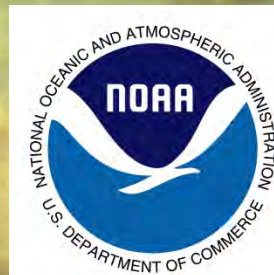


Salmon responses to climate change: From life-cycle models to a multi-model approach

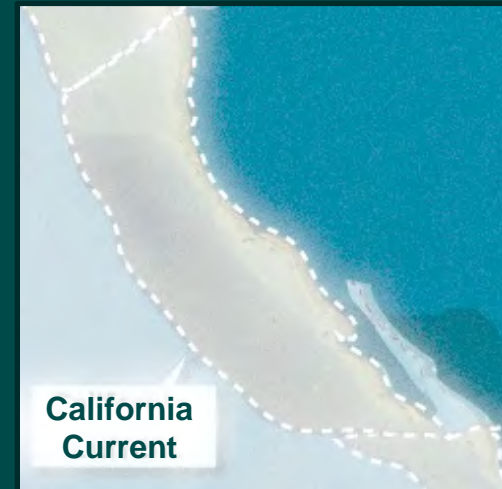
Effects of Climate
Change on World's
Oceans
June 5, 2018,
Washington, D.C.

Lisa Crozier

**NWFSC,
NOAA-Fisheries**



Salmon: Ecosystem indicator



- Integrated Ecosystem Assessment (IEA) of the California Current Large Marine Ecosystem (CCLME)
 - Salmon co-vary with other species of interest

Salmon: Human importance

Cultural
identity &
values



Commercial
& subsistence
fisheries

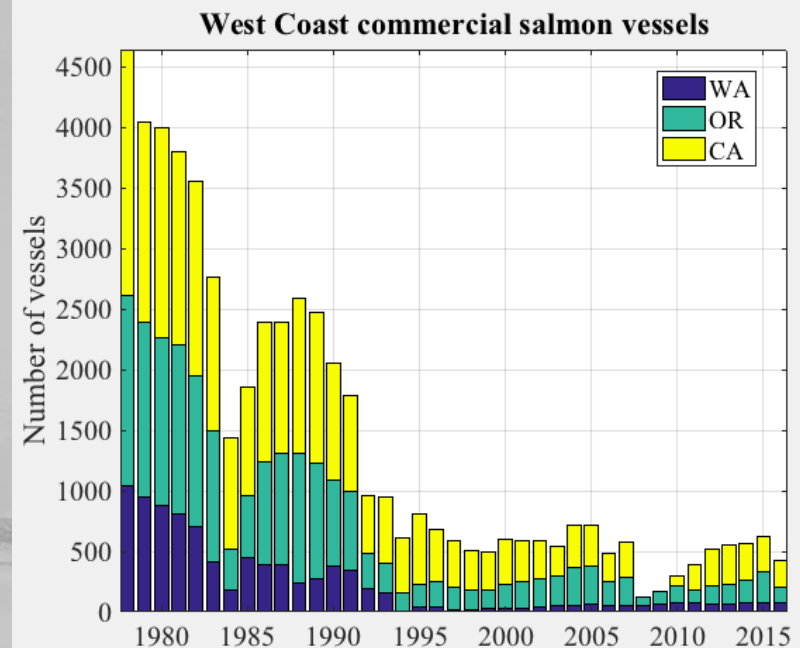
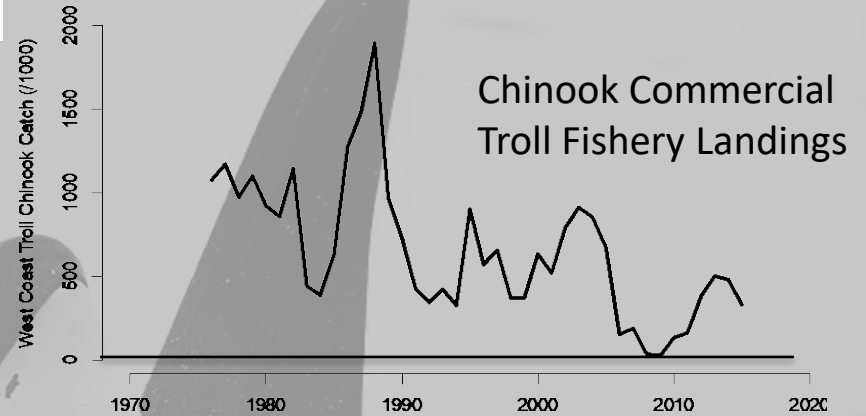


Recreational
endeavors



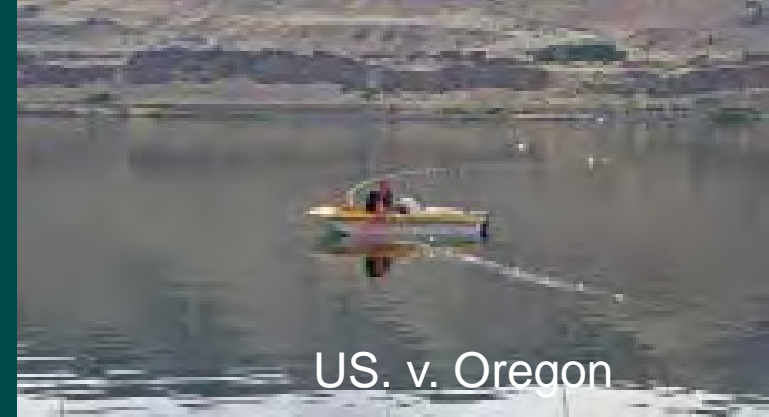
Salmon decline

In-River catches in the Columbia River



- Fisheries in severe decline; frequent Federal Disaster Declaration requests
- Southern Resident Killer Whales at risk – insufficient food (Chinook) seems key
- Emerging conflicts with growing predator populations (marine mammals, birds)

Management options to improve salmon viability



Columbia River Treaty with Canada
Federal Power System Biological Opinion

Adding climate change is complex

Headwaters > Migration corridors > Estuary >

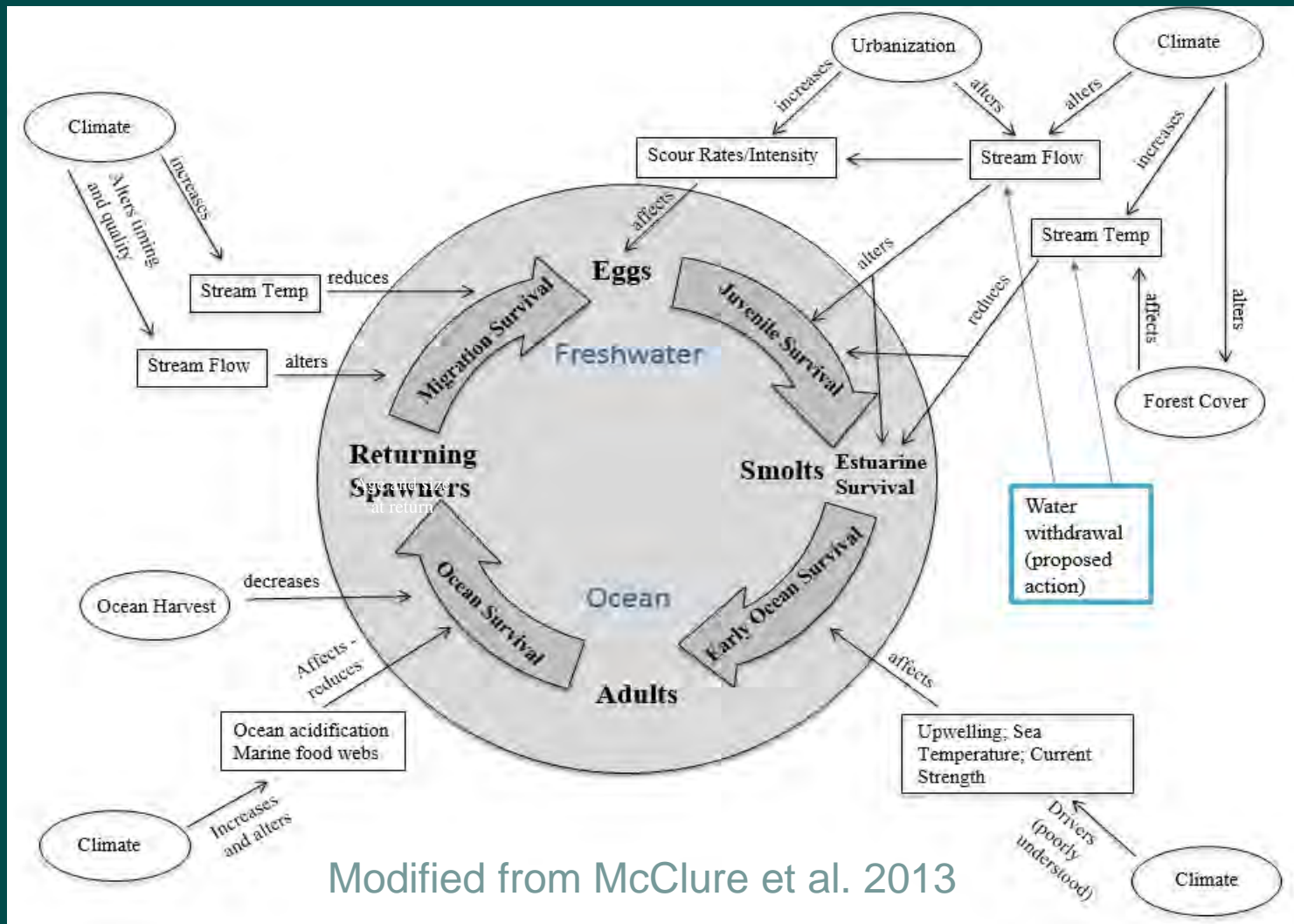
Salmon Life Cycle

The salmon life cycle has long fascinated people worldwide. This illustration depicts some of the life stages and events of salmon from the cold waters of Puget Sound to the Pacific Ocean. Salmon are anadromous: they hatch in fresh water, migrate to the ocean where they spend most of their lives, then return to fresh water to reproduce, or spawn.

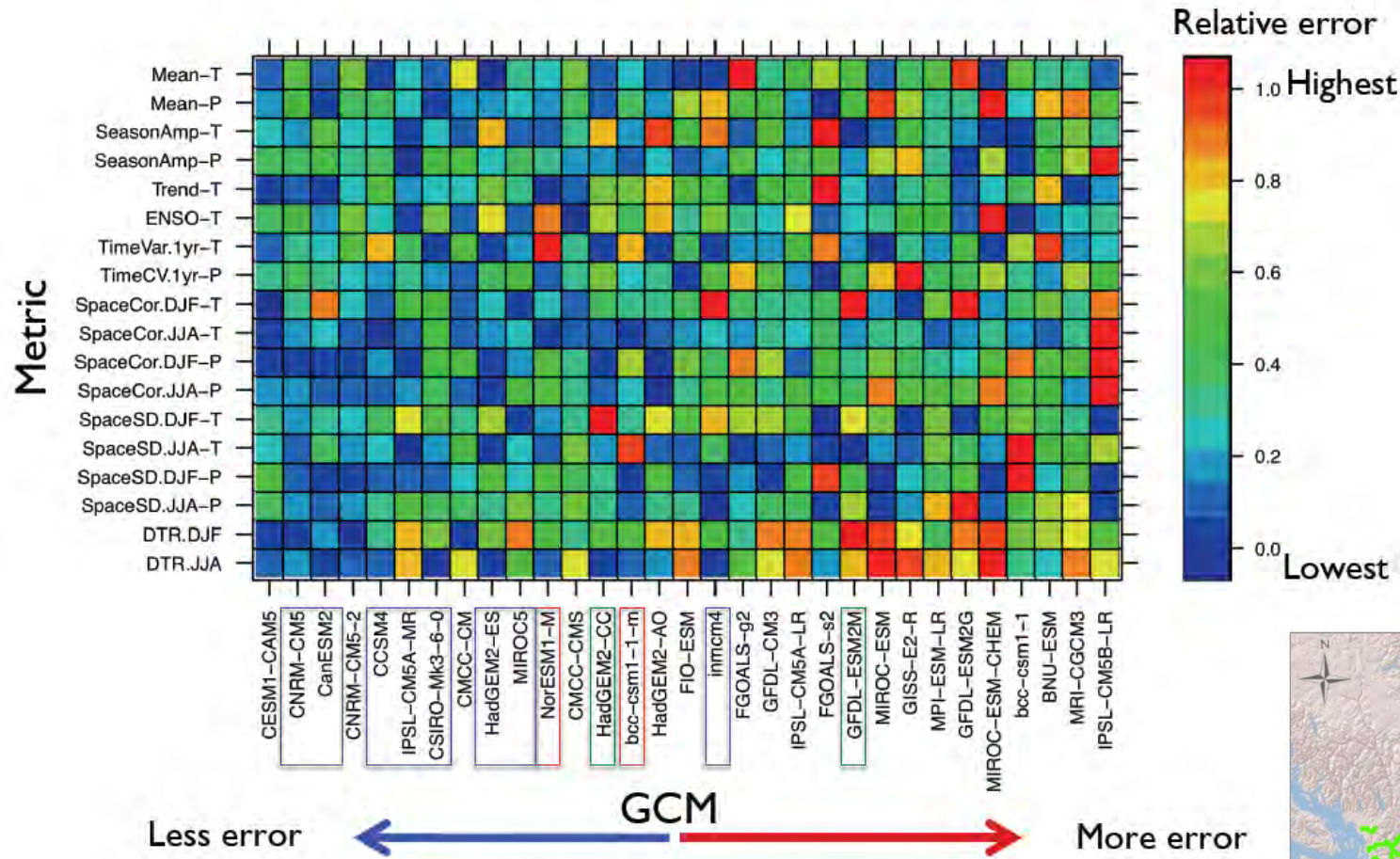
A salmon's life cycle has a number of stages: eggs, alevin, fry, smolt, ocean phase and spawning stage. All Pacific salmon share these stages, but differ in their ability to swim and live several times in the ocean; some spend thousands of miles at sea to spawn, while others complete their lifecycle.

http://www.ci.edmonds.wa.us/Discovery_programs_website/Pier_Signage.html

Conceptual Model of the Salmonid Life Cycle and Climate Change

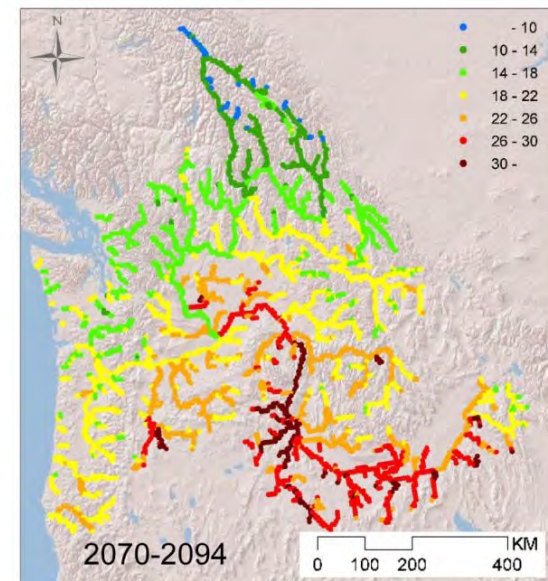


GCM Performance Quilt

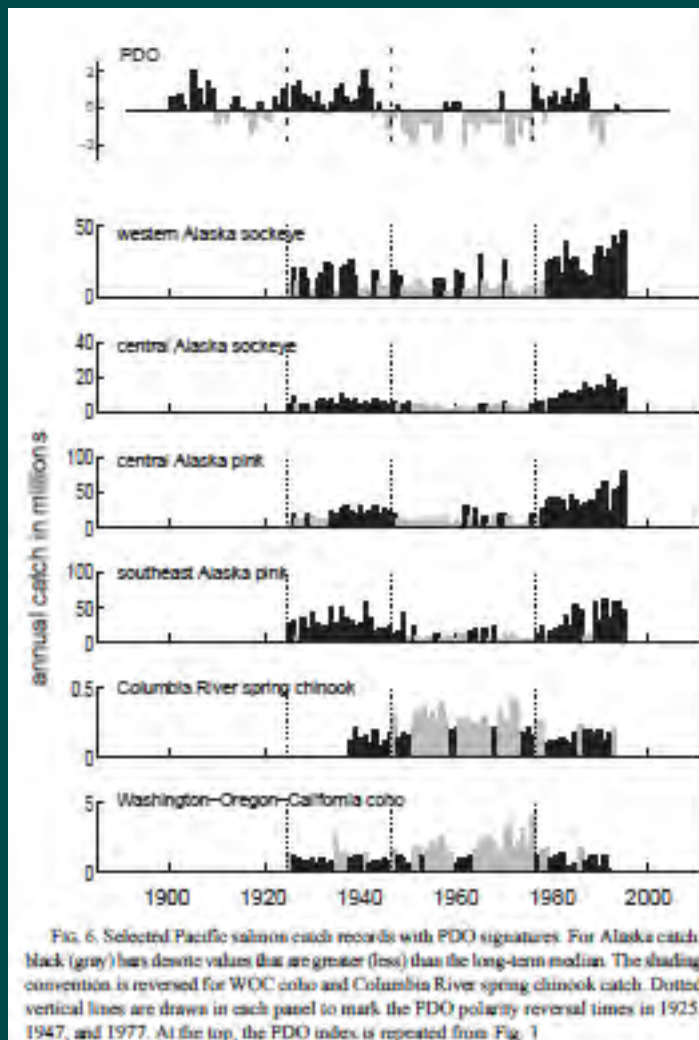


Wu et al 2012
Water Resources Research

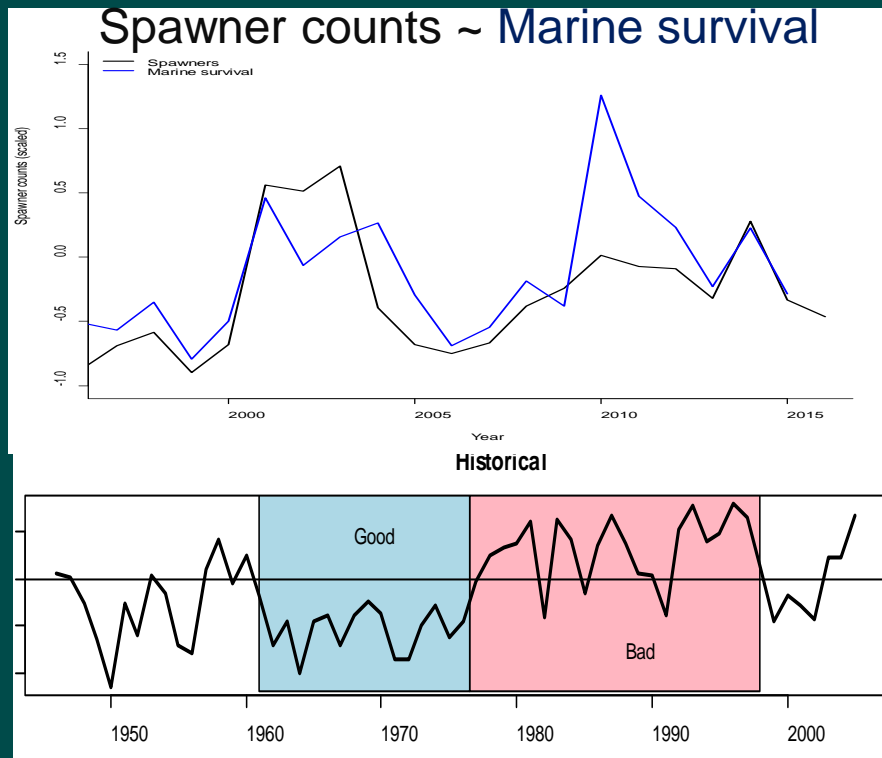
(Ordered by sum total of relative errors. All metrics treated equally.)



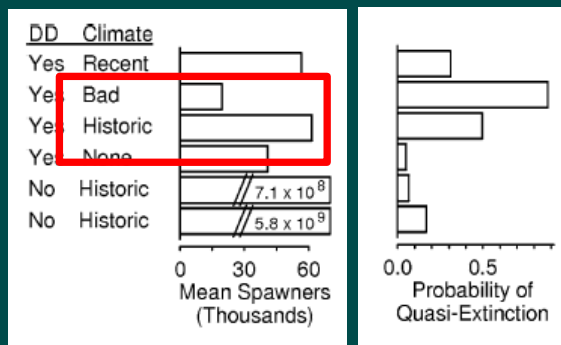
Marine survival historically predicted good/bad salmon returns



Mantua et al 1997 Bull. Amer. Met. Soc.

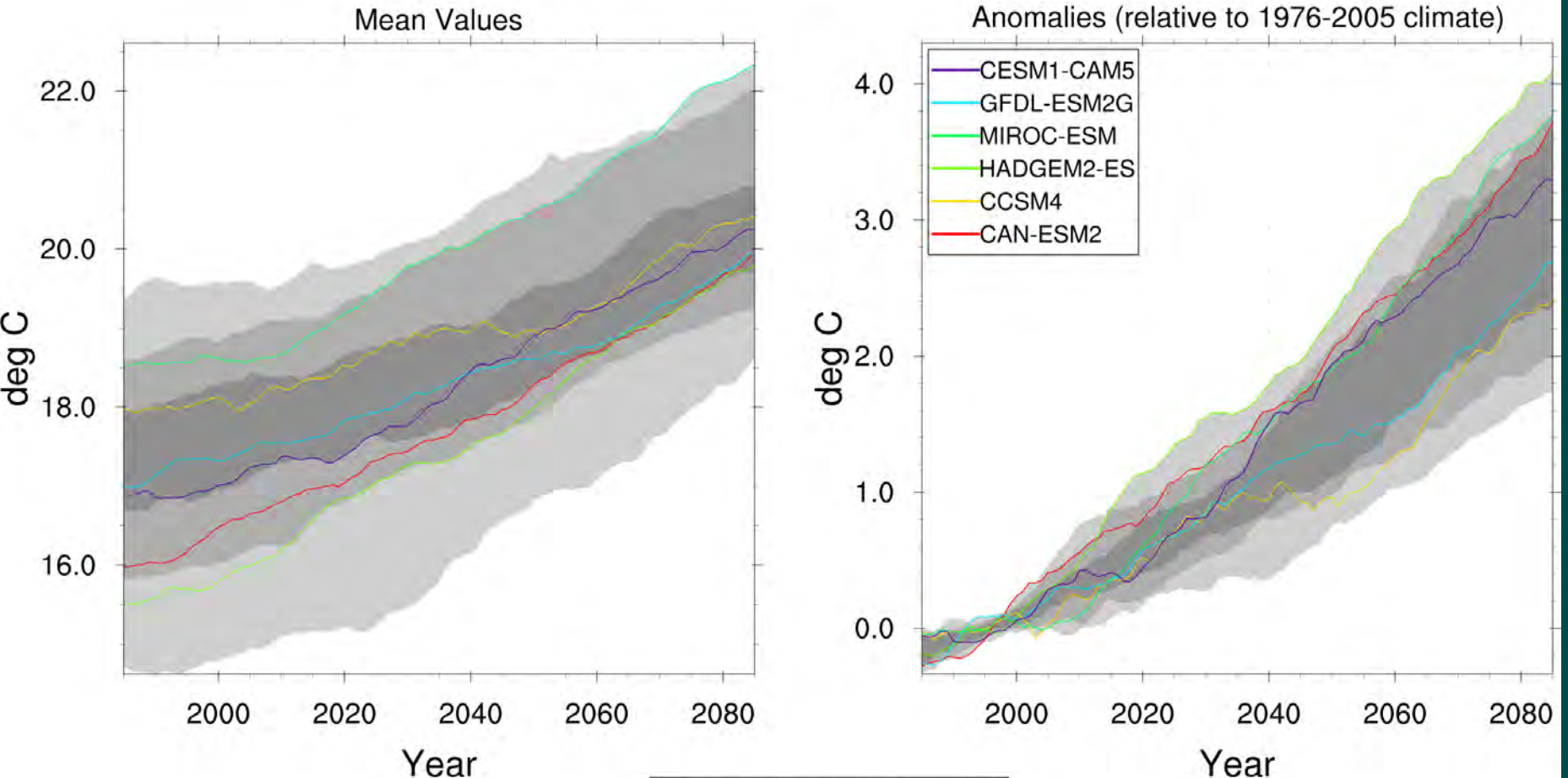


Zabel et al 2006. Cons. Biol.



How will a linear trend interact with these “good/bad” ecosystem setups?

ANN tos for California Current with 20 year running mean (20thC + rcp85)

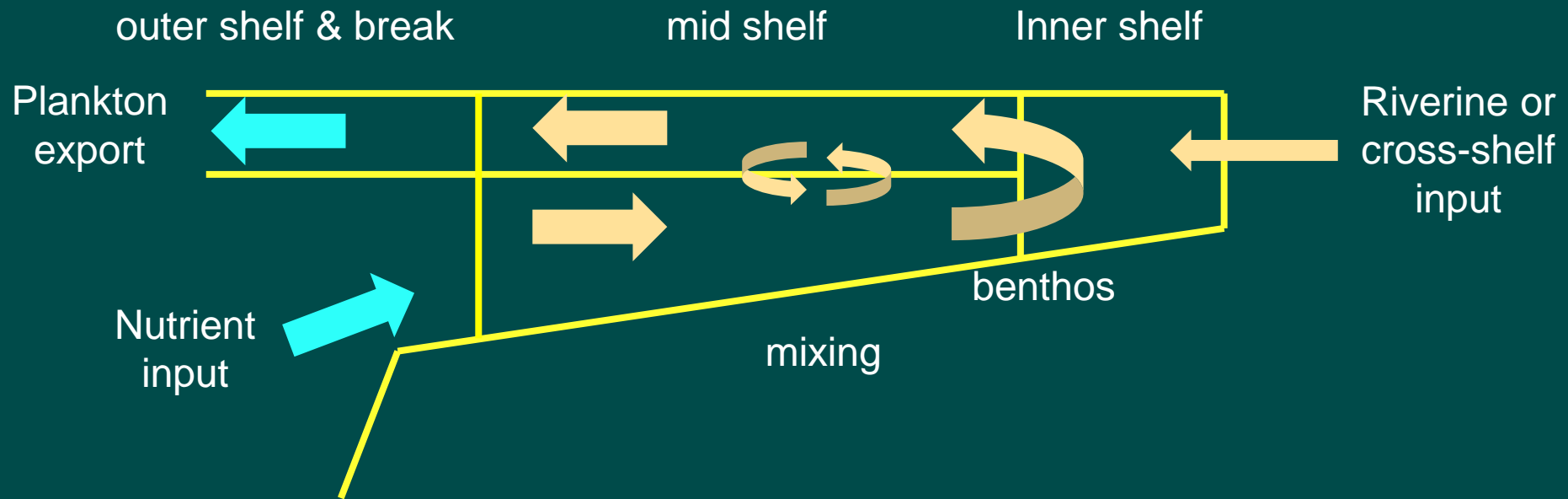


Why is marine survival so hard to model?

- Physical models do not represent upwelling very well – timing, intensity, duration all important
- Ecosystem models don't capture recruitment dynamics of either prey or predators
- Range shifts not incorporated

Intermediate-complexity models: Simpler models allow exploration of many hypotheses

ECOTRAN model coupled to 5-box physical model

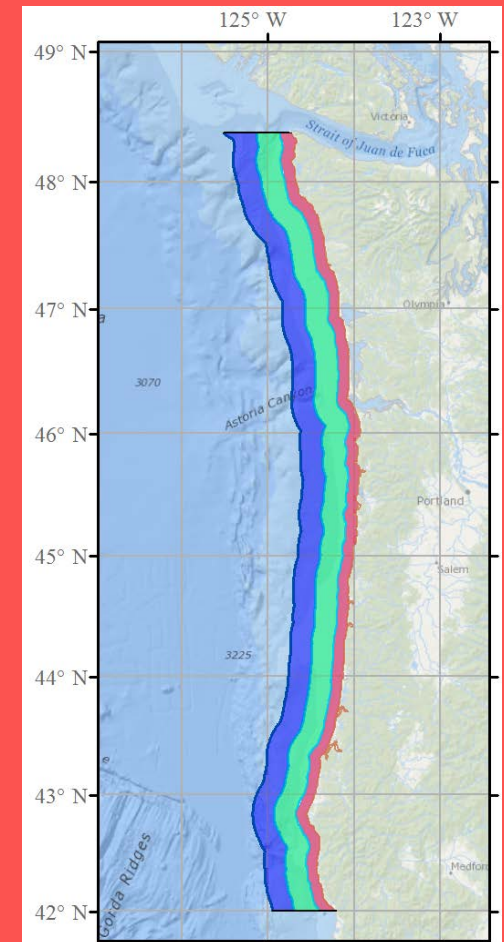
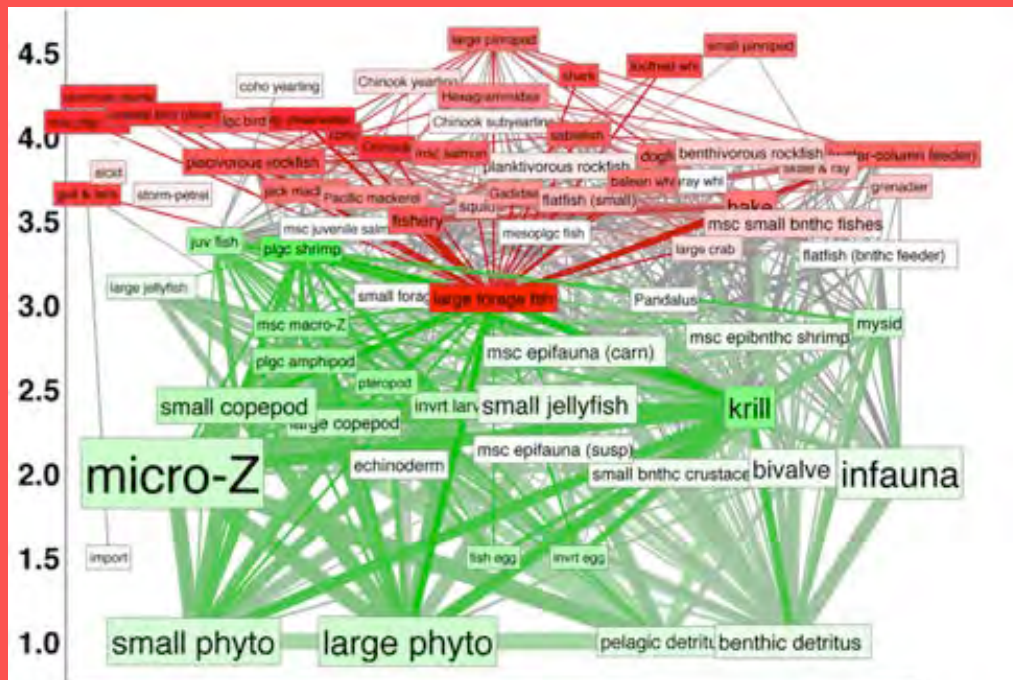


Interannual variability in the Northern California Current food web structure: Changes in energy flow pathways and the role of forage fish, euphausiids, and jellyfish

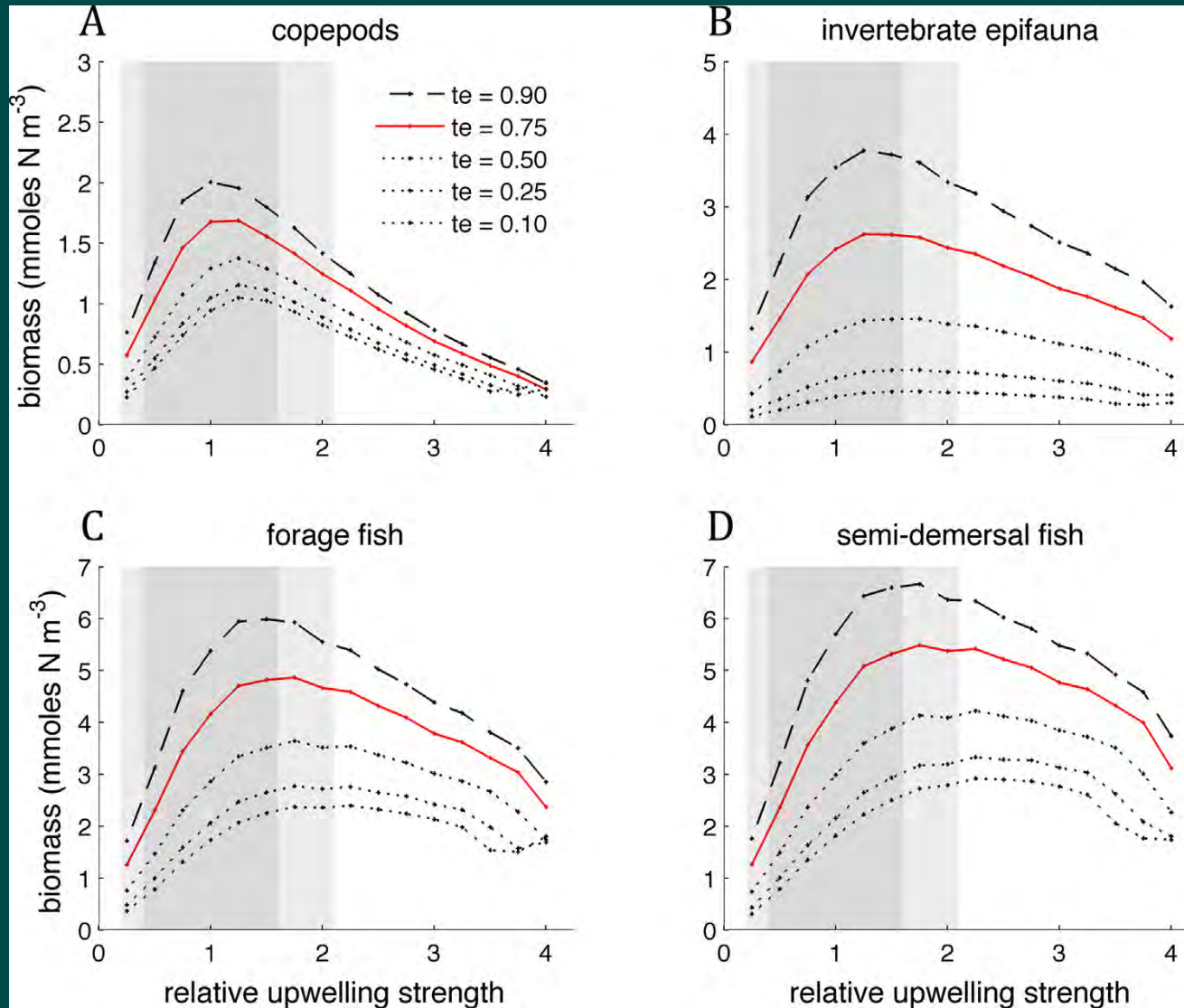
James J. Ruzicka^{a,*}, Richard D. Brodeur^b, Robert L. Emmett^b, John H. Steele^c, Jeannette E. Zamon^d, Cheryl A. Morgan^a, Andrew C. Thomas^e, Thomas C. Wainwright^b

Progress in Oceanography 102 (2012) 19-41

Upwelling: Northern California Current



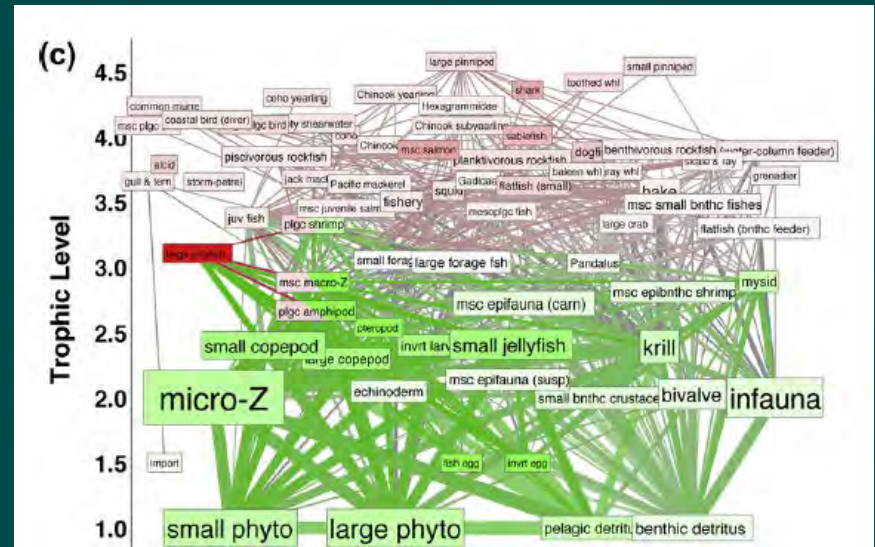
Ecosystem models for salmon driven by bottom-up dynamics, esp upwelling



Competition with jellyfish

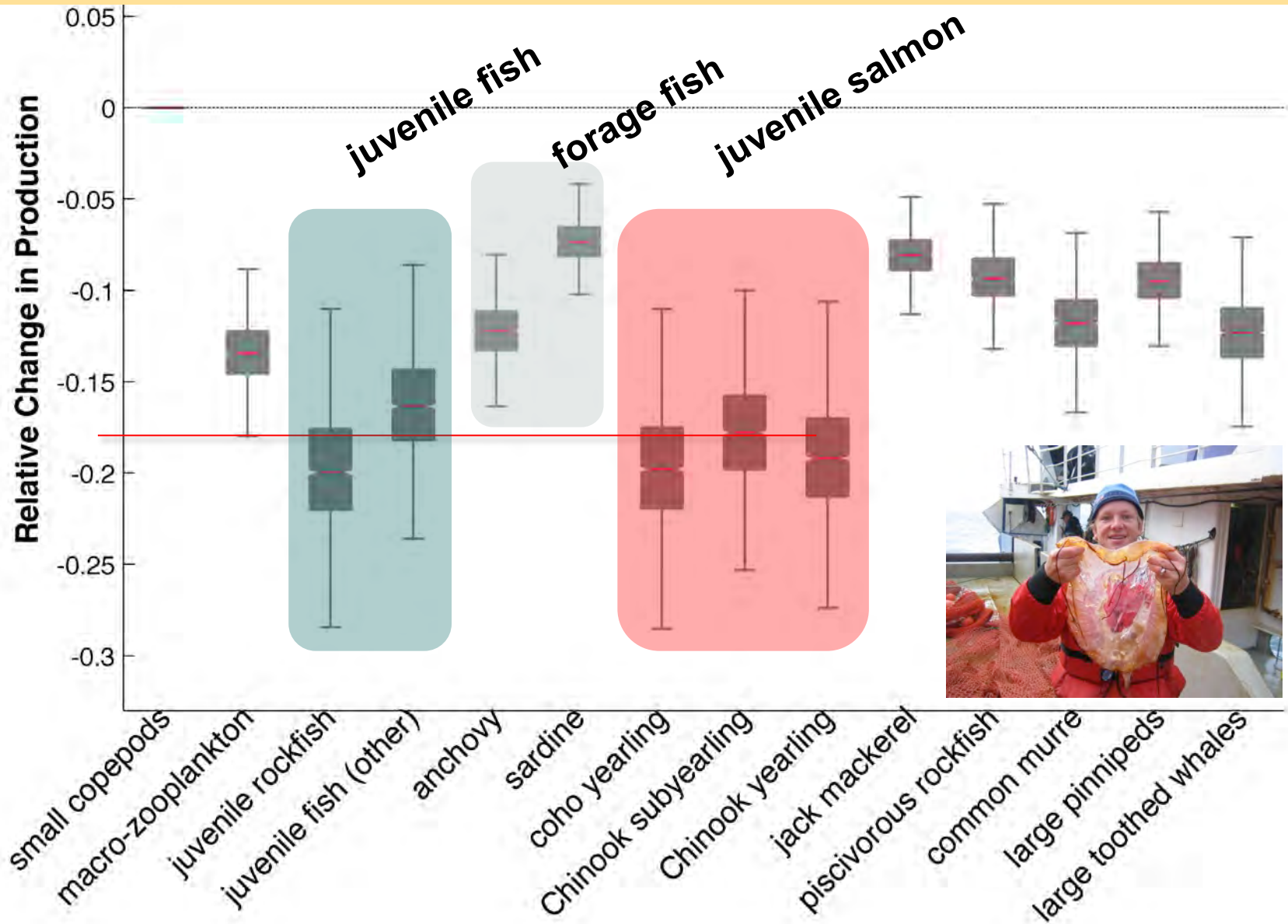


And competition with jellyfish

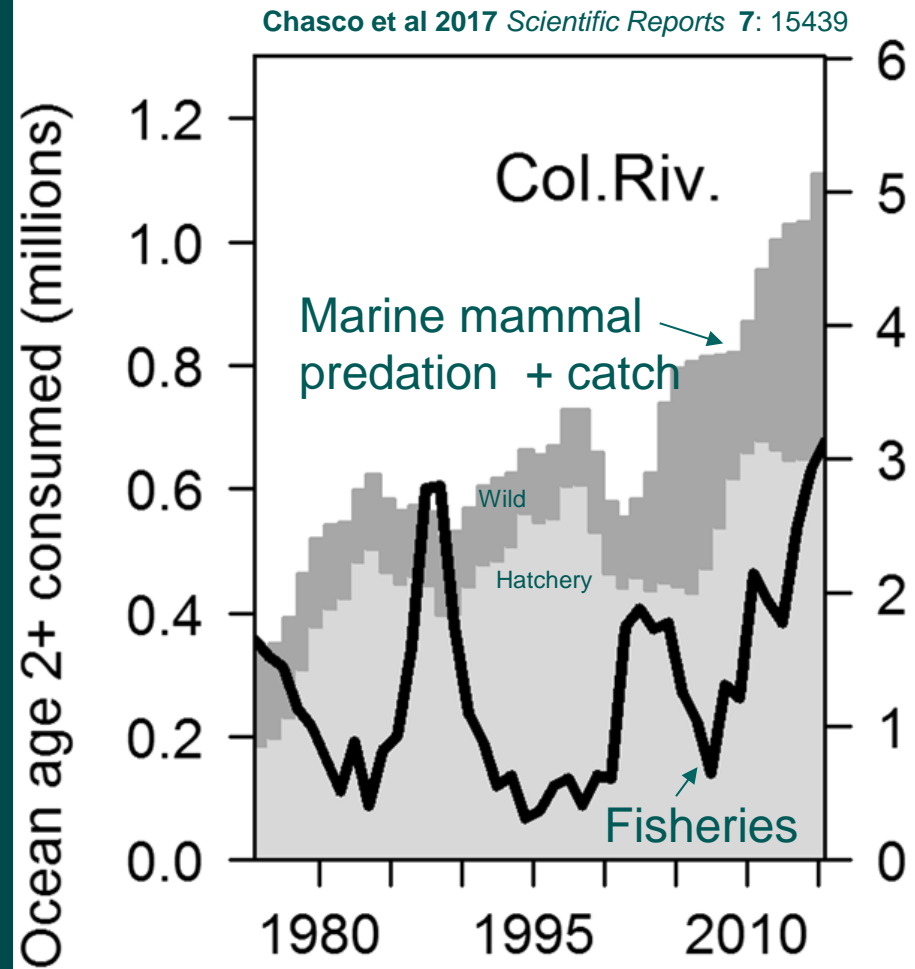


Static Simulation: Effects of a Jellyfish bloom

(simulation of a 1 stdev increase over 1999 – 2012 mean jellyfish biomass)



Role of predators



Why is marine survival so hard to model?

- Physical models do not represent upwelling very well – timing, intensity, duration all important
- Ecosystem models don't capture recruitment dynamics of either prey or predators
- Range shifts of predators
- Freshwater conditions affect marine survival (body size, timing, age of maturation)
- Freshwater conditions are correlated with marine conditions
- Hatchery fish populate most ocean data, but do not represent wild fish
- Flexibility of salmon foraging behavior uncertain

Conclusions

- Salmon are a great case study and major challenge for climate impacts modeling
- Need better high-resolution physical models of the northeast Pacific
- Intermediate-complexity models can improve our understanding of marine survival
- Marine ecosystem models need to be coupled with freshwater population dynamics

Questions?

