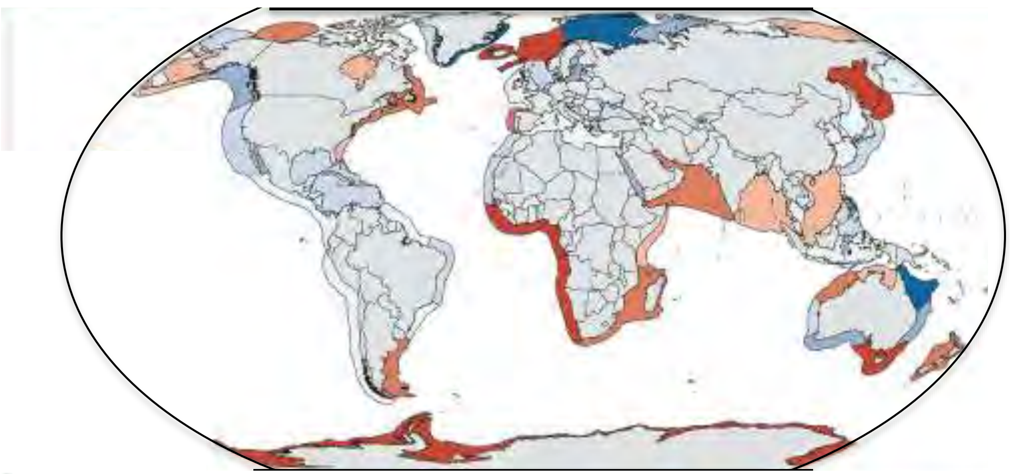
Progress and Challenges

- Present assessments: magnitude, direction, and first-order drivers of climate-change impacts
- Priority developments:
  - Strengthen mechanistic and quantitative connections between climate drivers and ecosystem responses
  - Provide predictions and projections on time-scales ranging from seasons to centuries.
  - Improve resolution of local/regional impacts
  - Consider responses to multiple stressors

Stock et al., *On the use of IPCC-class models to assess the impact of climate on Living Marine Resources.* Progress in Oceanography 120, 1-28.

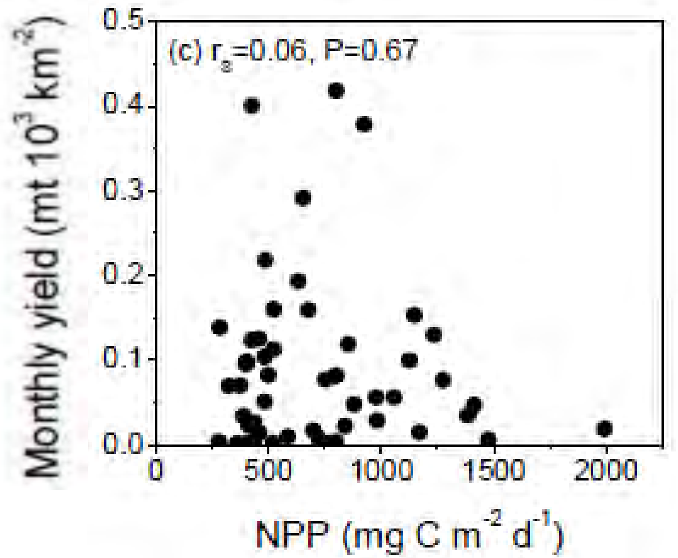
Connecting climate and global fisheries

Primary production alone is not a good indicator of fisheries yields



Large Marine Ecosystems

Ken Sherman (NOAA/NMFS)



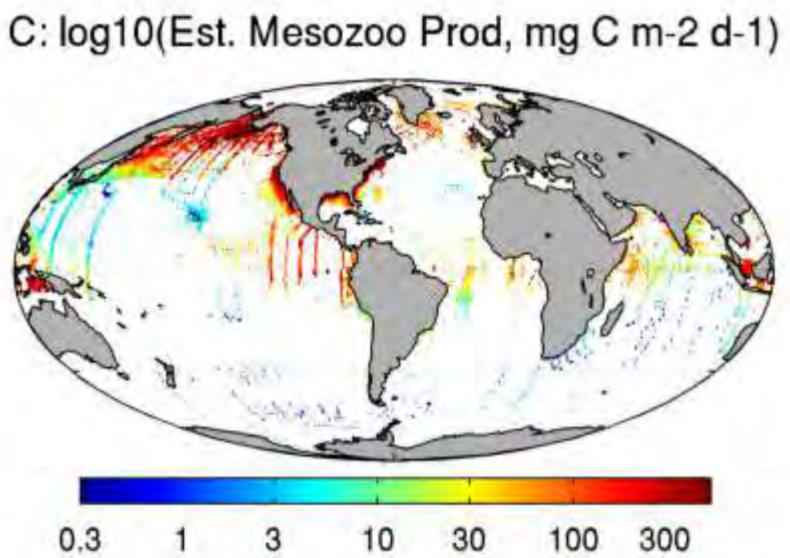
Friedland, K. D., C. A. Stock, et al., 2012: *Pathways between Primary Production and Fisheries Yields of Large Marine Ecosystems.* PLoS ONE

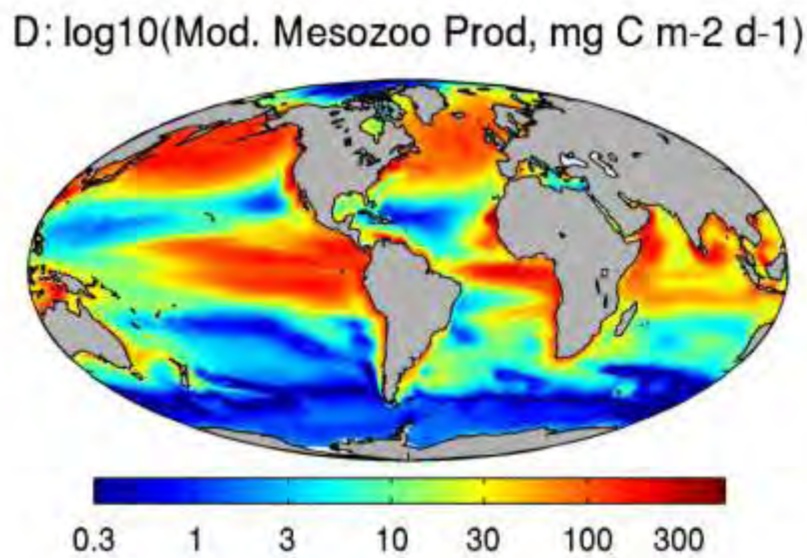
COBALT Marine Ecosystem Model

- Capture interactions between climate and ocean biogeochemistry with a more resolved, mechanistic representation of the plankton ecosystem dynamics.
- Capture the impact of climate on the flow of carbon and energy through the planktonic food web to fisheries and other living marine resources
- A robust, quantitatively supported baseline for continued model development

Stock, C.A., J. P. Dunne, and J.G. John, 2014: *Global-scale Carbon and Energy Flows through the Marine Planktonic Foodweb.* Progress in Oceanography 120, 1-28.

Quantitative C fluxes throughout plankton foodweb





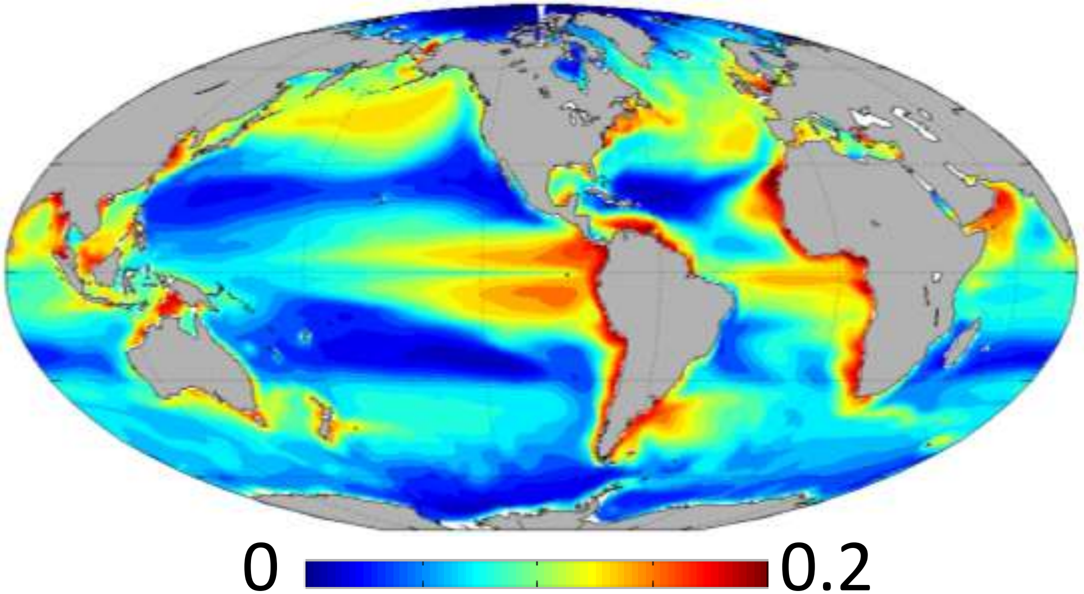
Obs-based mesozooplankton production (NOAA Copepod database, O'Brien, 2005; Hirst and Bunker, 2003; SeaWiFS)

Mesozooplankton production in GFDL's COBALT ecosystem model

Stock, C.A., J. P. Dunne, and J.G. John, 2014: *Global-scale Carbon and Energy Flows through the Marine Planktonic Foodweb.* Progress in Oceanography 120, 1-28.

Spatial differences in foodweb transfer efficiency

Ratio of Mesozooplankton Production to Primary Production

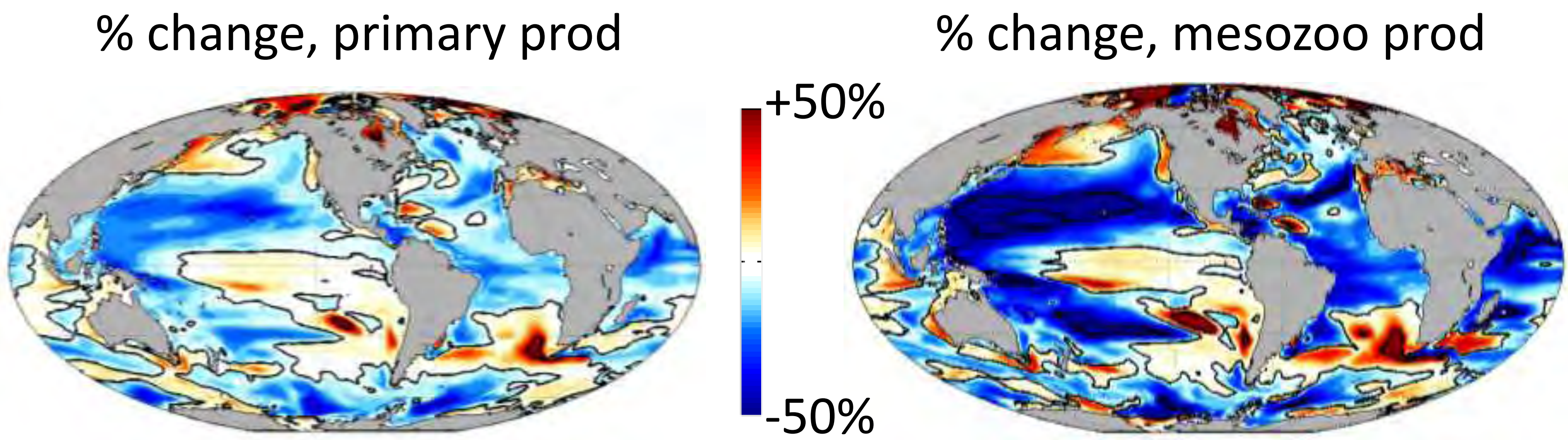


Stock, et al., 2014: Progress in Oceanography 120, 1-28.

Attributed to spatial variations in 3 factors:

- Number of trophic steps between phytoplankton and mesozooplankton
- Efficiency of trophic links
- Strength of coupling between consumers and phytoplankton in surface ocean

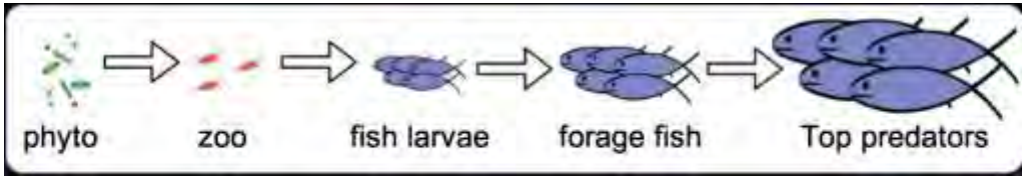
Amplification of ocean productivity changes

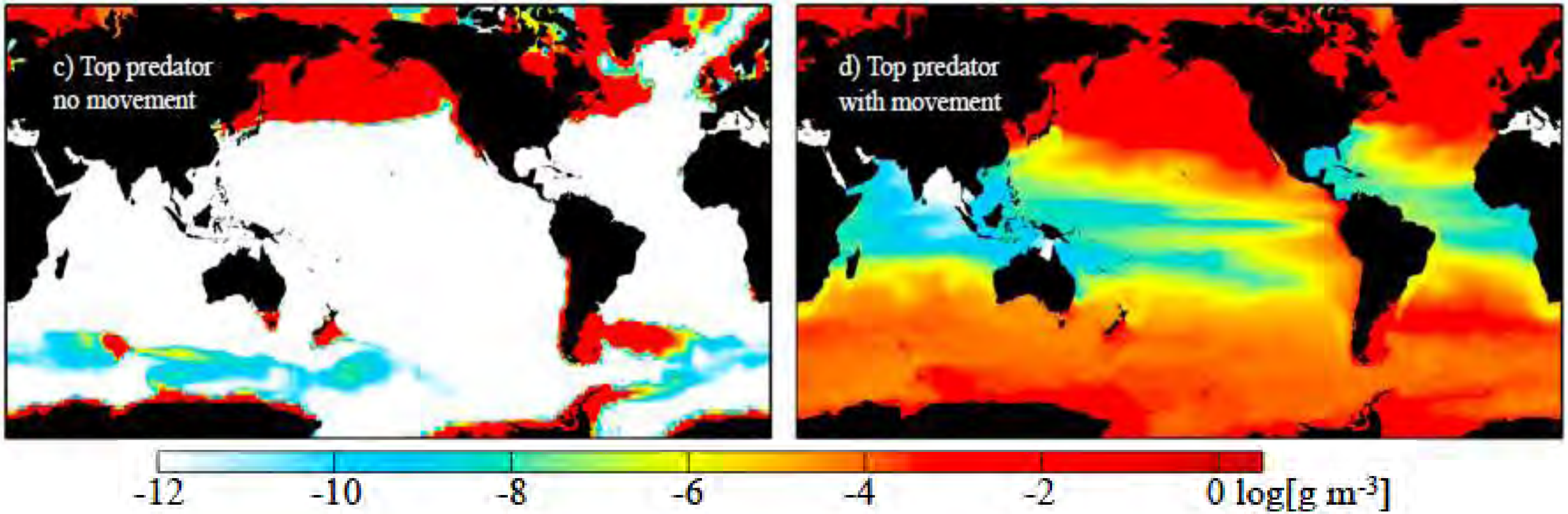


- Projected percent changes in mesozooplankton productivity are 2X primary productivity changes
- Large regional changes
- Quantitative attribution to the same planktonic food web characteristics that drive spatial gradients

Stock, C.A., J. P. Dunne, and J.G. John, submitted: *Understanding trophic amplification of ocean productivity trends in a changing climate.*

Simulating global fish dynamics





Watson, J., C. A. Stock, J. Sarmiento, in revision, *The role of movement in determining the global distribution of marine biomass.* Progress in Oceanography

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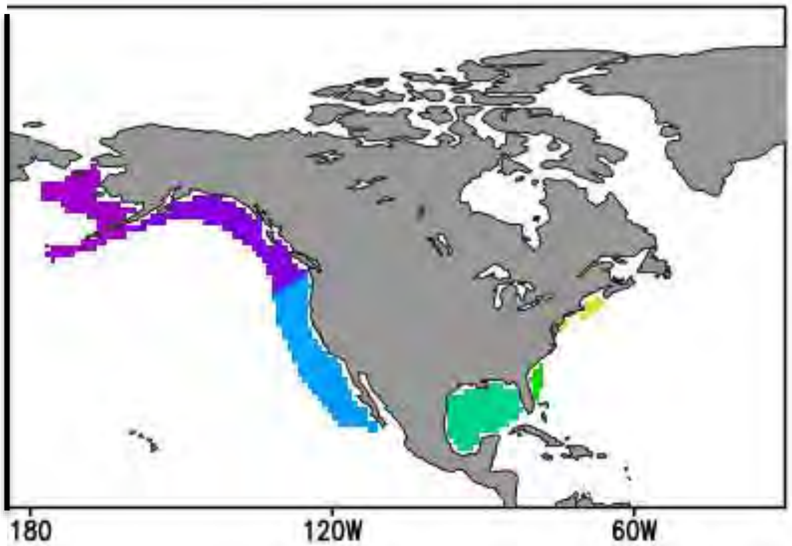
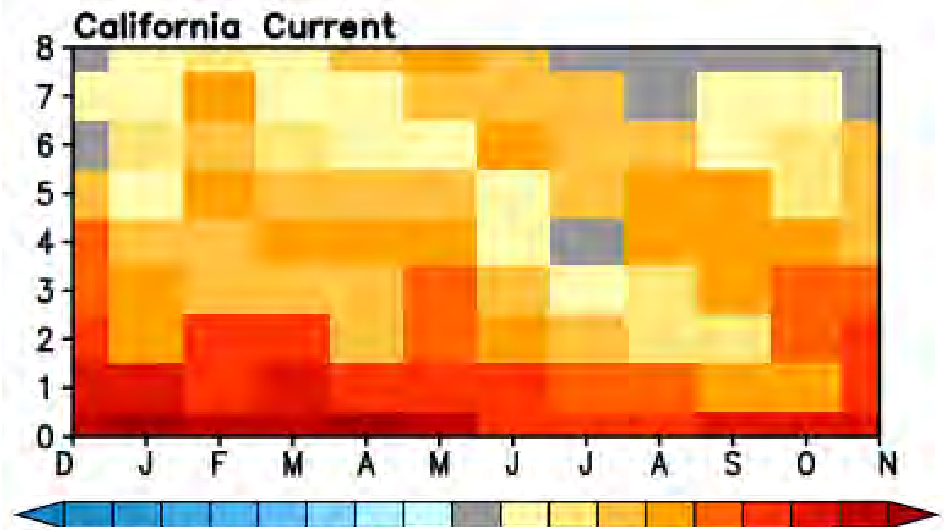
Seasonal/decadal predictions for marine resources

How predictable are shelf scale hydrographic anomalies?



GFDL CM2.1 SST anomaly Correlation for Cal. Current



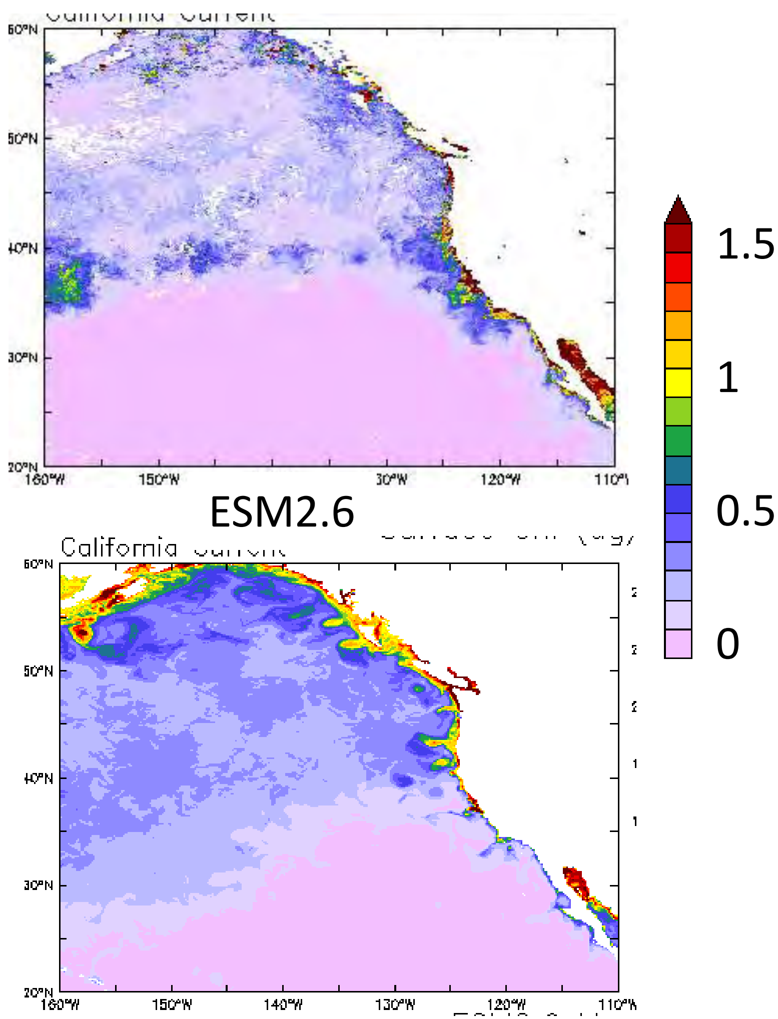
0.9 0 0.9

How many sardines should we catch next year?

SEED Grant, OAR/NMFS S&T – GFDL, ESRL, NCEP, PMEL, NMFS

High-resolution ESMs

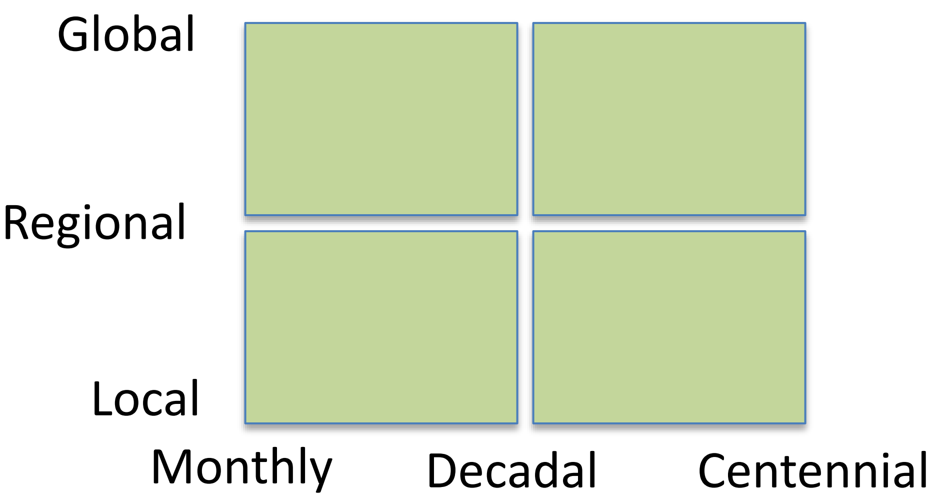
Satellite Chlorophyll (mg Chl m^{-3})



- What controls marine resource yields across global shelf ecosystems?
- What is the role of shelves in global biogeochemical cycles?
- Where are abrupt change in shelf ecosystems likely? Which stressors drive these changes?
- How can we improve integration of global and distributed regional ecosystem modeling capacity?

Summary

Robust, quantitative predictions of climate-ecosystem interactions across scales through integration of ecosystem dynamics across GFDL model configurations



Building confidence in ecosystem predictions by:

- Increasingly rigorous and holistic model-data comparisons
- Progressive incorporation of improved ecology and physiology based on principles expected to hold in a changing climate