Recent advances, ongoing challenges, and future directions in ecosystem approaches to fisheries management in the central North Pacific

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CLIMATE CHANGE & NORTHERN FISH POPULATIONS

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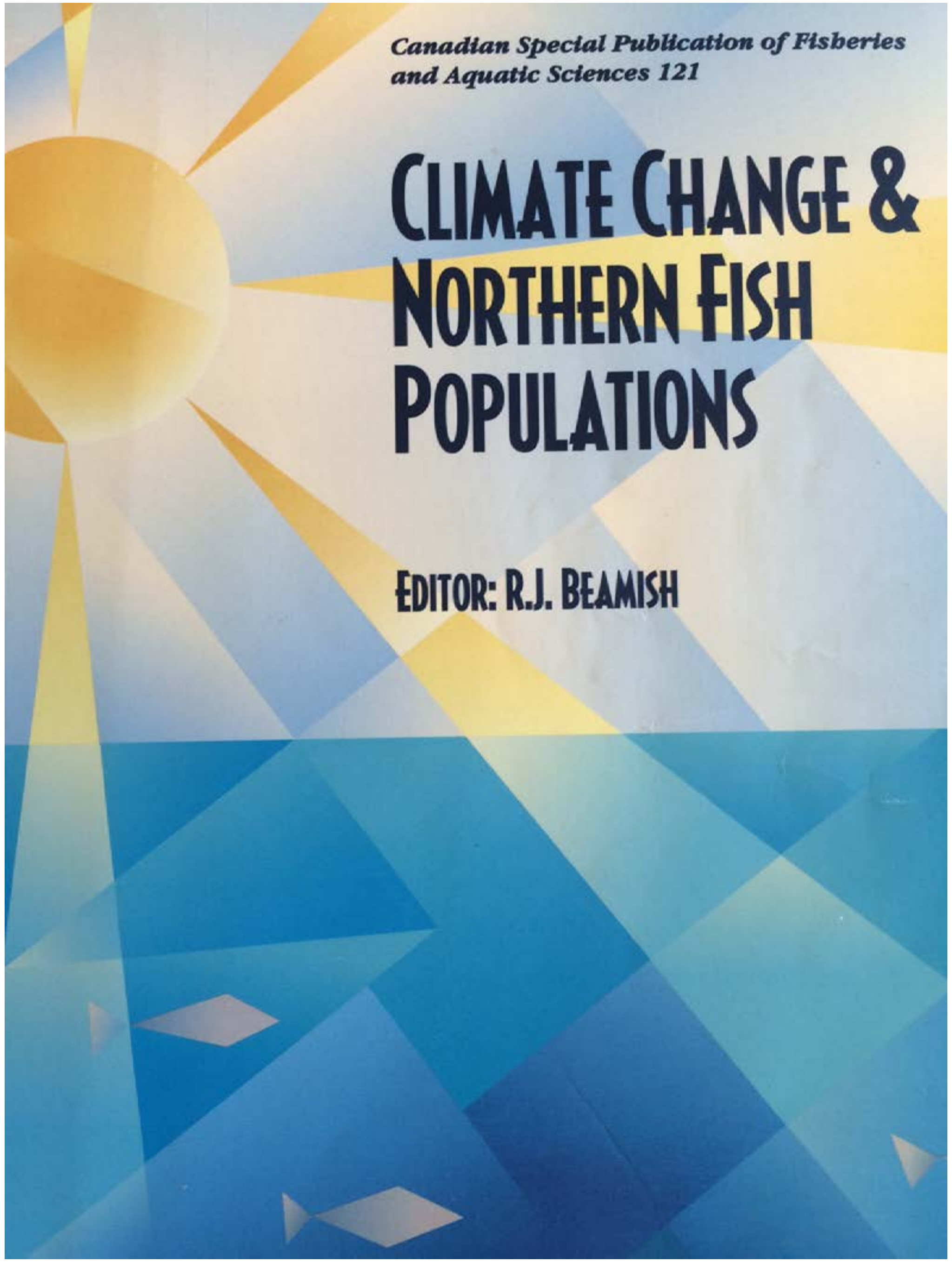
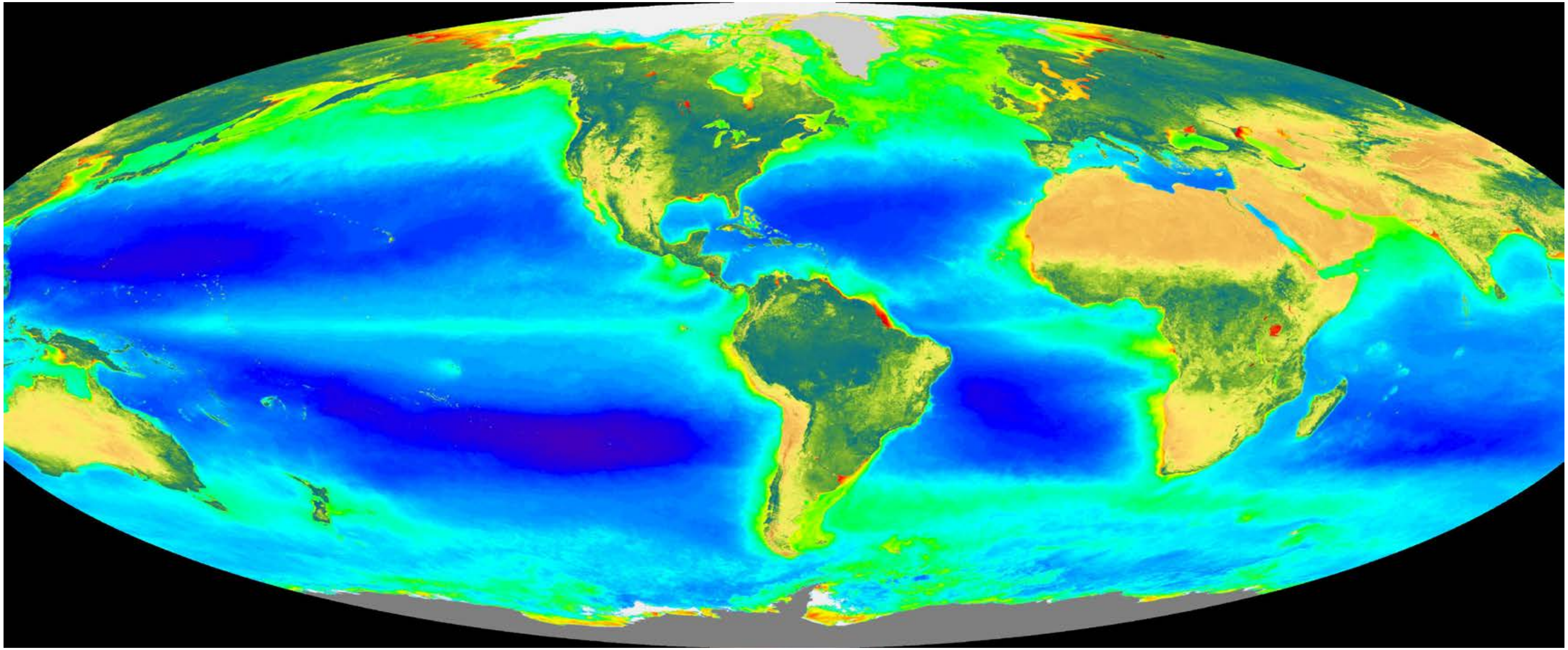


Subtropical gyres indicated by low surface chlorophyll (blue)



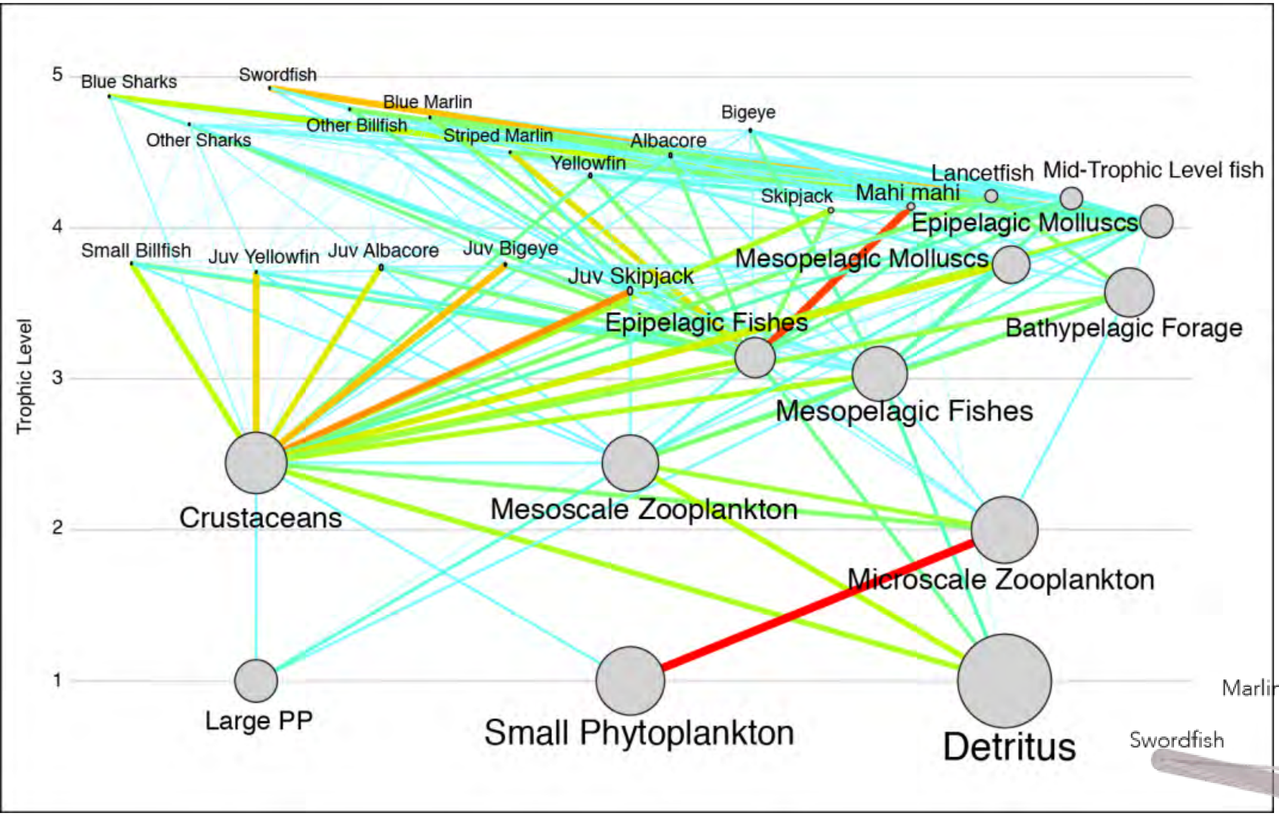
Objectives in an Ecosystem Approach to Fisheries Management for the North Pacific Subtropical Gyre

- Describe ecosystem structure and services
- Describe impacts of fishing on the ecosystem
- Describe the impacts from interannual, decadal, and climate change on the ecosystem and fishery
- Challenges and future directions

Tools and datasets

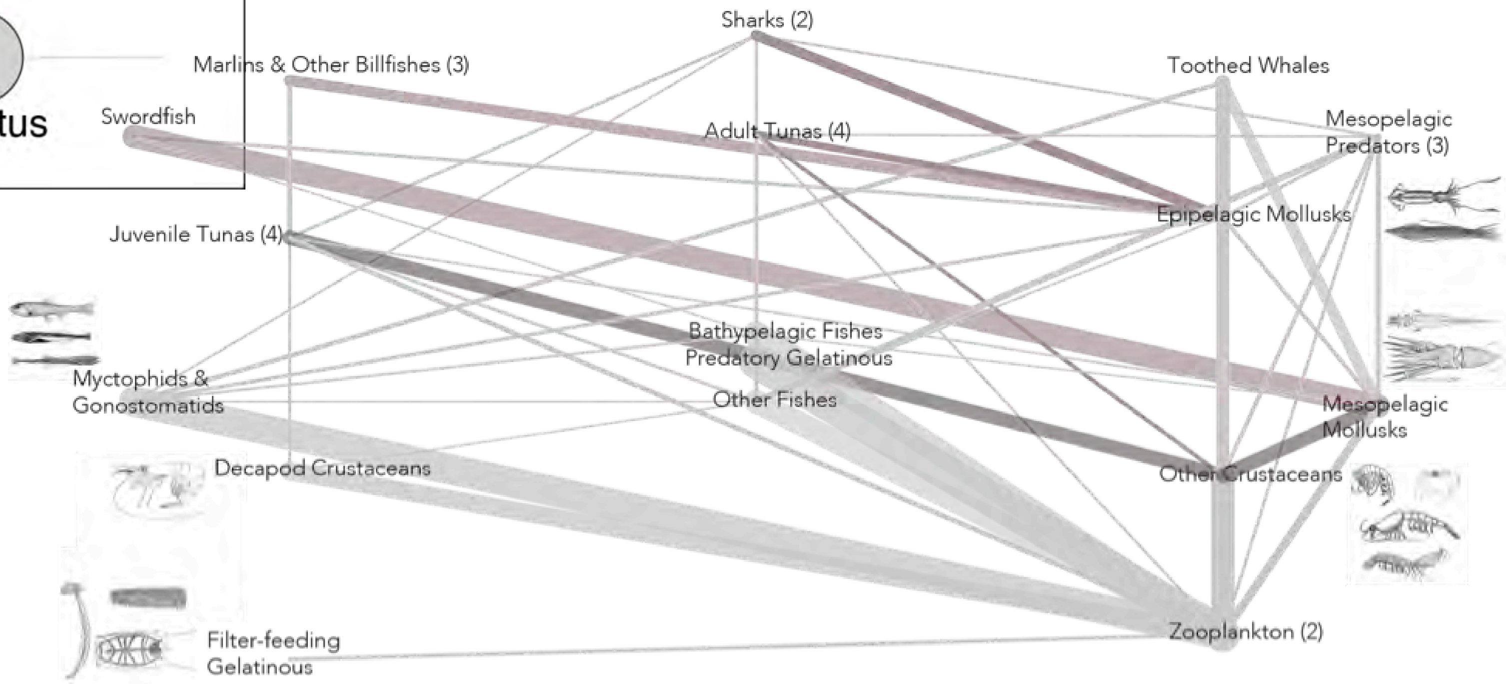
- Models: Ecosystem (species and size-based), Coupled Physical-Biological (hindcast), Earth System (climate projections)
- Fisheries data (logbook, observer, and dealer)
- Fish diet data

Central North Pacific Subtropical Ecosystem Food Web



Howell et al. 2012

Choy et al. 2016

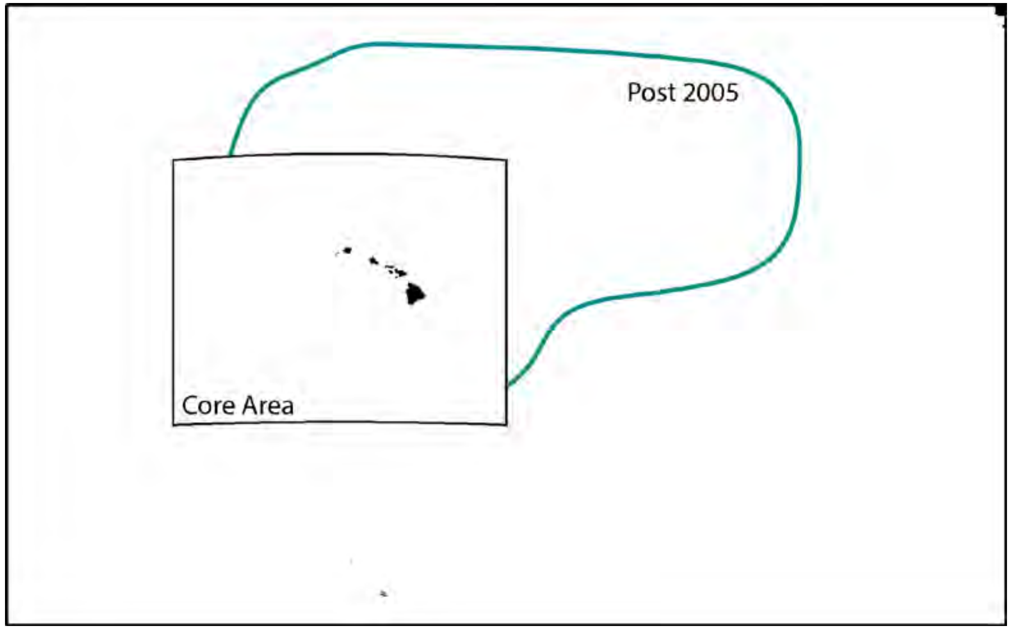


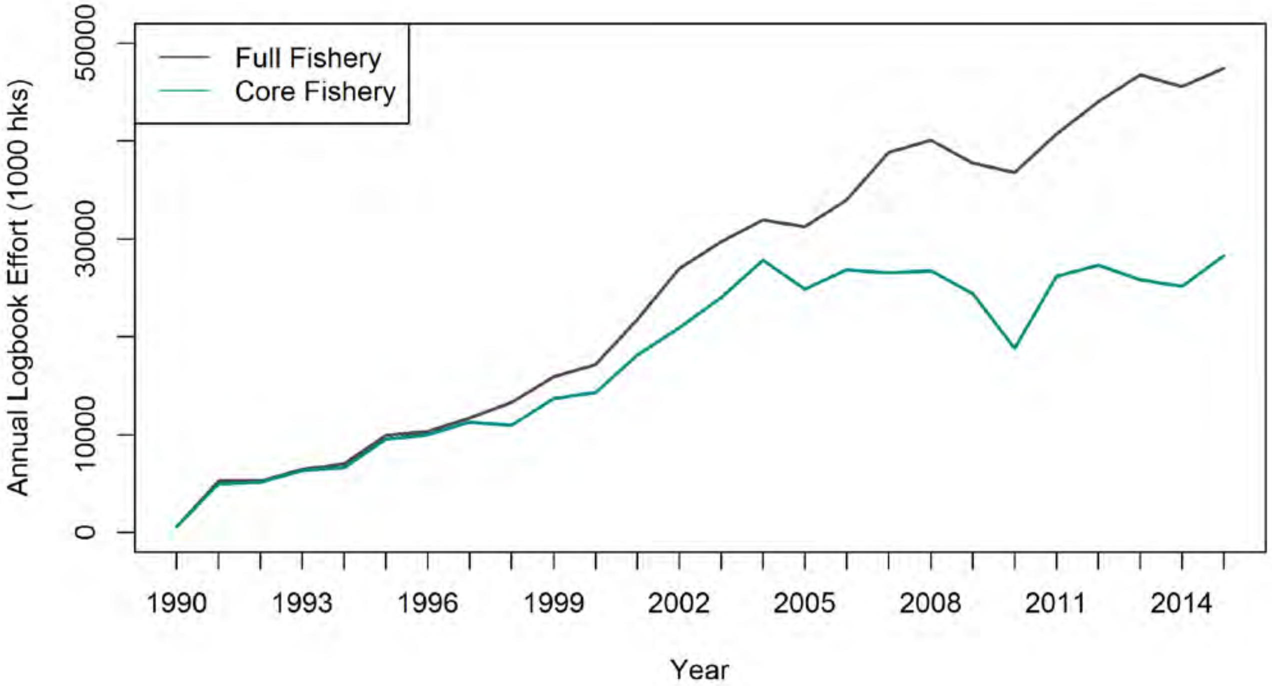
180- 140W Long., 10-35 N Lat

2015 Hawai‘i Longline Effort and Catch

- 142 vessels fished
- 48.7 million hooks set
- Fishing grounds approximately 13 million sq km
- 229,221 bigeye tuna
- 13,498 striped marlin
- 20,381 swordfish
- 101,054 sharks (kept 0.76%)
- 63,062 mahi mahi
- 29,507 opah
- 2015 revenue $94 million

Hawaii-based deepset longline grounds and effort





Core area 12-27 N latitude, 170-150 W longitude - 3.5 million sq km

CPUE of large (apex) species declining

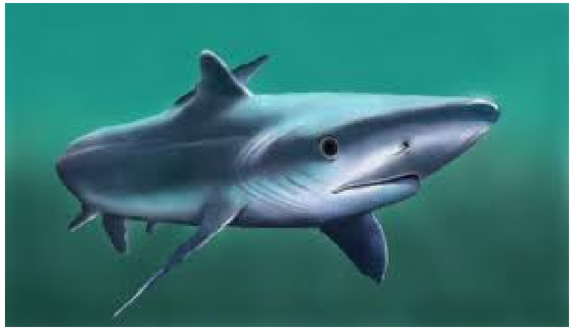
Bigeye tuna -2%/yr

Shortbill spearfish -4%/yr

Blue marlin -5%/yr

Oceanic white-tip -7%/yr

Blue shark -4%/yr



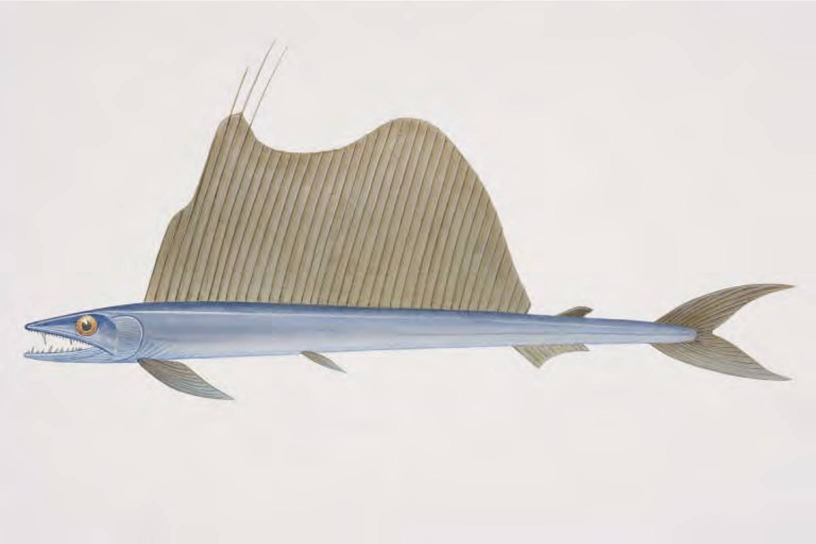
Striped marlin -5%/yr

Polovina and Jefcoats-Woodworth 2013

CPUE of small species increasing

Mahimahi (*Coryphaena hippurus)* +7%/yr

Lancetfish (*Alepisaurus ferox*)+2%/yr



Escolar, walu, (*Lepidocybium flavobrunneum*)+12%/yr

Snake mackerel (*Gempylus serpens*)+15%/yr

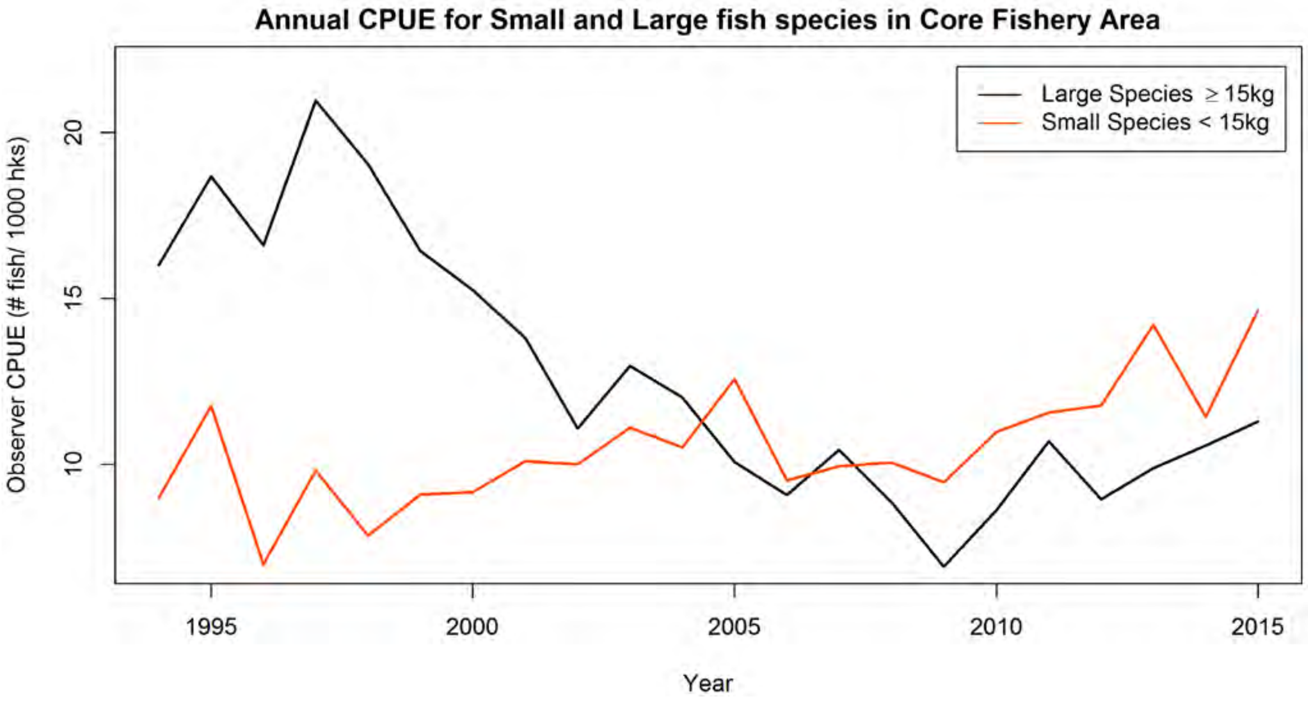
Sickle pomfret (*Taractichthys steindachneri*) +6%/yr

Polovina and Jefcoats-Woodworth 2013

Small Fishes Increase and Large Fishes Decrease over time

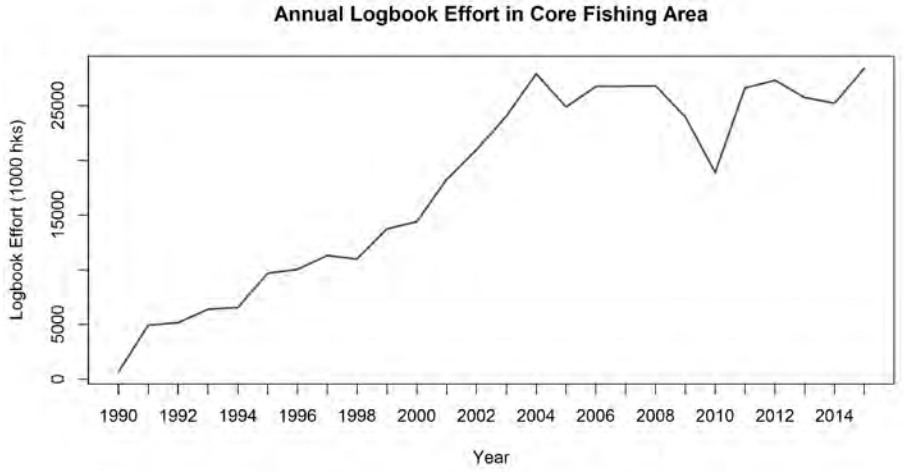
Small Fishes: < 15 kg

Escolar: 6.2 kg
Mola: 8.8 kg
Skipjack Tuna: 7.9 kg
Mahi Mahi 5.9 kg
Lancetfish: 2.8 kg
Great Barracuda: 5.9 kg
Pomfrets: 4.9 kg
Pelagic Stingray: 3.0 kg
Snake Mackerel: 2.6 kg
Wahoo 13.1 kg



Large Fishes: ≥ 15 kg

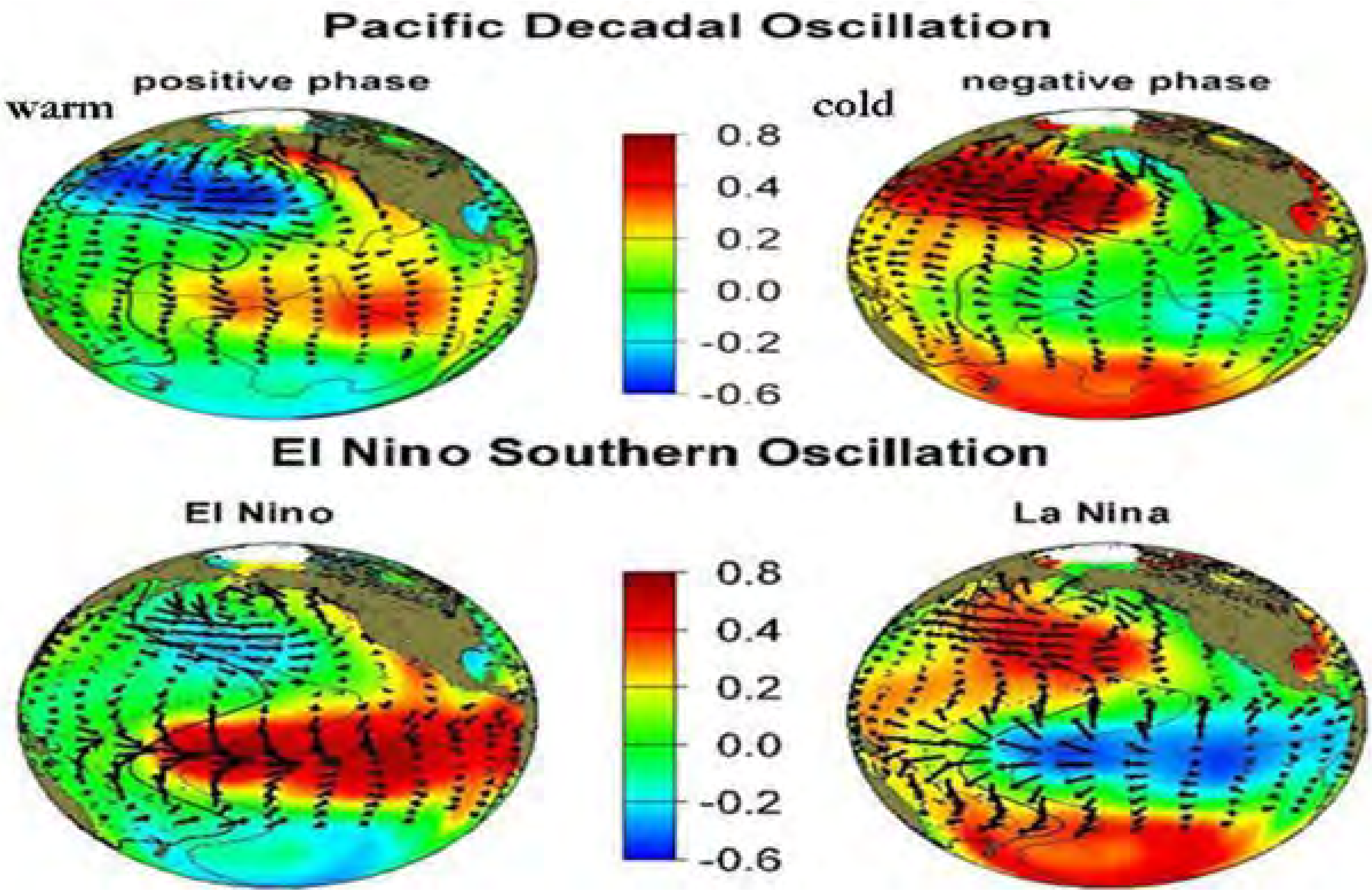
Blue Marlin: 52.5 kg
Blue Shark: 106.4 kg
Striped Marlin: 26.3 kg
Shortbill Spearfish: 15.5 kg
Shortfin Mako Shark: 48.3 kg
Swordfish: 38.6 kg
Yellowfin Tuna: 25.8 kg
Opah: 36.9 kg
Bigeye Thresher Shark: 19.8 kg
Unidentified Tuna: 22.0 kg
Bigeye Tuna: 25.6 kg
Oceanic White-tip Shark: 19.0 kg
Albacore Tuna: 16.1 kg



Polovina and Jefcoats-Woodworth 2013

Ecosystem response to fishing

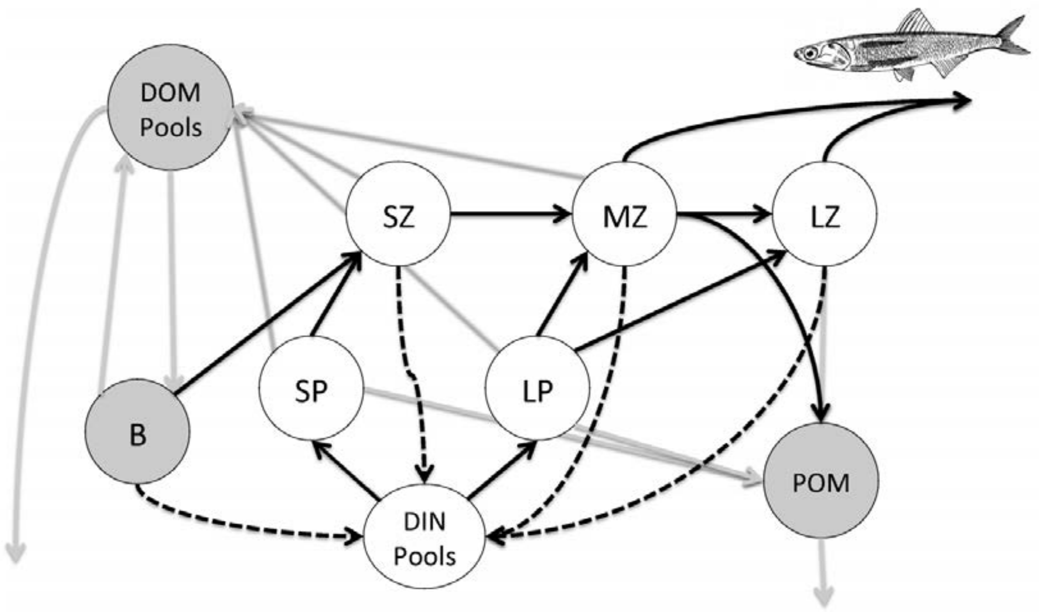
- **Region-wide** longline fishery acts as a keystone species. It changes the size structure and species composition of the ecosystem.
- The fishery produces a size-based cascade with a decrease in abundance of large, apex species resulting in an increase in smaller lower trophic species.
- Catch rates of several vulnerable species (pelagic stingray, whitetip shark) have declined to very low levels.
- Current basin-wide management sets harvest limits only for 3 species (bigeye and yellowfin tunas and striped marlin).
- There may be a need for more of an ecosystem approach to set quota on total yield to limit changes in ecosystem structure, species mix, and protect vulnerable species.

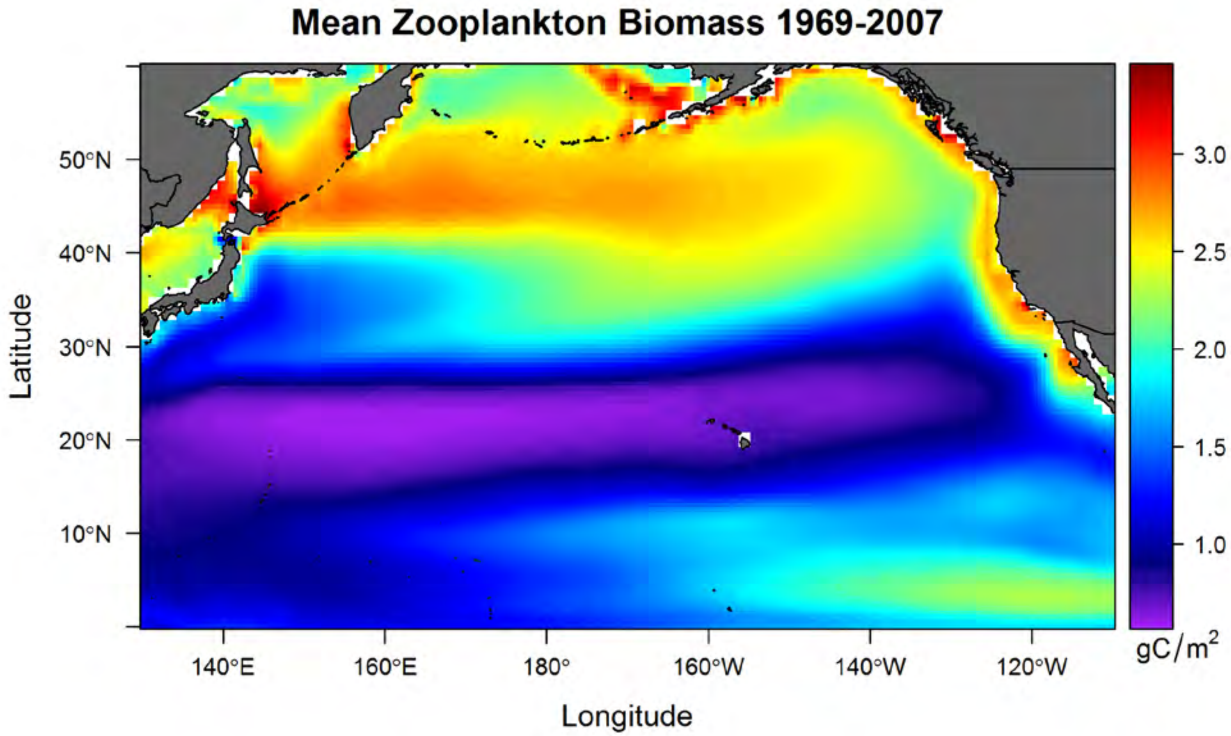


Pacific Decadal Oscillation
positive phase
warm
negative phase
cold
0.8
0.4
0.2
0.0
-0.2
-0.6
El Nino Southern Oscillation
El Nino
La Nina
0.8
0.4
0.2
0.0
-0.2
-0.6

Carbon Ocean Biogeochemistry And Lower Trophics (COBALT) Model

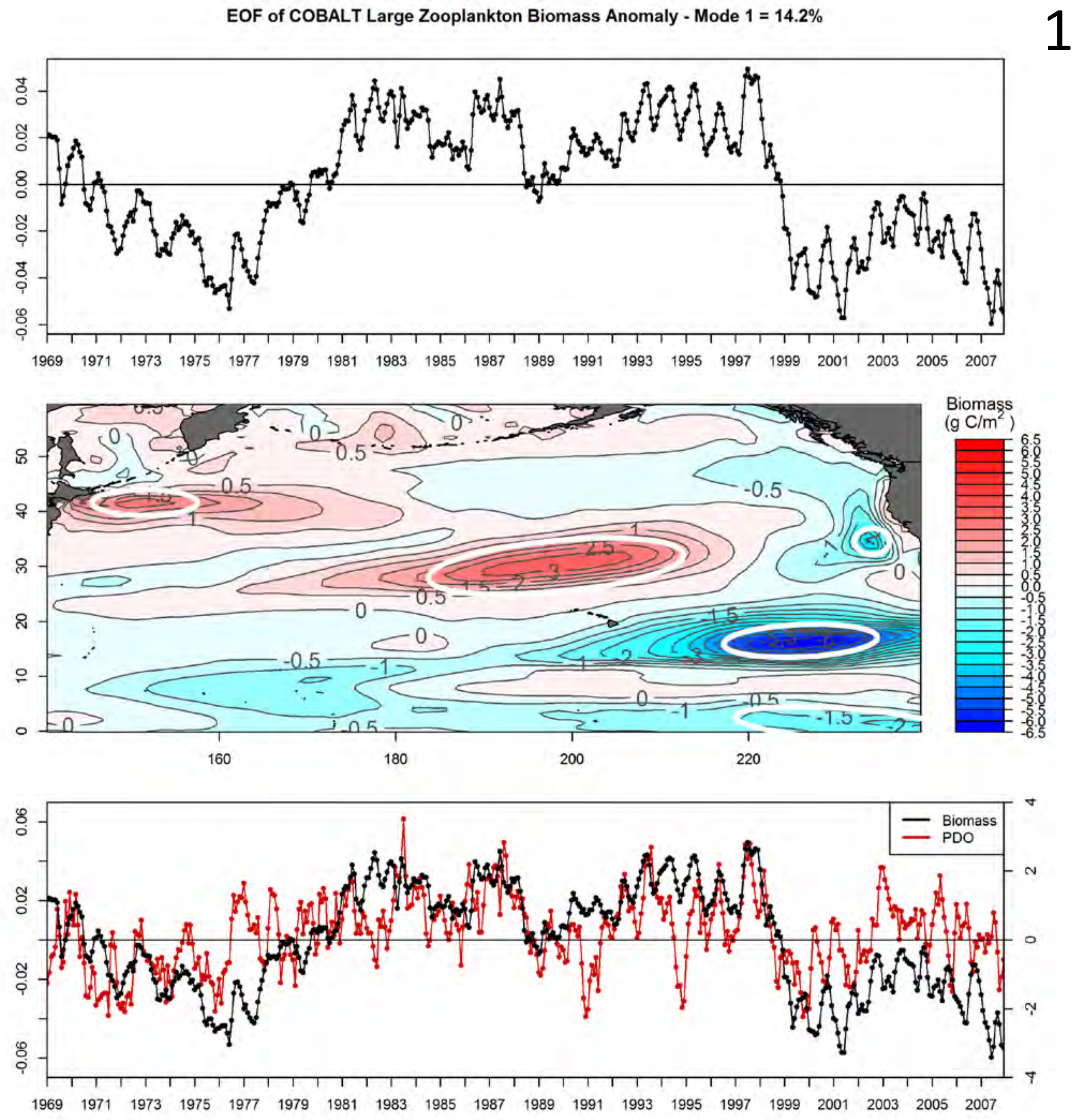
(NOAA GFDL)(Stock et al. 2014)

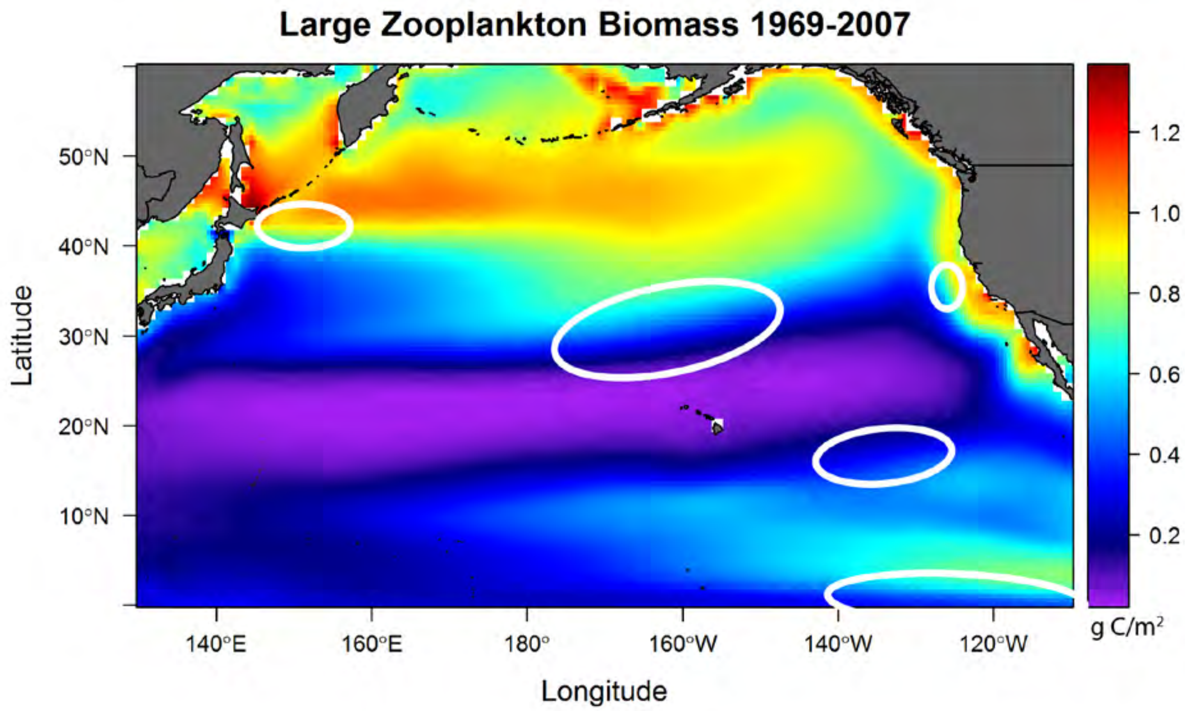




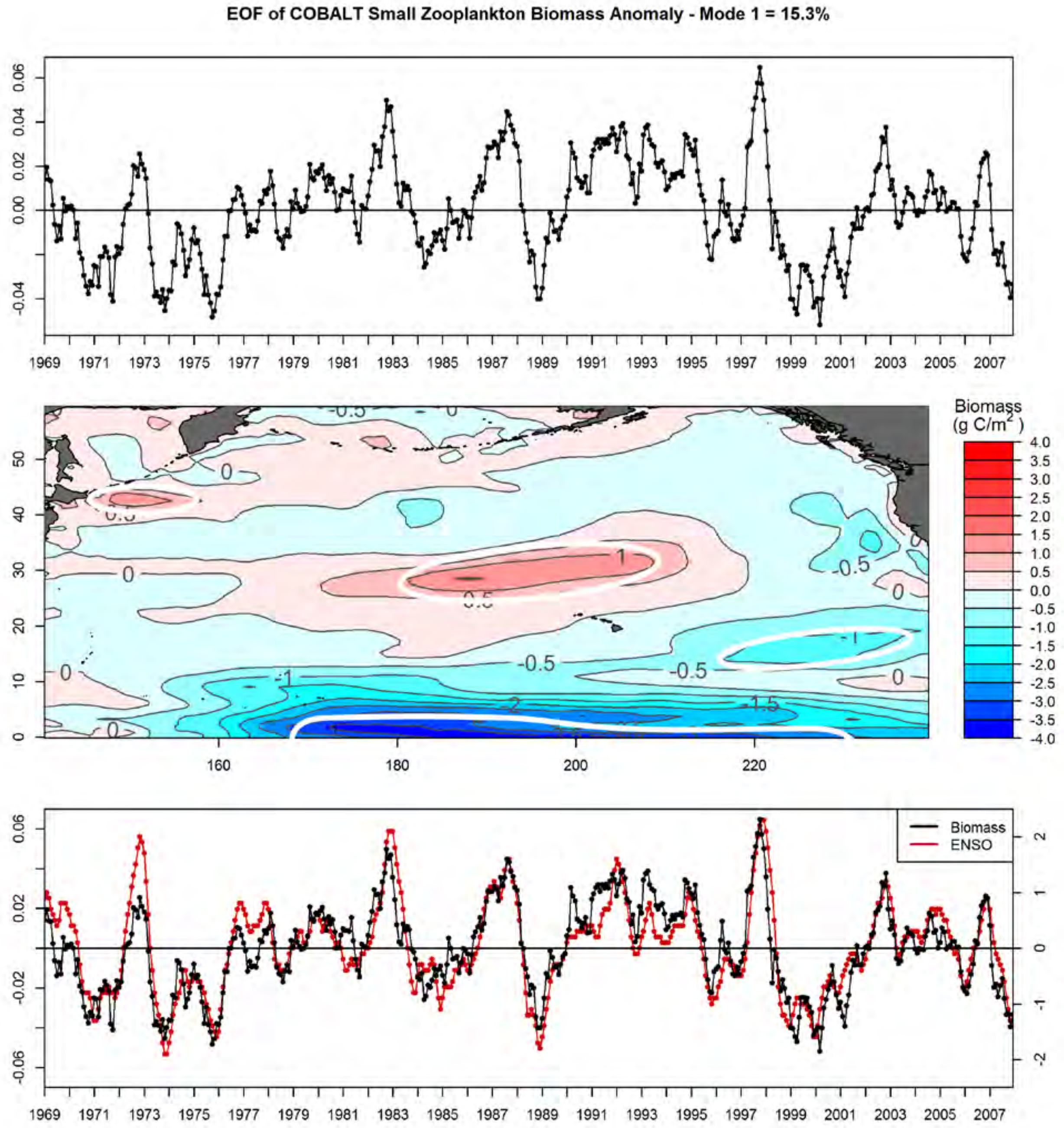
1 to 1/3 degree spatial resolution
50 vertical layers
Forced by CORE-II 1948-2007

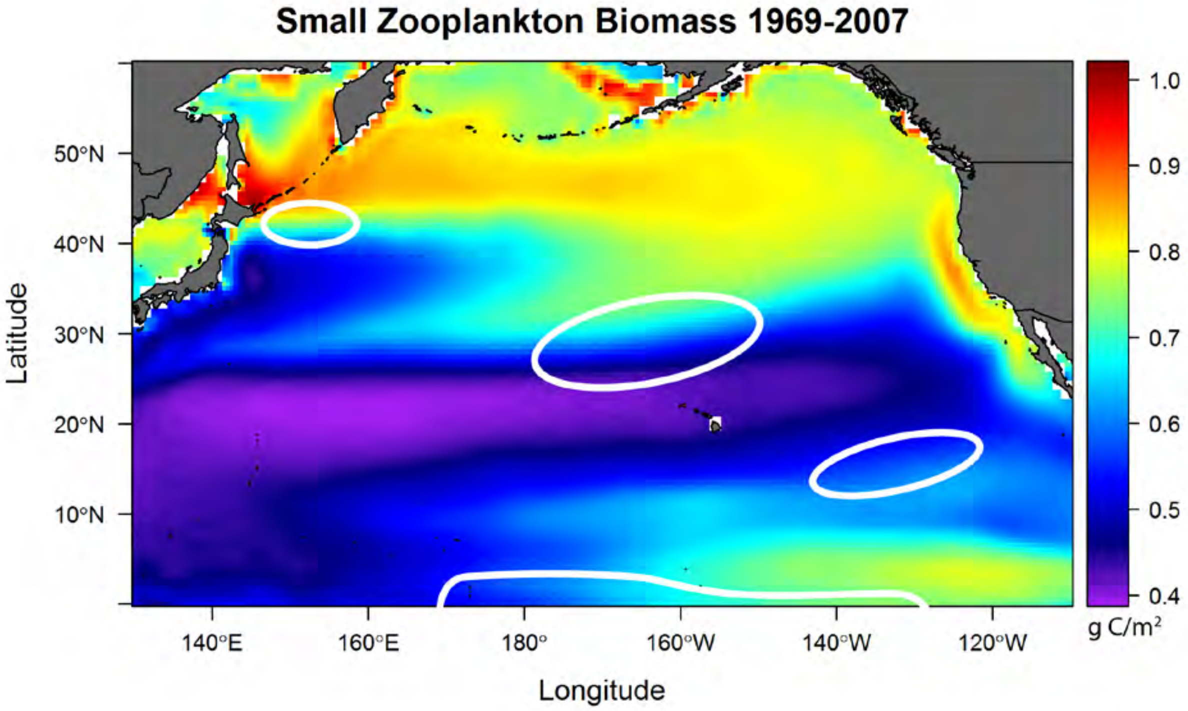
1st EOF of large zooplankton 1969-2007



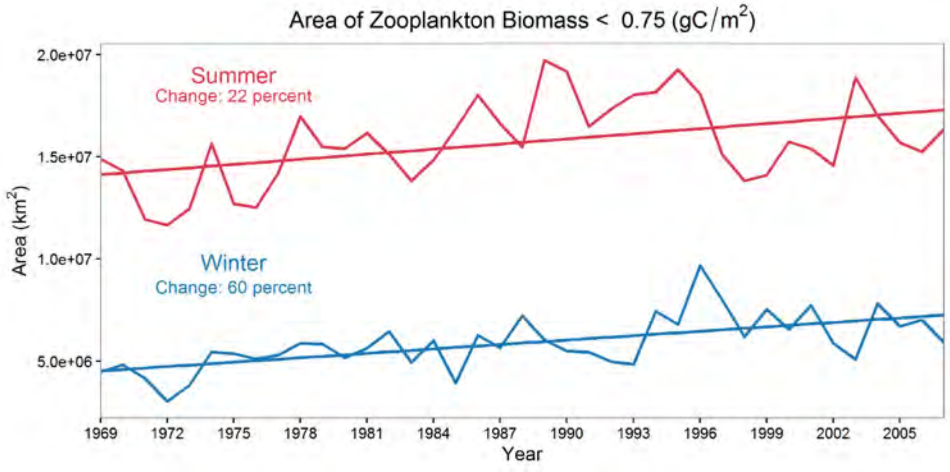


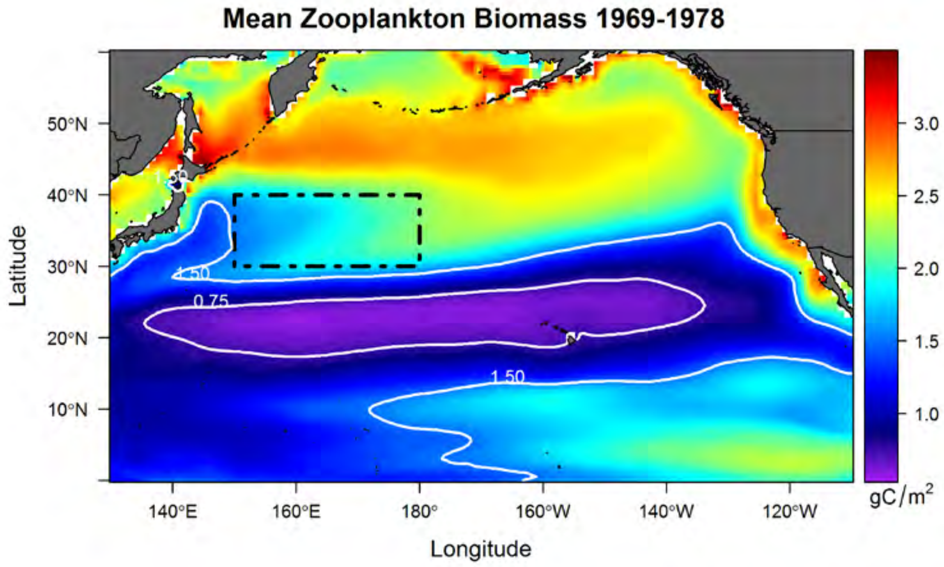
1^{st} EOF of small zooplankton 1969-2007

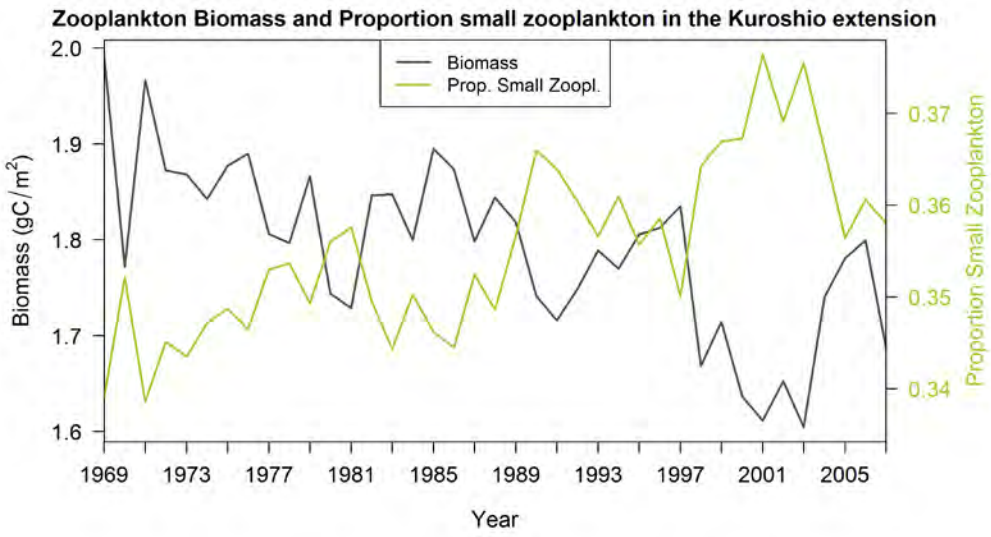


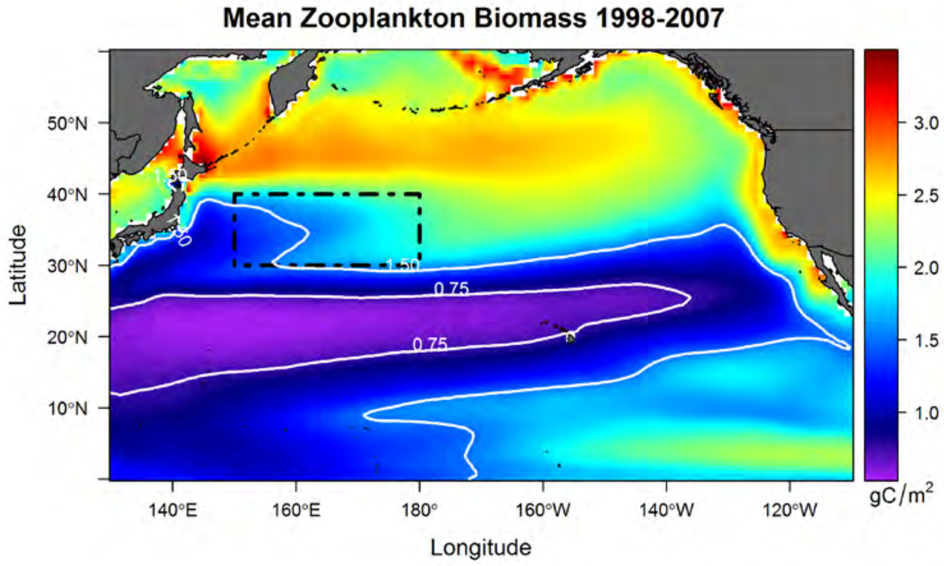


Multi-decadal Zooplankton changes 1969-2007

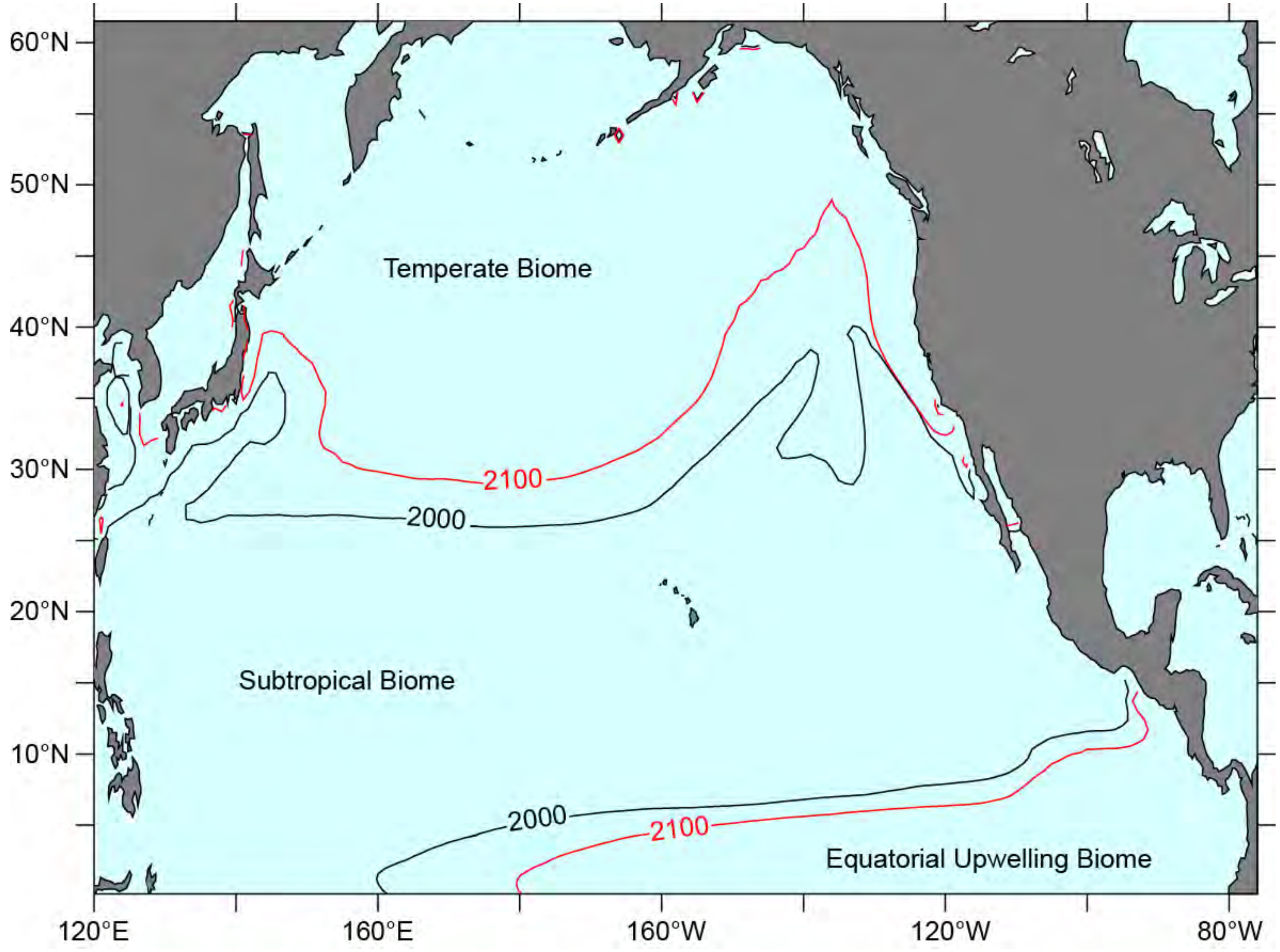






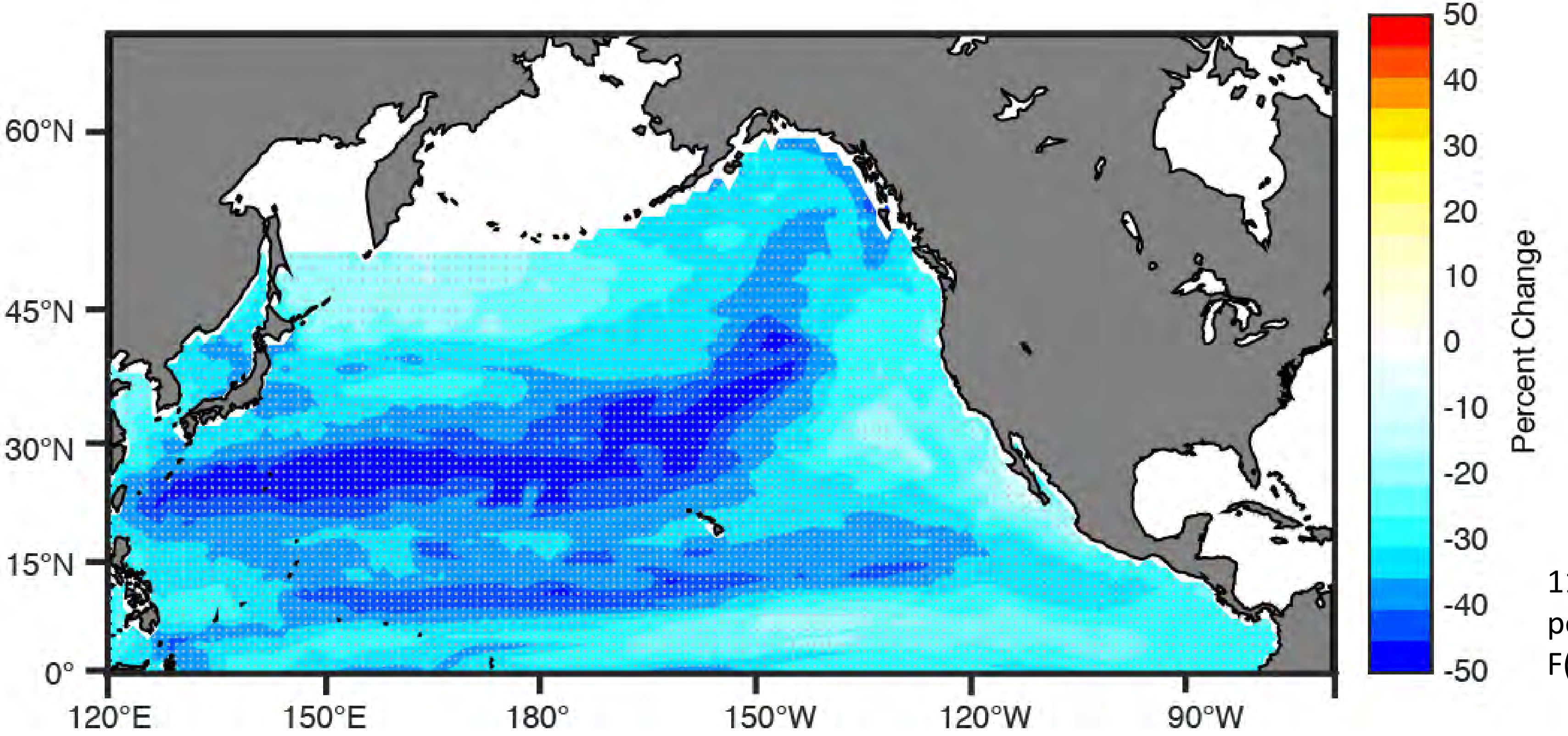


Expansion of the subtropical gyre between the beginning and end of the 21st Century
(GFDL ESM2.1)



Polovina et al. 2011

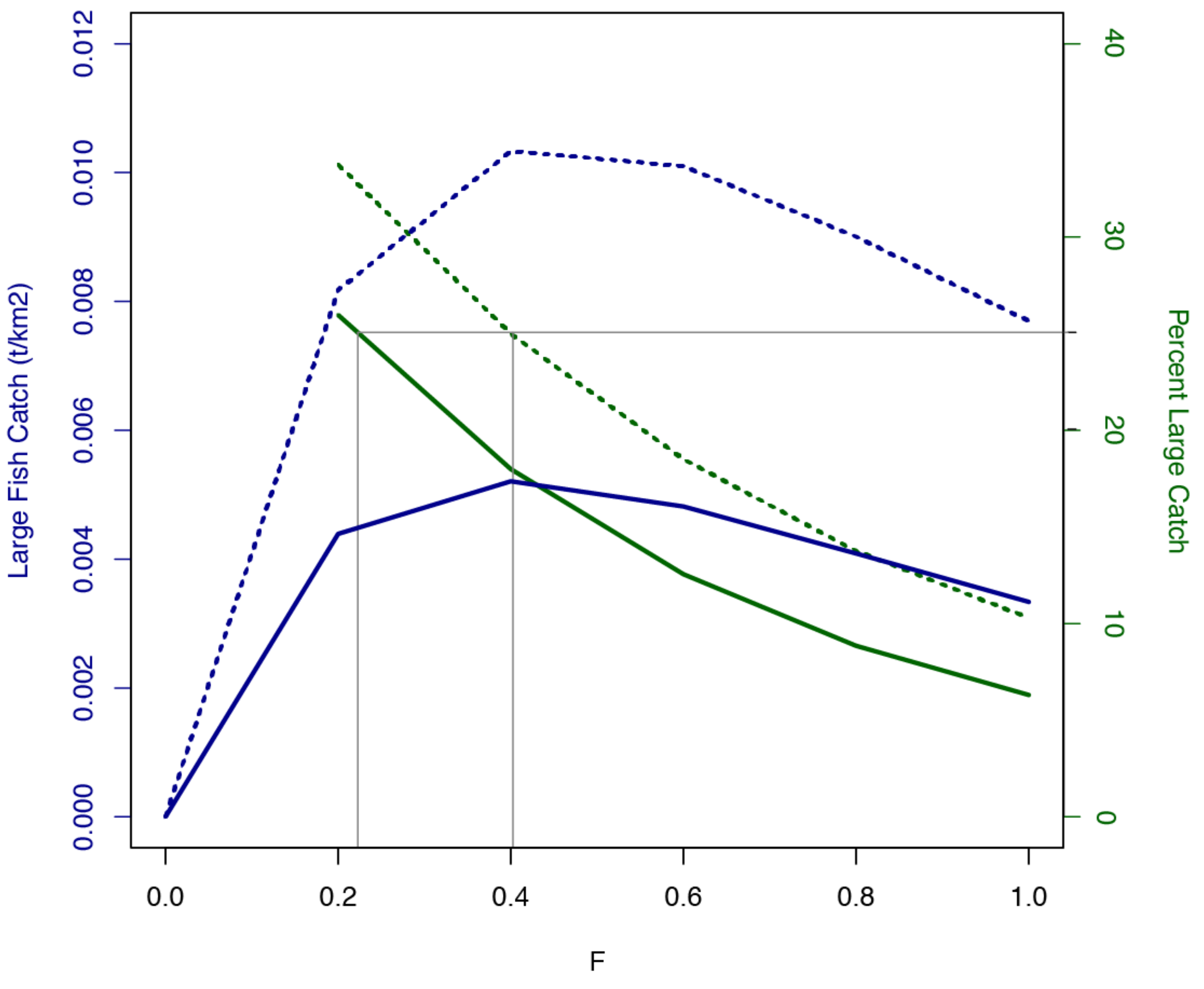
Climate change impacts on Carrying Capacity by the end of the 21st Century



11 CMIP5 model median projected change in potential Carrying Capacity F(Zooplankton density and T)

Woodworth-Jefcoats et al. 2016

Size-based food web model for total large fish catch and % large fish in catch with and without climate change (2081-2100) using phytoplankton output from GFDL, ESM2.1



Dashed lines: no climate change
Solid lines: climate change

Ecosystem response to climate variation and change

- ENSO and PDO induced biological variation can be viewed as spatial shifts in productivity gradients at the gyre boundaries
- Climate change in subtropics is projected to reduce carrying capacity and fisheries yield.
- The combine impacts of fishing and climate change are projected to both shift the size structure to smaller size species
- A reduction of fishing effort can help mitigate this shift

Challenges and Future Directions

- Understanding climate impacts (changing temperature and chemistry) across the entire ecosystem – all trophic levels.
- Developing climate-informed reference points and robust management strategies
- Understanding spatial movement of fishes and impacts of spatially separated fisheries.
- Developing and running spatial ecosystem models to provide both short term and long range forecasts
- Monitoring more of the ecosystem (micronekton)
- Determining the ecosystem impacts of large pelagic MPAs