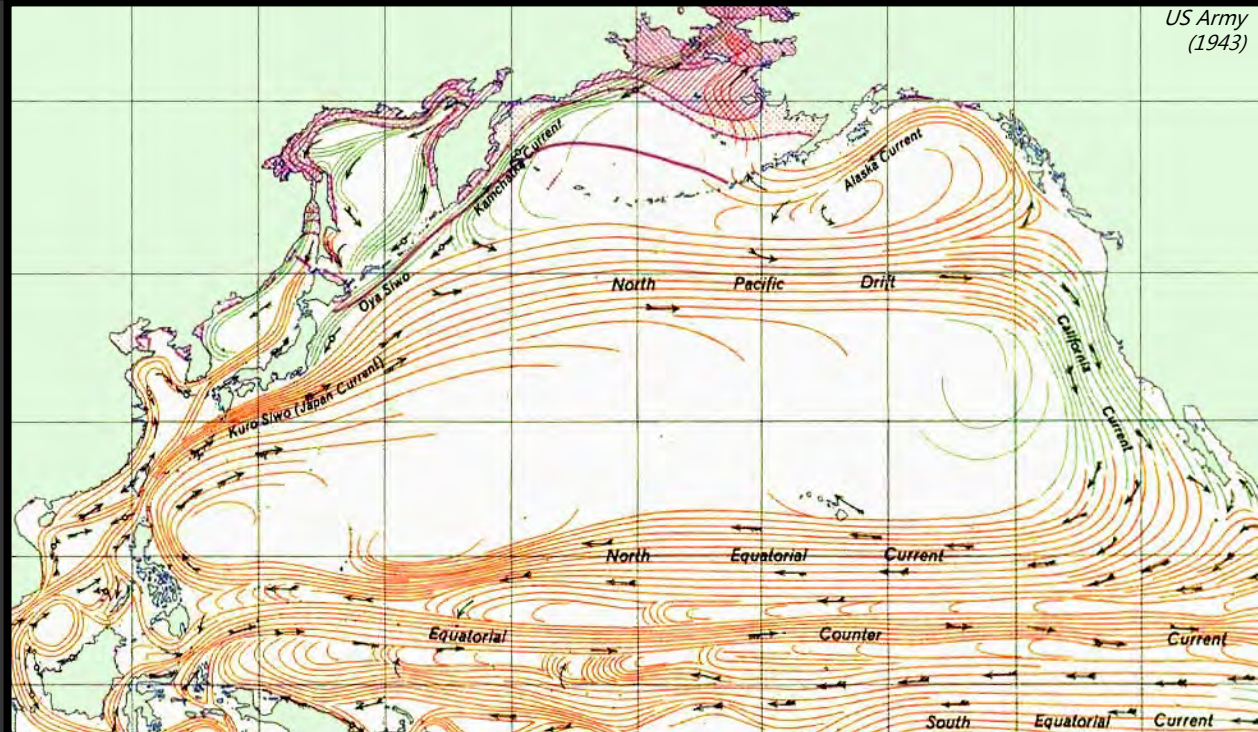# The future of nutrients, fish, and fisheries in the California and Kuroshio Currents:
A multi-model approach

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Columbia, SC, US

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Boulder, CO, US

US Army (1943)

UNIVERSITY OF SOUTH CAROLINA
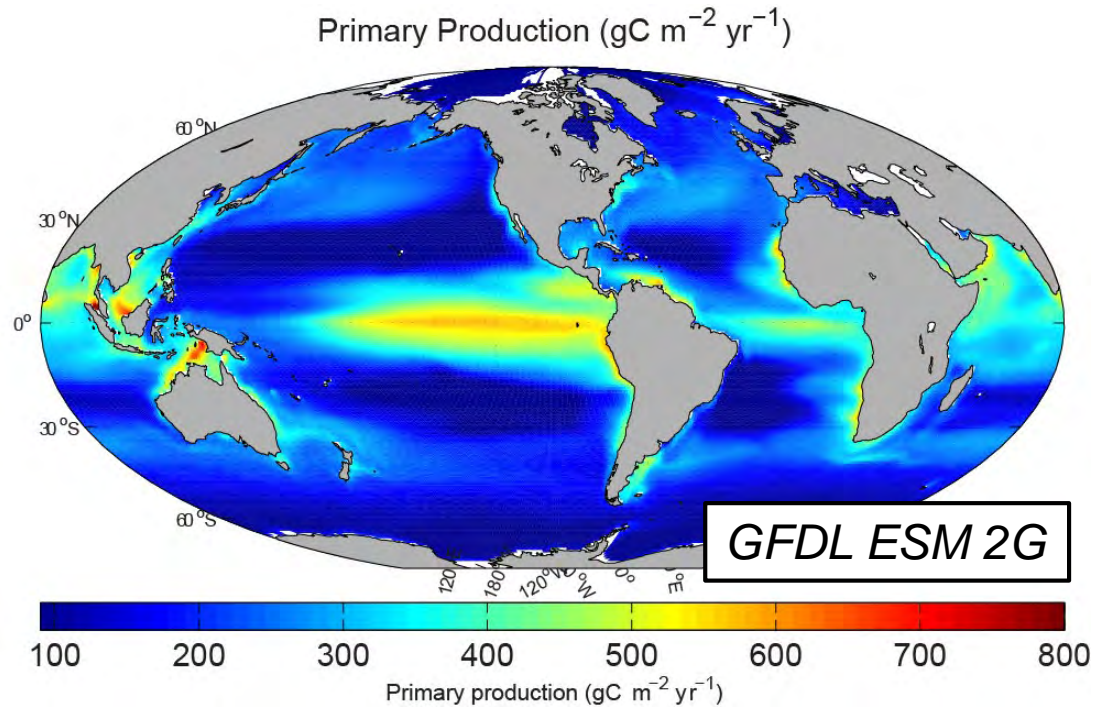
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日本財団 THE NIPPON FOUNDATION

The Nippon Foundation
NEREUS PROGRAM
Predicting Future Oceans

Our ability to model primary production is improving

Changes in primary production are expected to be driven by changes in:

nutrient availability, light availability, and temperature.

Although the sensitivity of these factors to future climate change are fairly well understood, projections of primary production vary quite broadly across different earth-system models.

Primary Production (gC m^{-2} yr^{-1})

GFDL ESM 2G

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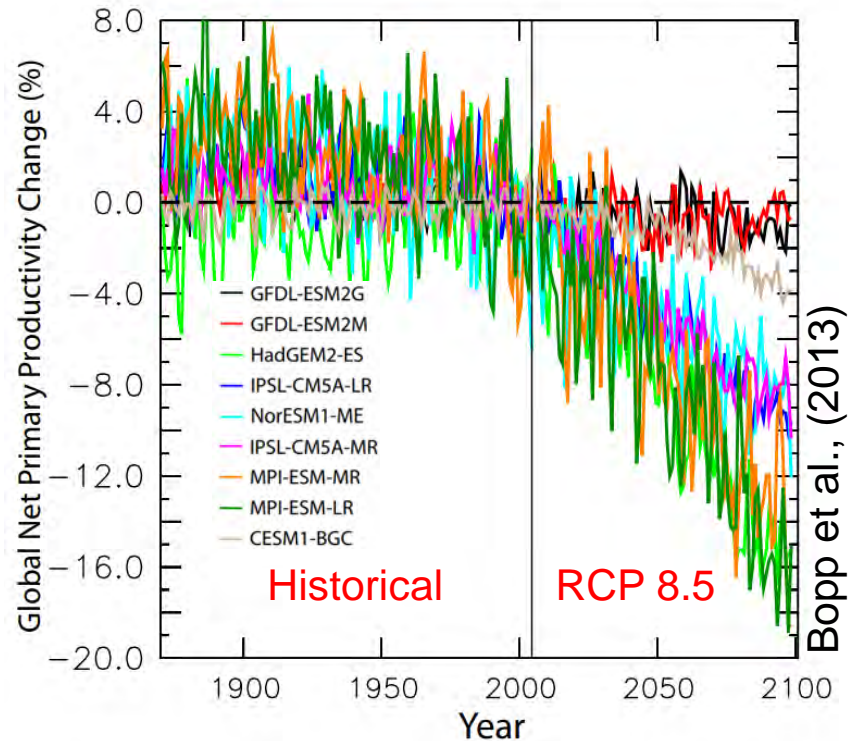
Projected changes in NPP range from relative stability to steep declines.

Bopp et al., (2013)

GFDL-ESM2G
GFDL-ESM2M
HadGEM2-ES
IPSL-CM5A-LR
NorESM1-ME
IPSL-CM5A-MR
MPI-ESM-MR
MPI-ESM-LR
CESM1-BGC

Historical   RCP 8.5

Uncertainties seem to scale with increasing societal relevance

Despite the ongoing uncertainties in projections of primary production, attempts to simulate changes in higher-trophic-level productivity (*i.e., **fisheries***) march forward.

However, the community of ecological modelers simulating fisheries productivity does so with recognition of the need to quantify and understand sources of vast uncertainty.

The Fisheries and Marine Ecosystem Model Intercomparison Project, or Fish-MIP, is a network of more than 40 global and regional marine ecosystem modelers from around the world.

FISHERIES & MARINE ECOSYSTEM

FISH-MIP

MODEL INTERCOMPARISON PROJECT

Motivating questions:

What is the uncertainty and magnitude of projected changes in potential fisheries production?

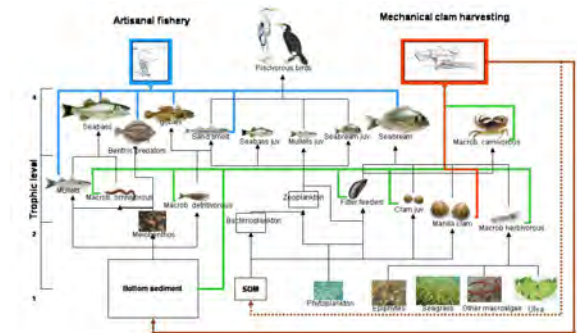How can sources of uncertainty be partitioned across model structures, forcings, scenarios, and internal variability?
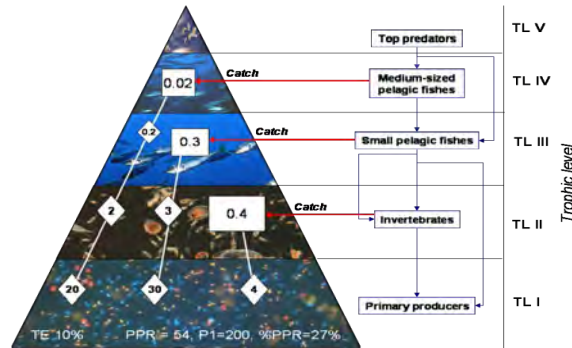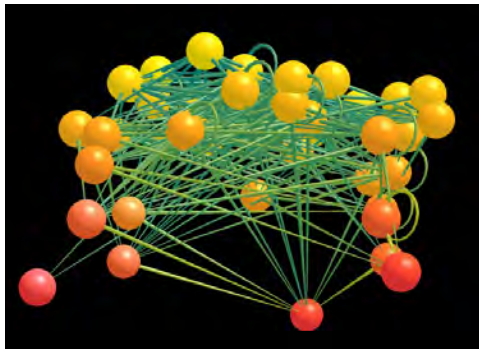
What is the future of: Fish & Fisheries? Seafood supply? Marine biodiversity? Marine-ecosystem functioning?

FISHERIES & MARINE ECOSYSTEM
FISH·MIP
MODEL INTERCOMPARISON PROJECT

Goal:

To bring together disparate marine ecosystem models to better understand and forecast the long-term impacts of climate change on fisheries and marine ecosystems.

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Coordinators:

Overall: Derek Tittensor
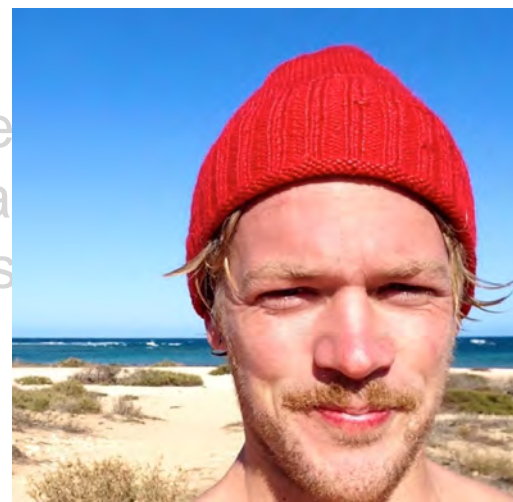Regional models: Tyler Eddy (tyler.eddy@sc.edu)
Global models: Eric Galbraith and Julia Blanchard

FISHERIES & MARINE ECOSYSTEM

FISH MIP

MODEL INTERCOMPARISON PROJECT

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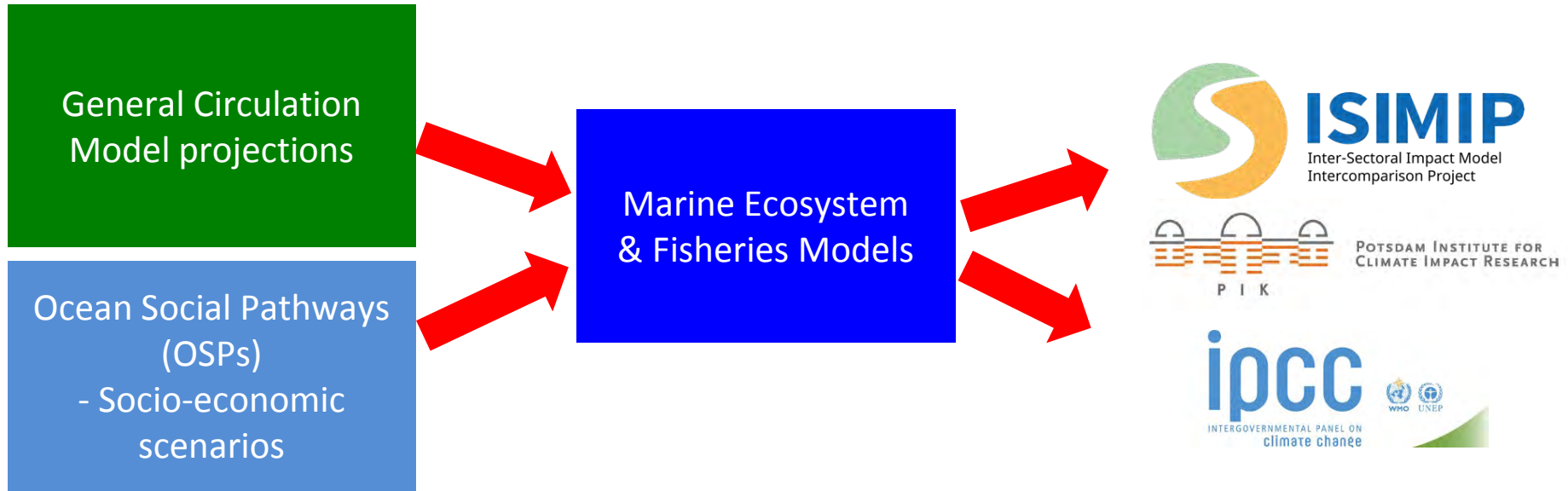
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FISHERIES & MARINE ECOSYSTEM

FISH◦MIP

MODEL INTERCOMPARISON PROJECT
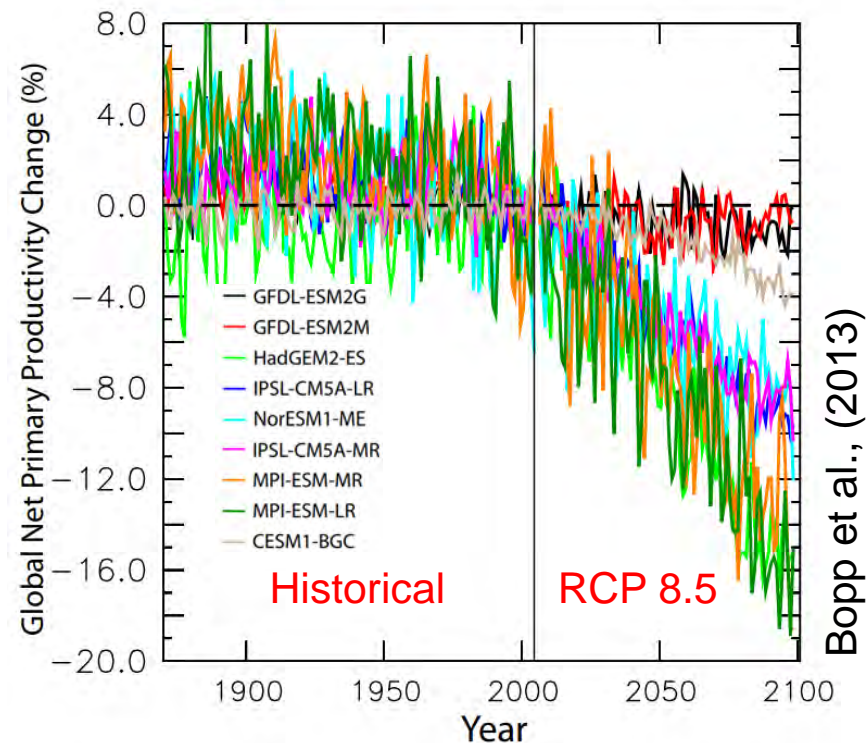
Fish-MIP: an effort to understand future fisheries production

Is uncertainty in fisheries projections exacerbated by reliance on bulk NPP?

Our group's specific interest (for a small project):

What portion of the variability in projections of fish production can be attributed to varying representation of primary production across earth-system models?

Bopp et al., (2013)

Is uncertainty in fisheries projections exacerbated by reliance on bulk NPP?

Our group's specific interest:

What portion of the variability in projections of fish production can be attributed to varying representation of primary production across earth-system models?

Or perhaps:

> If we are careful in interpreting the output of earth-system models, do the projections of future fisheries production reduce to a "fancy" scaling of changes in nutrient supply, light, and temperature?
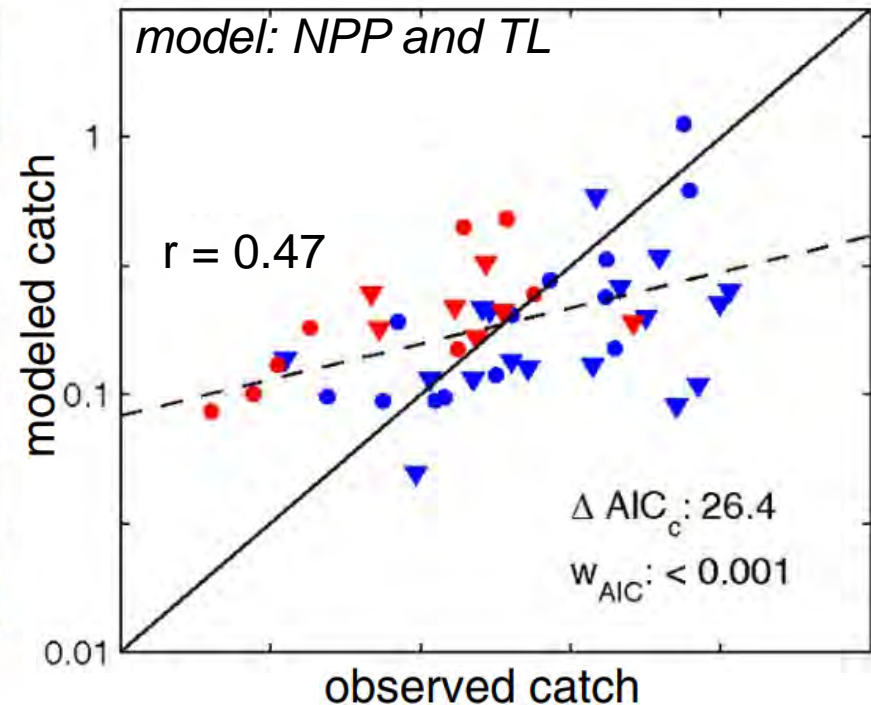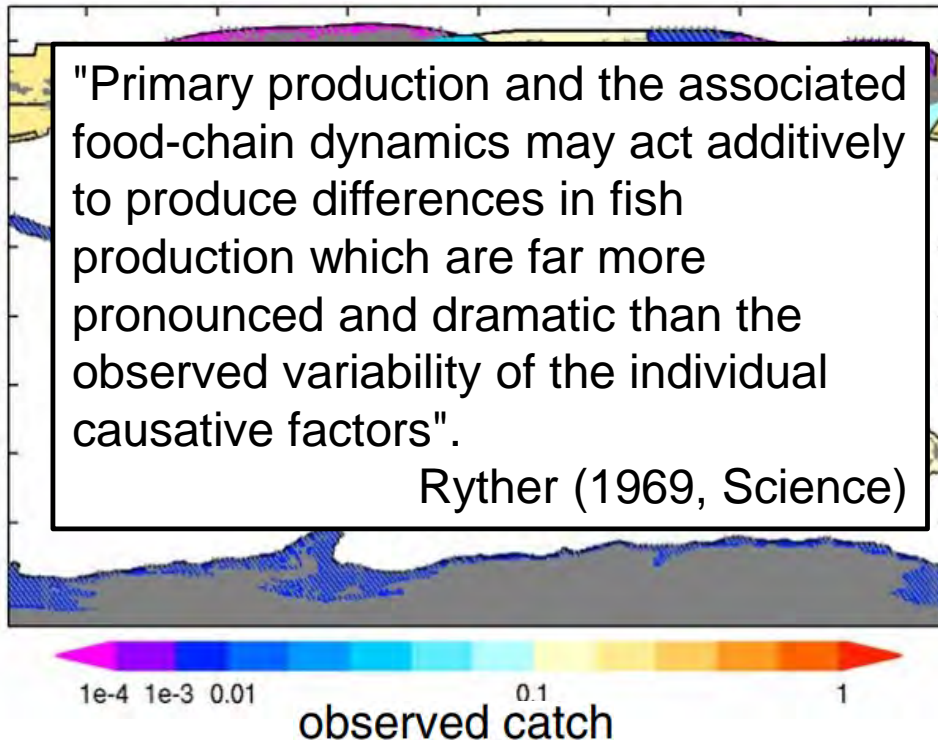
NPP (net primary production) alone is a poor predictor of fisheries catch

"Primary production and the associated food-chain dynamics may act additively to produce differences in fish production which are far more pronounced and dramatic than the observed variability of the individual causative factors".

Ryther (1969, Science)

Even a coarse representation of planktonic food-web structure can improve model fit

"Primary production and the associated food-chain dynamics may act additively to produce differences in fish production which are far more pronounced and dramatic than the observed variability of the individual causative factors".

Ryther (1969, Science)

model: export fluxes (detritus and mesozoopl.), TL, and temperature

r = 0.75

ΔAIC_c: 3.5

w_{AIC}: 0.15

modeled catch

observed catch

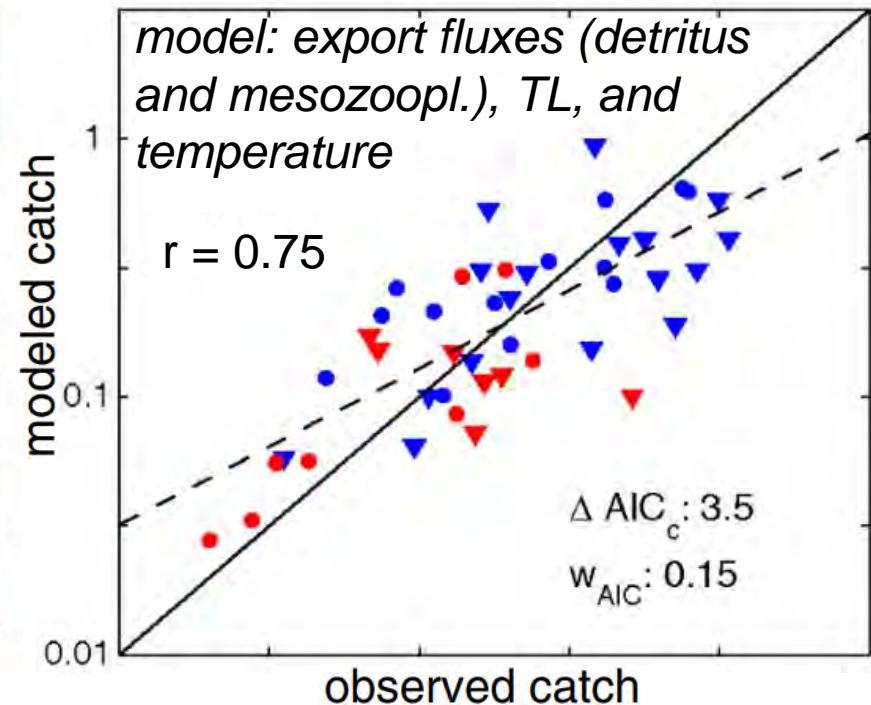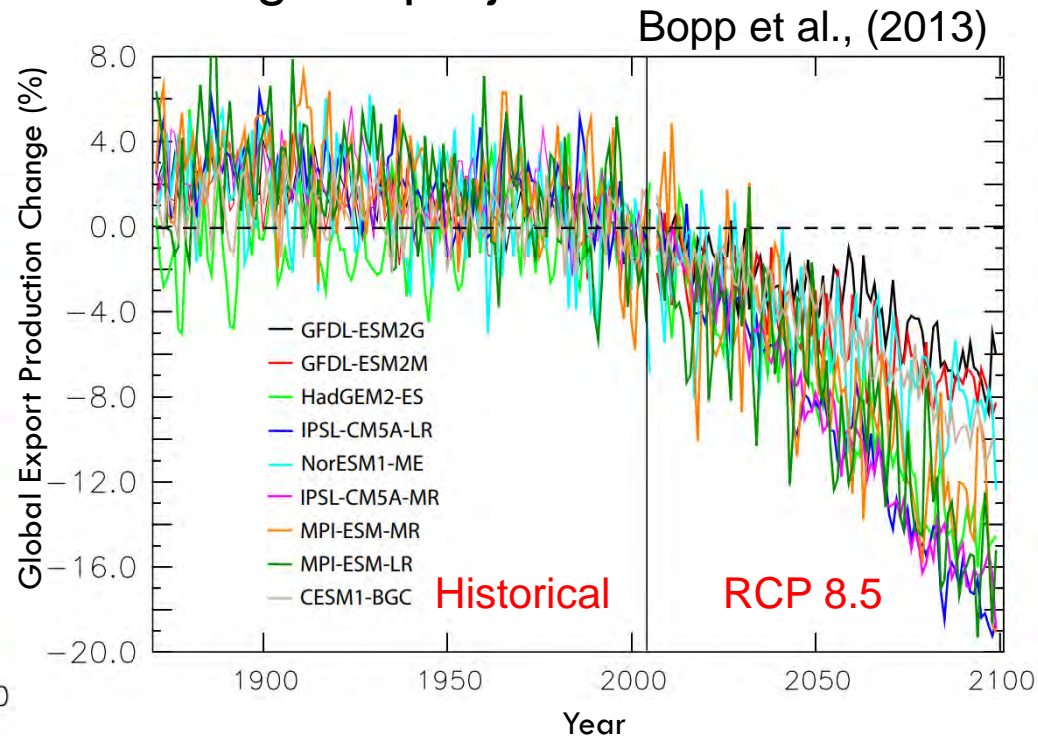1e-4 1e-3 0.01   0.1   1
observed catch

Can this insight be applied to a suite of ESM projections?

Such an detailed analysis and tuning is possible for a single model, but we might seek some broad simplifications in a multi-model comparison.

NPP is the common input for fish models. Why do earth-system models have such a broad range of projections?

Bopp et al., (2013)

Such an detailed analysis and tuning is possible for a single model, but we might seek some broad simplifications in a multi-model comparison.

But "bulk" NPP is the common input for fish models. Why do earth-system models have such a broad range of projections?

Option A:
Representation of large phytoplankters and new (or export) NPP is prioritized.

Result: High reductions in NPP with increasing water-column stratification.

Such an detailed analysis and tuning is possible for a single model, but we might seek some broad simplifications in a multi-model comparison.
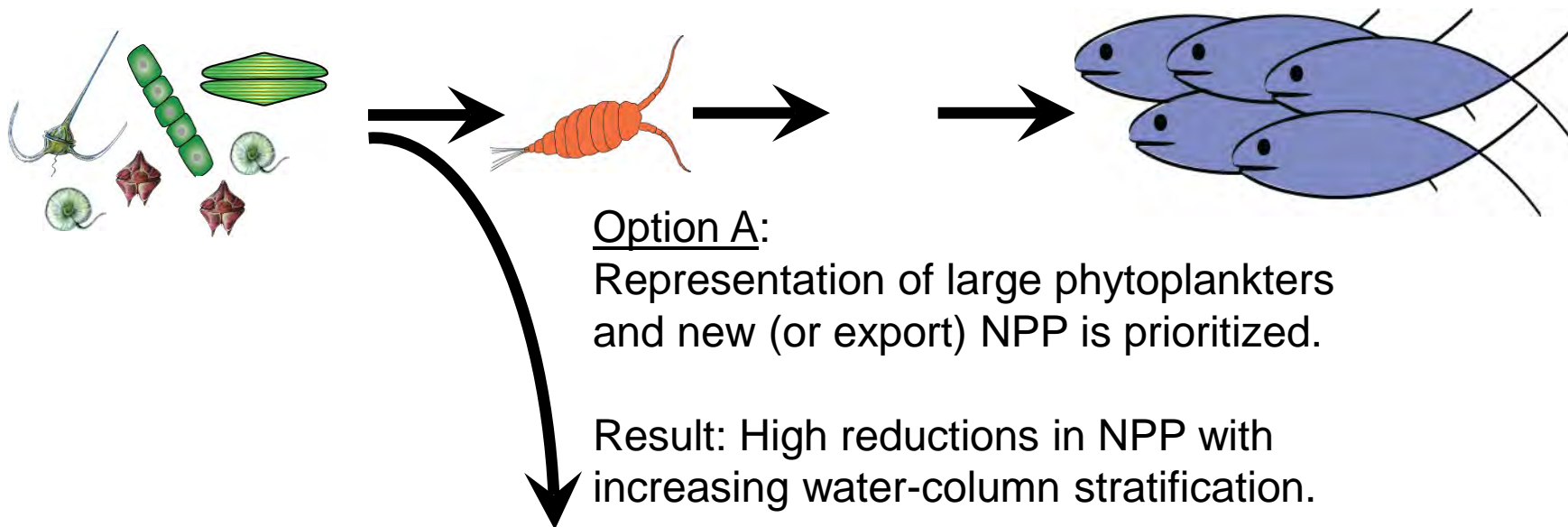
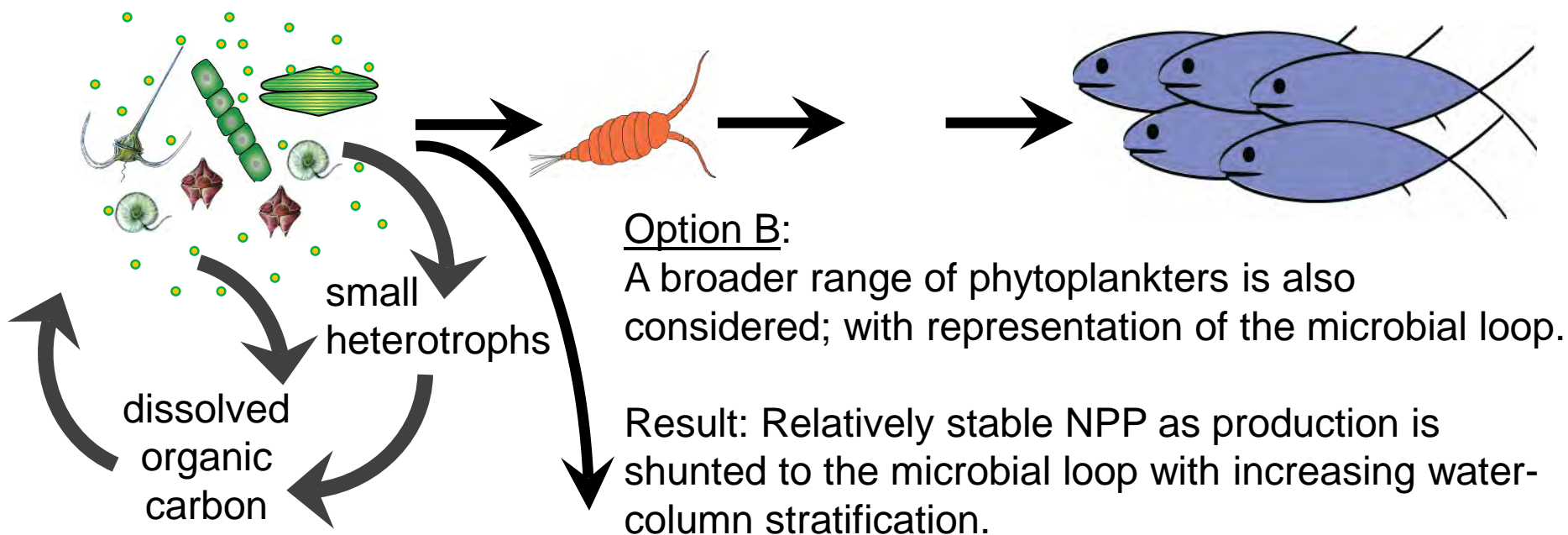But "bulk" NPP is the common input for fish models. Why do earth-system models have such a broad range of projections?

small heterotrophs

dissolved organic carbon

Option B:
A broader range of phytoplankters is also considered; with representation of the microbial loop.

Result: Relatively stable NPP as production is shunted to the microbial loop with increasing water-column stratification.

Differences in plankton representations are reflected (perhaps incorrectly) in projections of fish production

Lack of distinction between new/export NPP and NPP directed into the microbial loop plays a substantial role in the uncertainty of projections of fish biomass.

Figure removed. Contact Tyler Eddy.

Lotze et al. (submitted)

Can use of bulk NPP be replaced by use of something with more mechanistic relationship to higher trophic levels?

Ongoing research:
What are the sources of uncertainty in projections of fish production?

- bulk NPP vs size or pathway-specific NPP
    - "new" nutrient supply vs recycled nutrient supply
- physiological impacts of temperature on growth and transfer efficiency
- changes in community composition (and size structure)

Thus far, Tyler and colleagues have begun to analyze output for some of the fisheries models and explored the sensitivity of projections to temperature and bulk NPP.

Comparison of NPP and fish projections in North Pacific boundary currents

Domains for Kuroshio and California Current Analyses

Distance from Coastline (km)
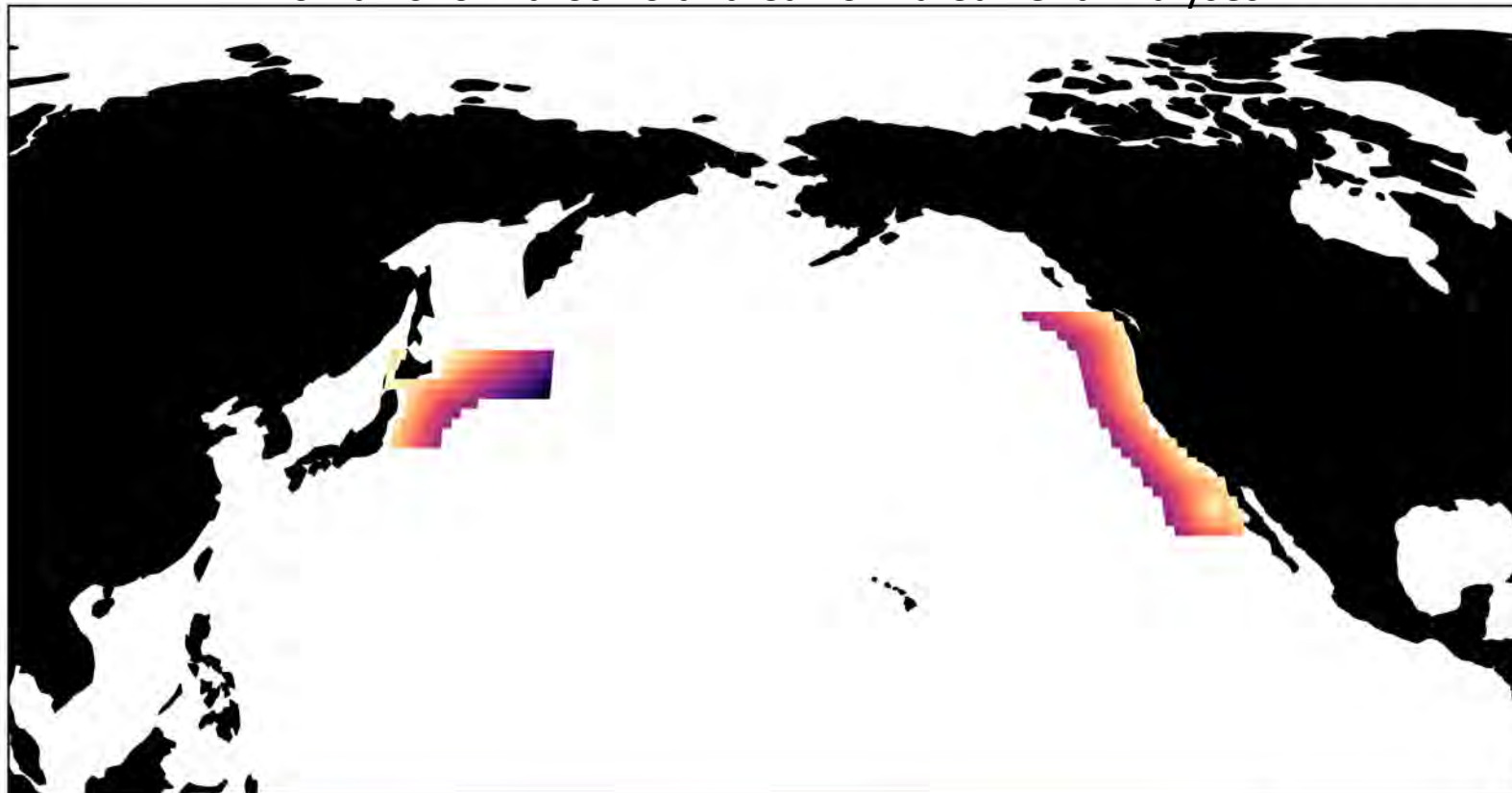
Comparison of NPP and fish projections in North Pacific boundary currents

Domains for Kuroshio and California Current Analyses

Preliminary model configurations:

- Global forcing (NPP and temperature) from the CESM under pre-industrial and RCP 8.5 pathways
- Control runs to distinguish effects of temperature (metabolic rate) and NPP (food availability) on modeled fish production
- Two fish model groups have provided results:
    - "BOATS" (BiOeconomic mArine Trophic Size spectrum; Galbraith et al., 2017)
    - "EcoTroph" (evolved from EwE; Gascuel and Pauly; 2009)

Distance from Coastline (km)

Combines size-based ecological theory and metabolic constraints to calculate the production of fish

Comparison of NPP and fish projections in North Pacific boundary currents

Domains for Kuroshio and California Current Analyses

Distance from Coastline (km)
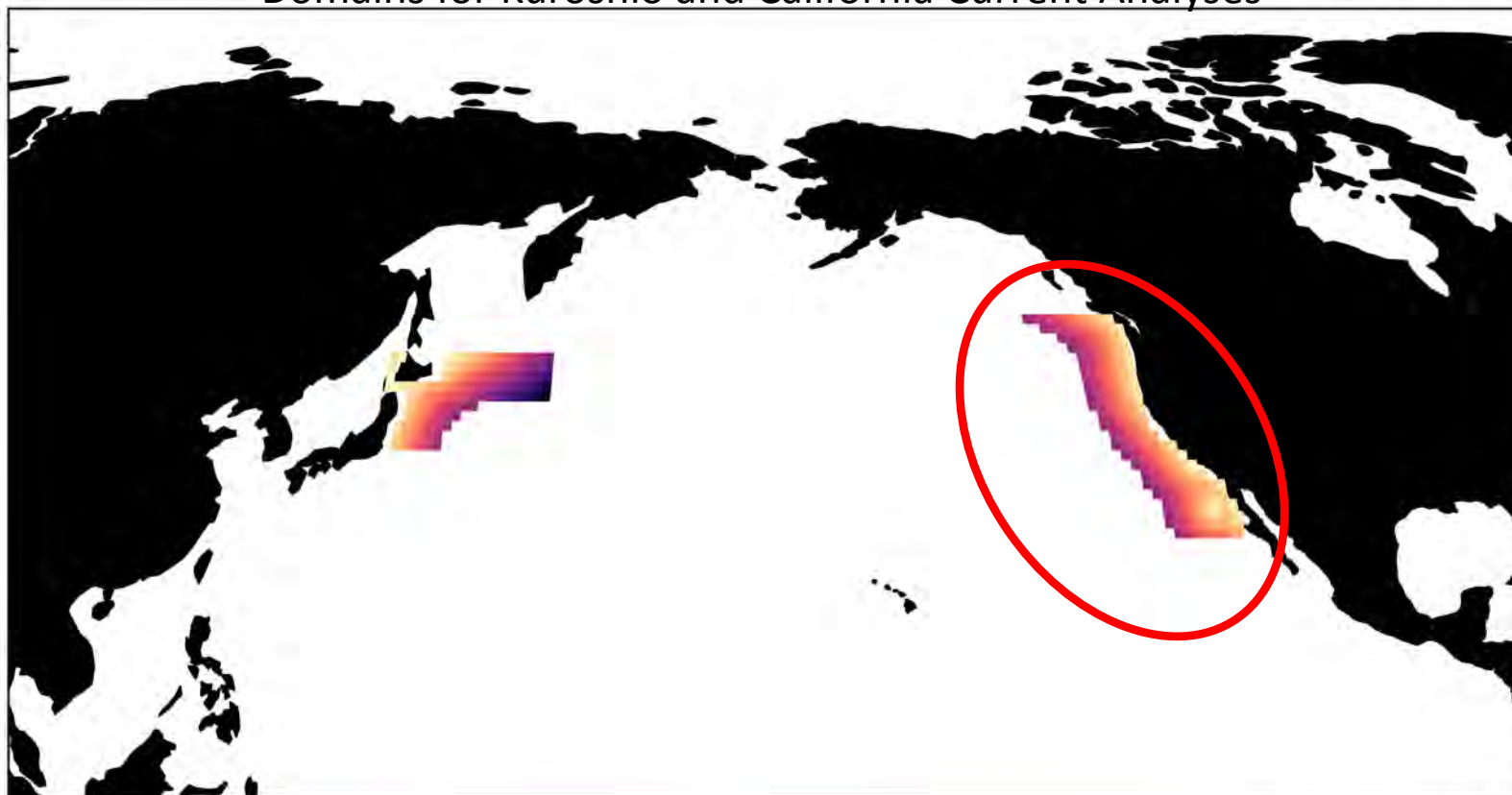
Bulk NPP in the CESM large ensemble – California Current

Results figure removed. Contact Tyler Eddy.

Projected change in fish biomass with "BOATS" model (CESM RCP 8.5 forcing; 2090-99 minus 1850-59)

Results figure removed. Contact Tyler Eddy.

Projected change in fish biomass with "BOATS" model (CESM RCP 8.5 forcing; California Current)

Results figure removed. Contact Tyler Eddy.

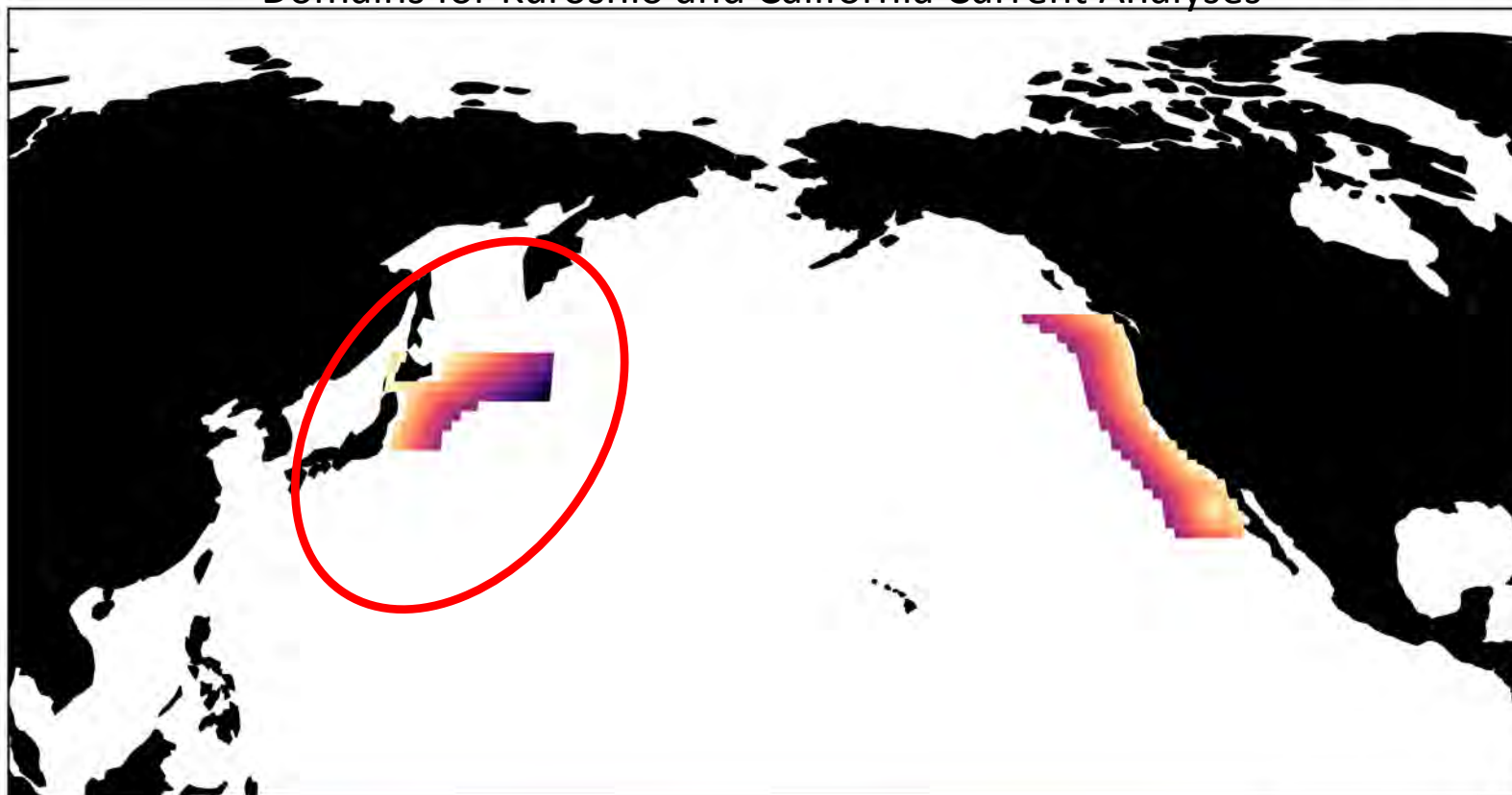# Projected change in fish biomass with "EcoTroph" model (CESM RCP 8.5 forcing; 2090-99 minus 1850-59)

Results figure removed. Contact Tyler Eddy.

Projected change in fish biomass with "EcoTroph" model (CESM RCP 8.5 forcing; California Current)

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Comparison of NPP and fish projections in North Pacific boundary currents

Domains for Kuroshio and California Current Analyses

Bulk NPP in the CESM large ensemble – Kuroshio Current

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Projected change in fish biomass with "EcoTroph" model (CESM RCP 8.5 forcing; Kuro Current)

Results figure removed. Contact Tyler Eddy.

Preliminary results (somewhat unrelated from the key question I am interested in)

One earth-system model projects increases in NPP for both the California and Kuroshio Currents under RCP 8.5.

This model output has been used to force two global scale models of potential upper-trophic level production.

Were NPP the only factor influencing the food web critical to fisheries, these models project modest increases in potential fish productivity.

However, the dominant factor appears to be increased metabolic rates associated with increased water temperatures.

Models runs considering various representations of primary production are yet to be completed.

Overall coordinator: Derek Tittensor

Global coordinators: Eric Galbraith, Julia Blanchard

Regional coordinator: Tyler Eddy (tyler.eddy@sc.edu)

https://www.isimip.org/gettingstarted/marine-ecosystems-fisheries/

or Google 'FISH-MIP'

Thanks!

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