

Climate Forcing and Regime Dynamics in the Ocean



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Santa Cruz, CA

AFS 2019 Annual Meeting

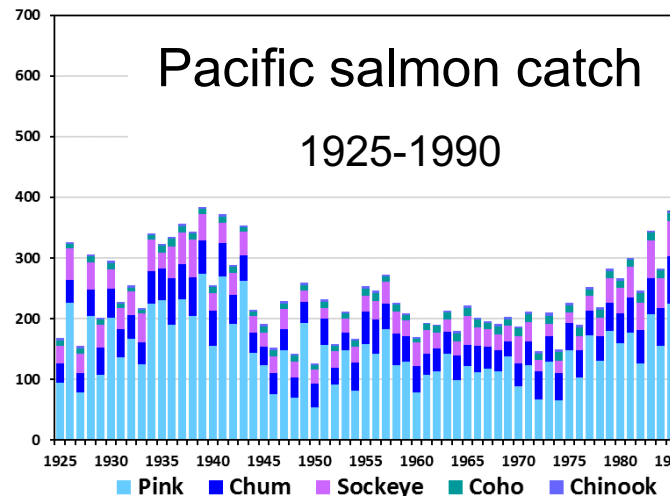
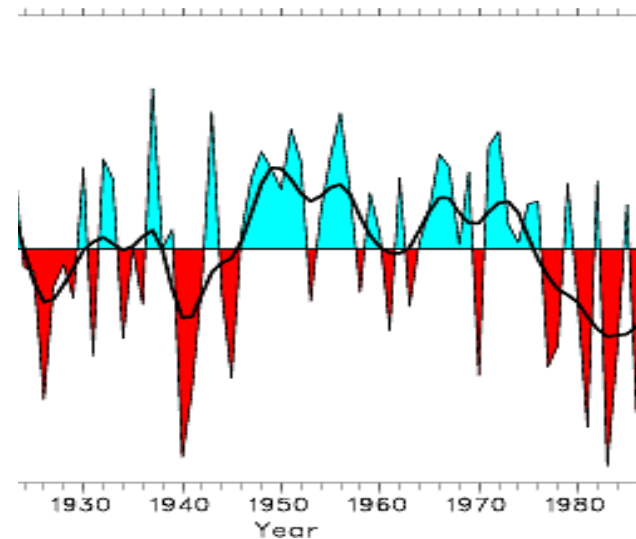
Reno, NV



The Regime Concept in Pacific Salmon Production

Beamish and Boullion (1991, 1993) report a relationship between the Aleutian Low Pressure system and Pacific salmon production – prolonged periods of stability separated by rapid shifts

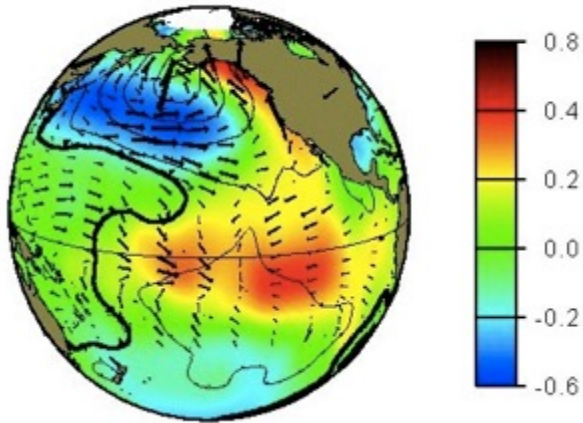
Aleutian Low Index



Data Source: North Pacific Anadromous Fish Commission (NPAFC). 2019. NPAFC Pacific salmonid catch : North Pacific Anadromous Fish Commission, Vancouver. Accessed July, 2019. Available: <https://npafc.org>

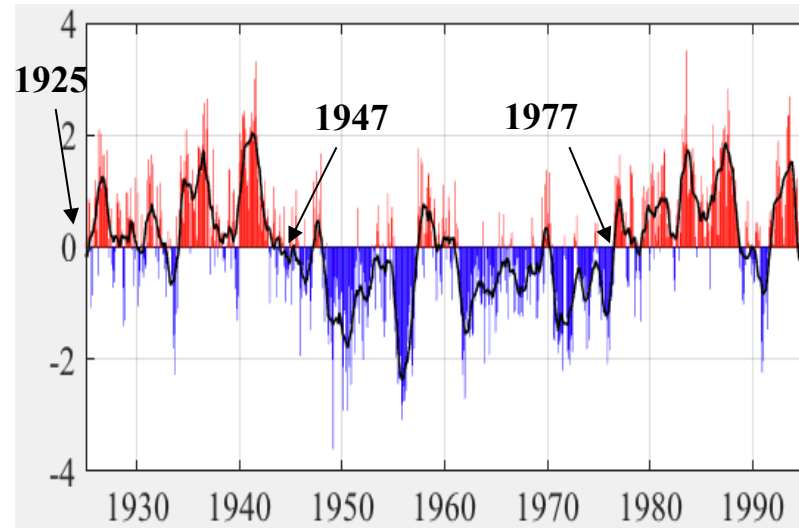
The Pacific Decadal Oscillation and Salmon Production Regimes

Pacific Decadal Oscillation (PDO)

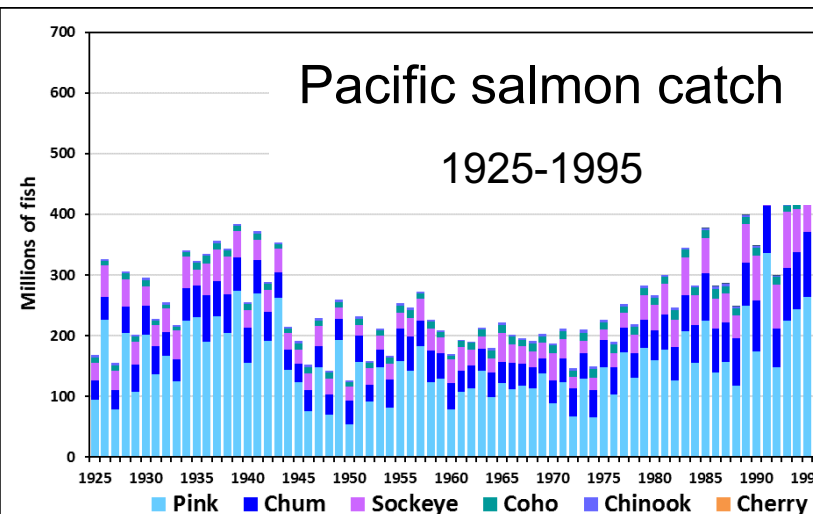


Hare and Francis 1995; Mantua et al., 1997; Hare et al. 1999

PDO Index: 1925-1995



Pacific salmon catch
1925-1995

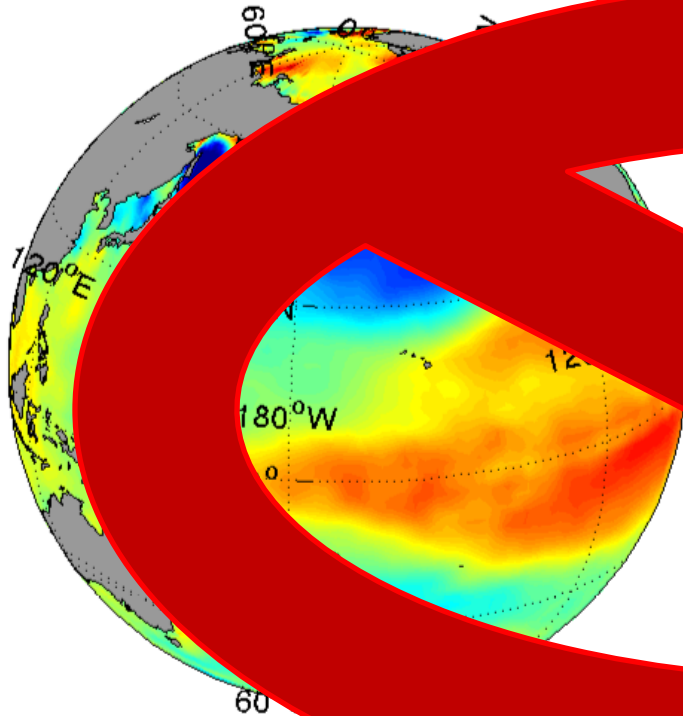


Data Source: North Pacific Anadromous Fish Commission (NPAFC). 2019. NPAFC Pacific salmonid catch statistics (updated North Pacific Anadromous Fish Commission, Vancouver. Accessed July, 2019. Available: <https://npafc.org>

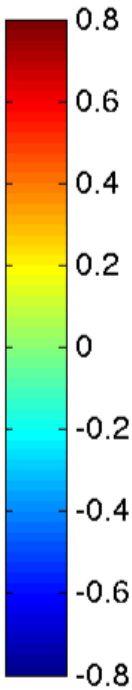
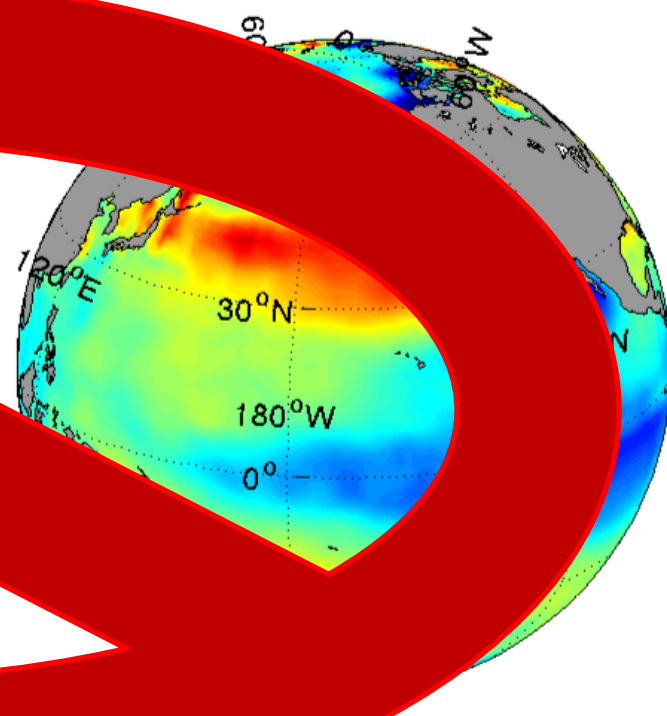
Two regimes in the North Pacific?

Beamish and collaborators, late 1990s NPAFC reports:
No – there are multiple and different kinds of states

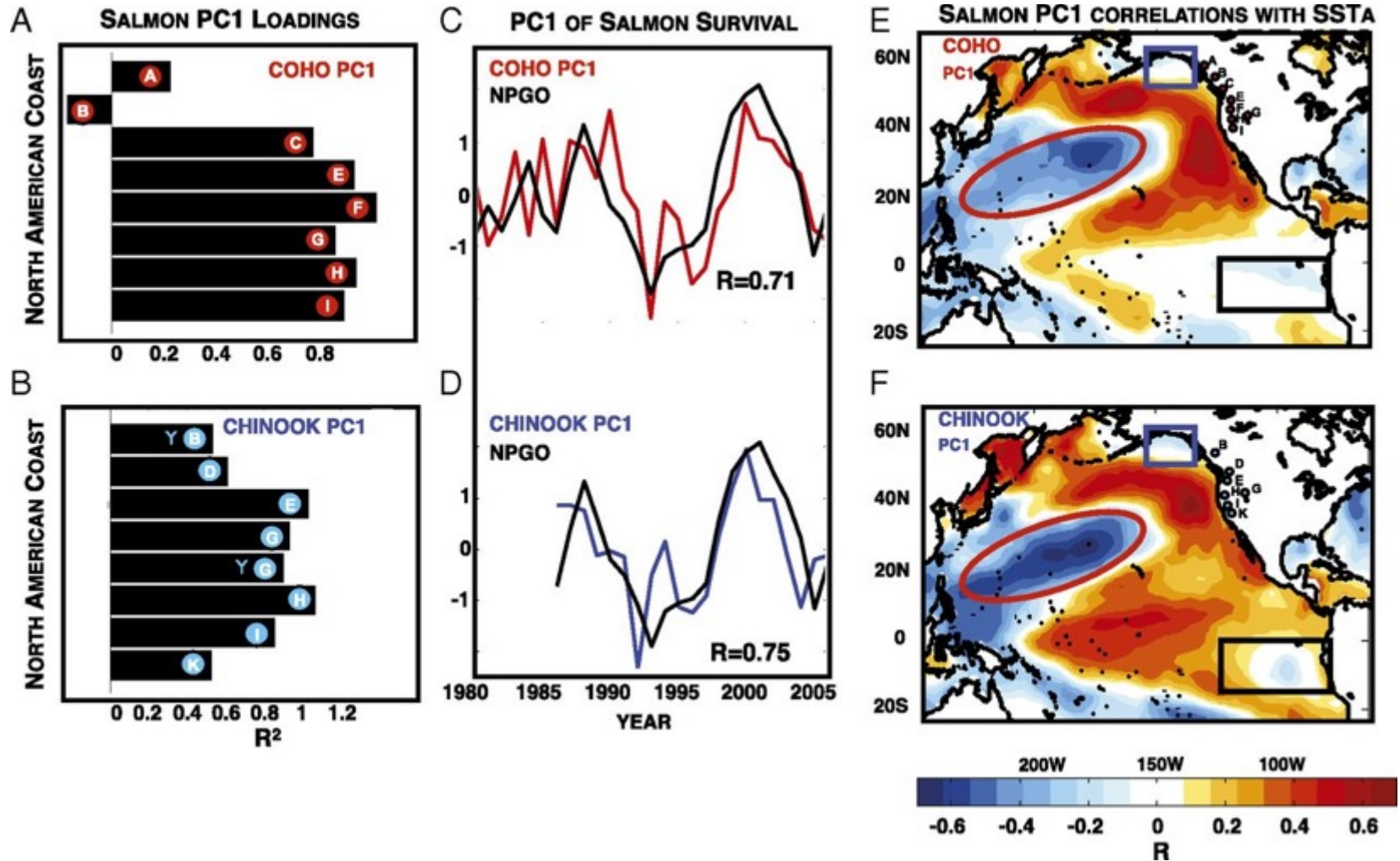
WARM PDO



COOL PDO



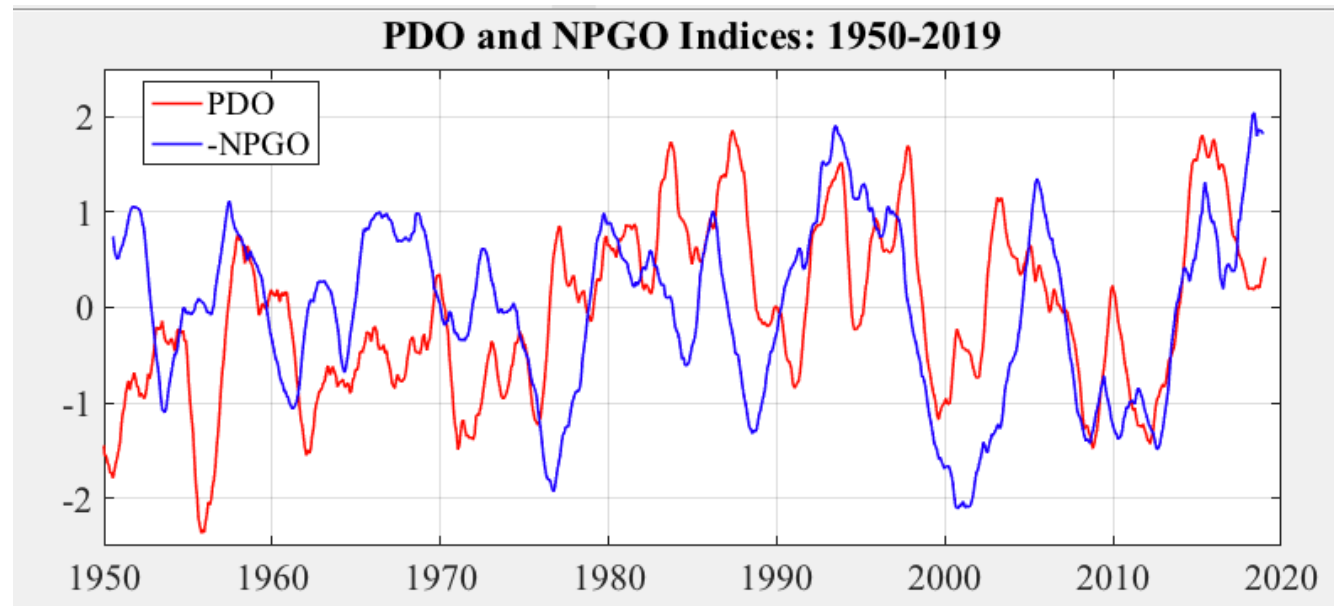
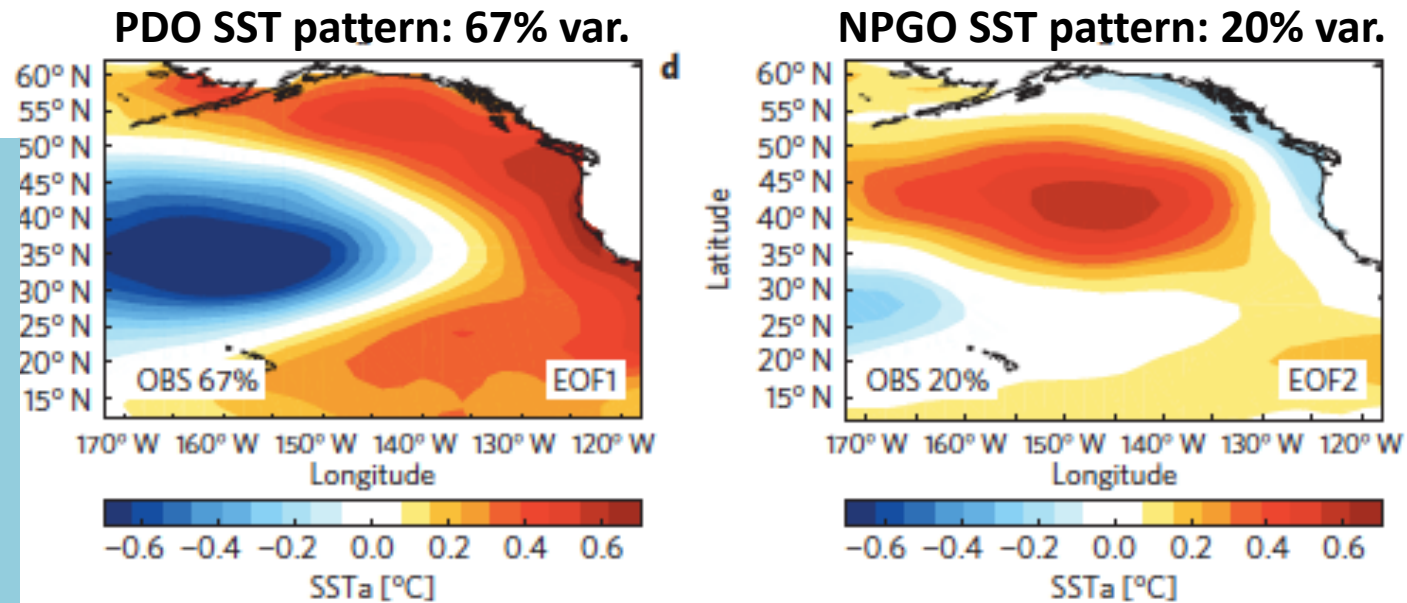
The North Pacific Gyre Oscillation and West Coast Coho and Chinook salmon SARs



D. Patrick Kilduff et al. PNAS
2015;112:35:10962-10966

The two leading patterns of Northeast Pacific SST variations account for most of the year-to-year variability

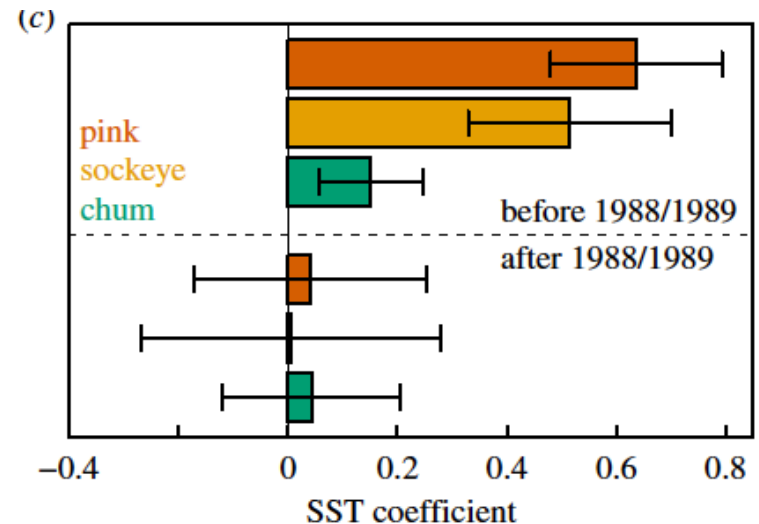
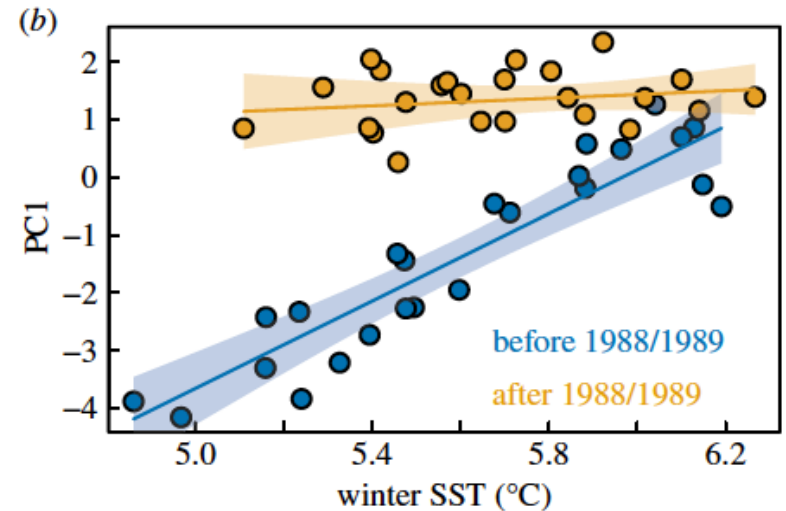
These variations aren't limited to 20-30 year regimes



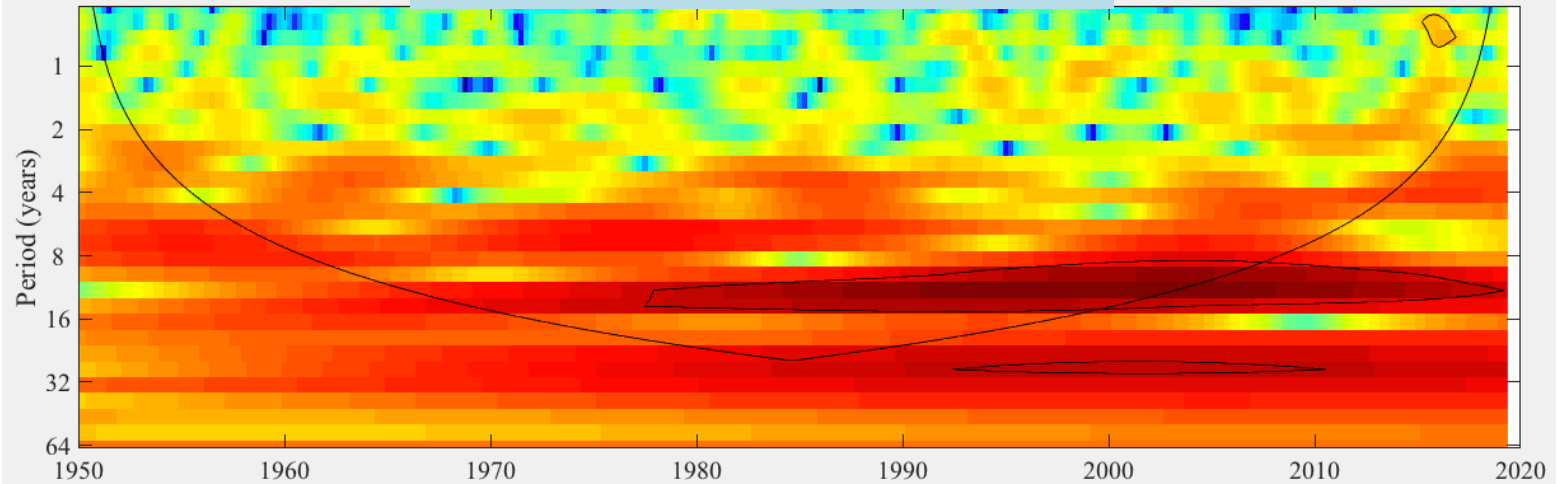
Non-stationarity in Alaska climate-salmon relationships

(Litzow et al. 2018, Proc. R. Soc. B.)

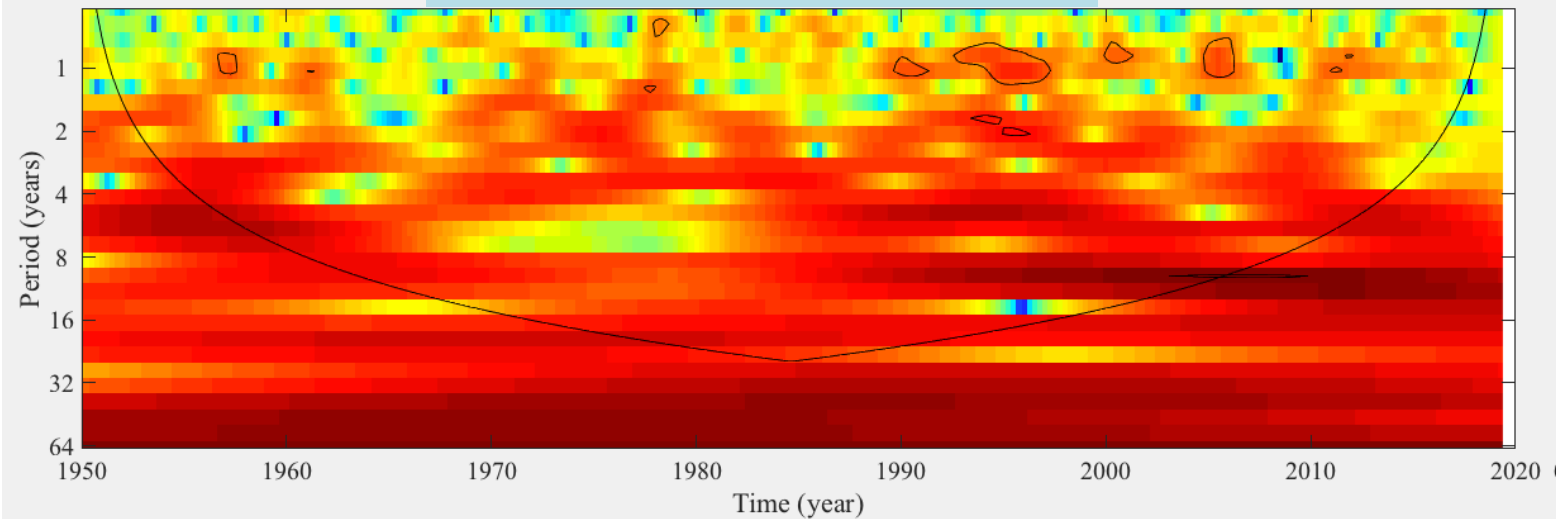
- non-stationary relationships between Gulf of Alaska salmon catch and SST (PDO too)
- NPGO pattern has had increasing variance since the 1990s



NPGO Wavelet Power Spectrum



PDO Wavelet Power Spectrum

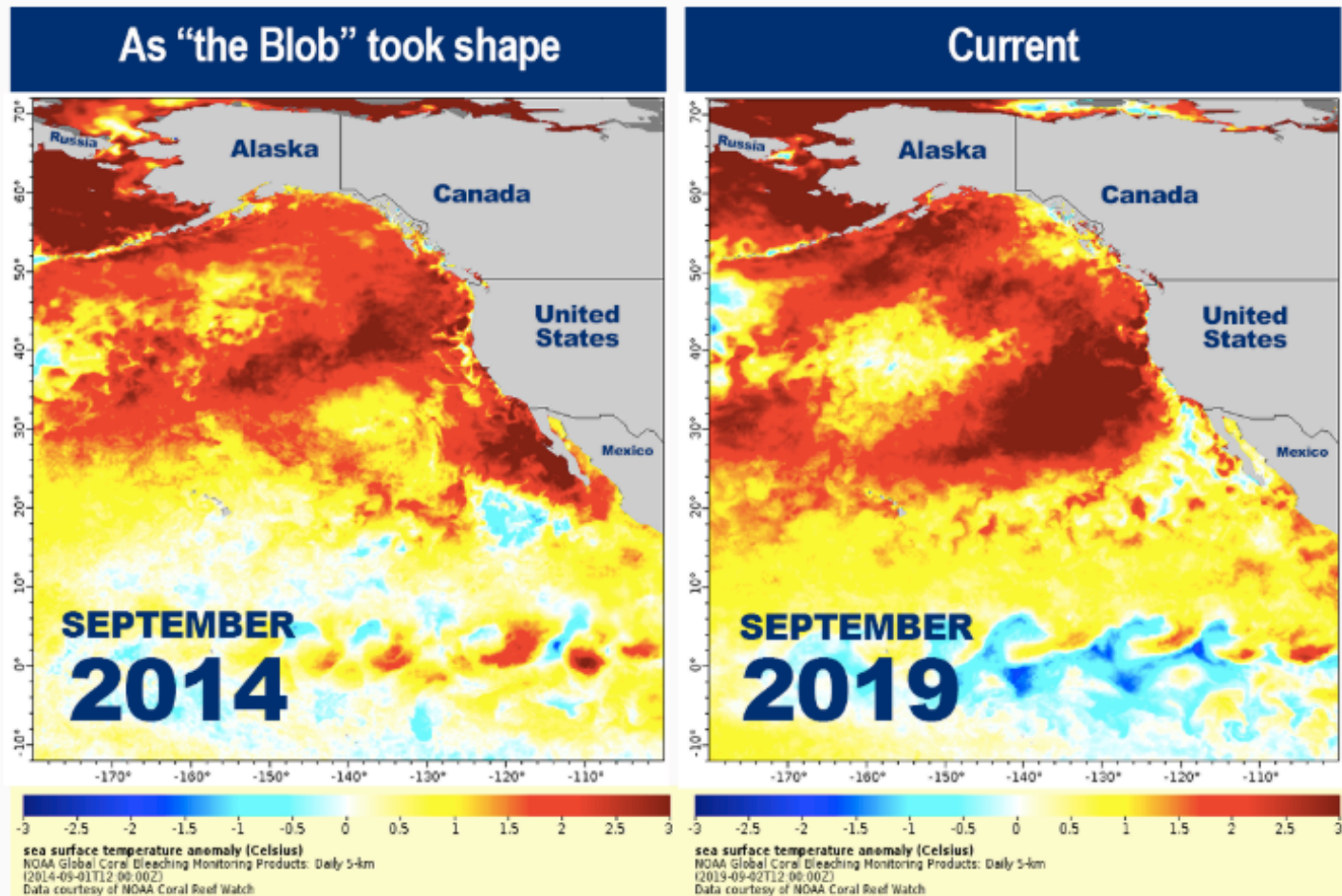


More variance in shorter (~ 4 to 8 year) “regimes” in the North Pacific since the 1990s, including multiyear marine heat waves

New Marine Heatwave Emerges off West Coast, Resembles "the Blob"

September 05, 2019

Researchers are monitoring a new marine heatwave off the West Coast for effects on the marine ecosystem.



<https://www.fisheries.noaa.gov/feature-story/new-marine-heatwave-emerges-west-coast-resembles-blob>

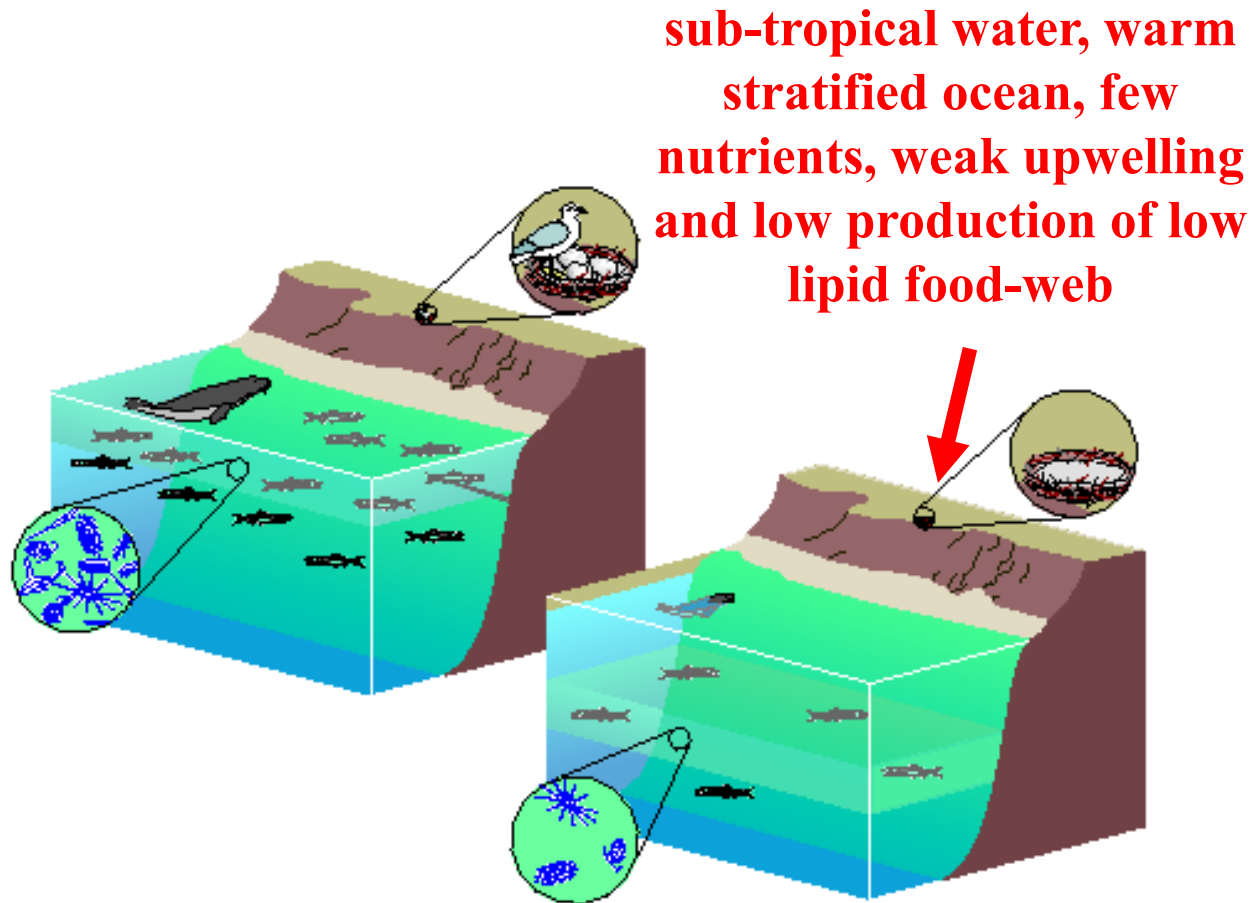
Bottom-up forcing impacts on salmon

Gyre and current strength, transport of subarctic vs. subtropical water masses, stratification and upwelling of nutrients

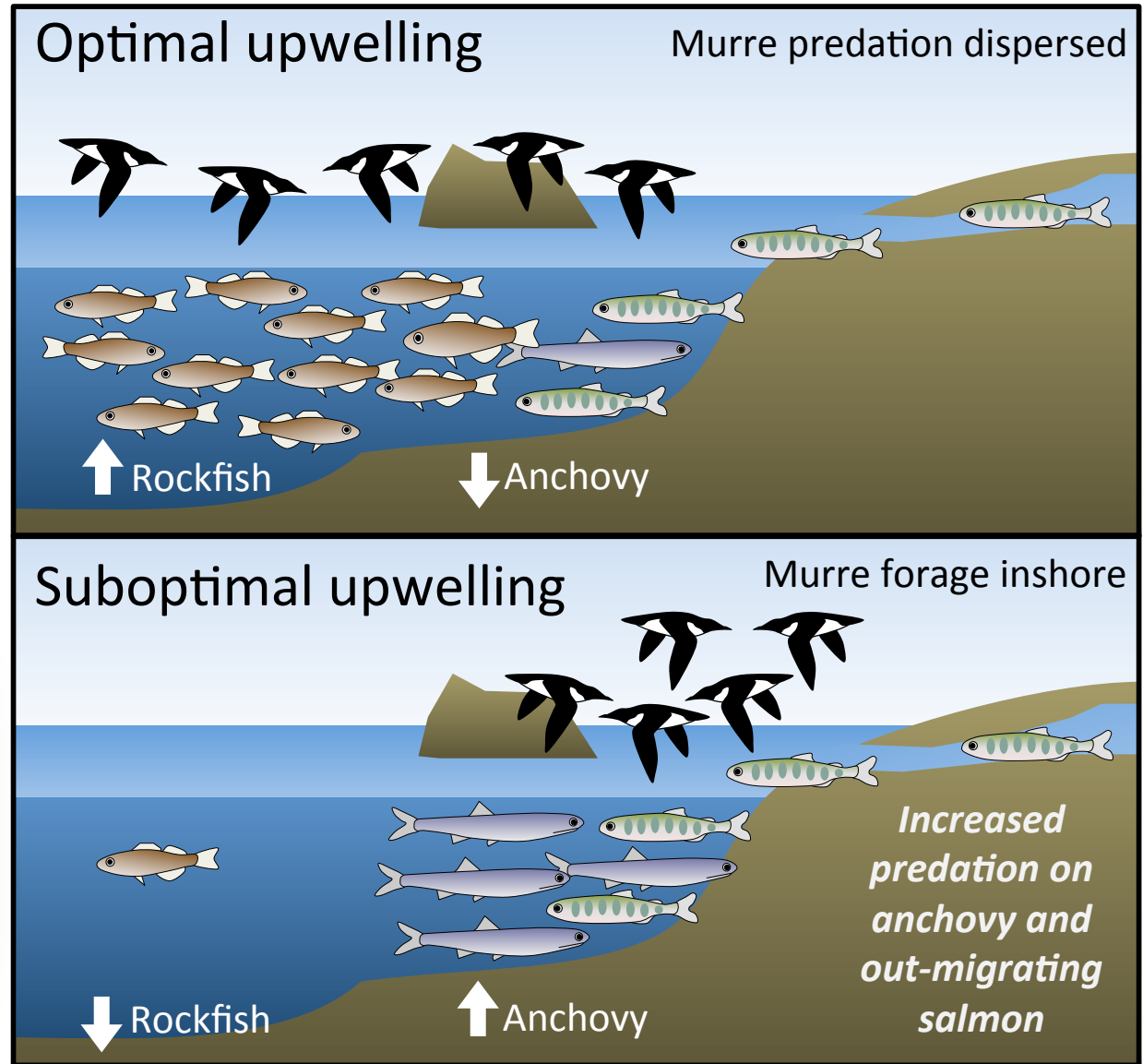


Thysanoessa spinifera

Mantua AFS Symposium 2019

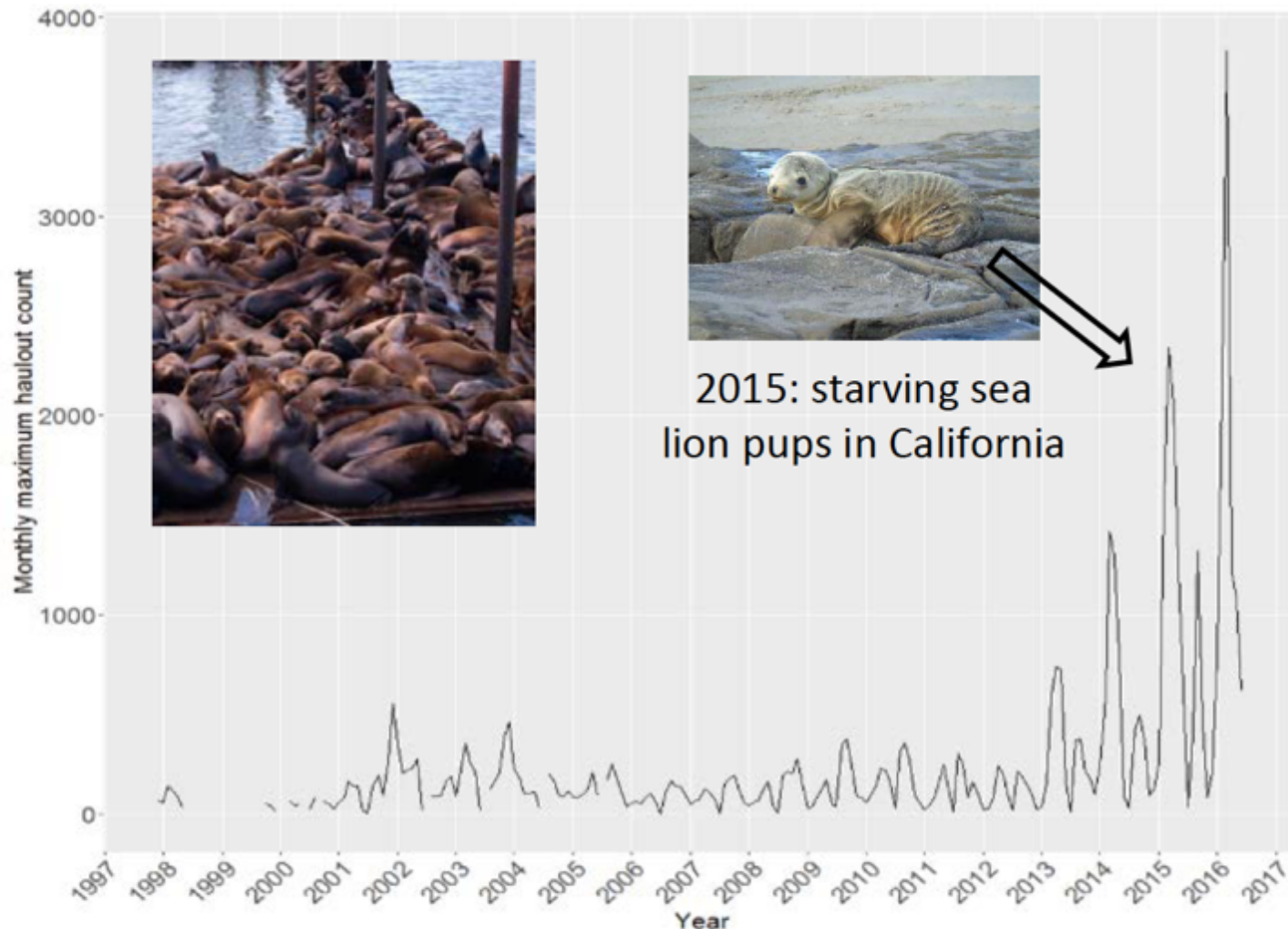


Bottom-up driven
prey-switching
impacting (top-
down) predation on
juvenile salmon



Wells, B.K., J.A. Santora, M.J. Henderson, P. Warzybok, J. Jahncke, R. W. Bradley, D. D. Huff, I.D. Schroeder, P. Nelson, J.C. Field, D.G. Ainley 2017. Environmental conditions and prey-switching by a seabird predator impacts juvenile salmon survival. *Journal of Marine Systems*

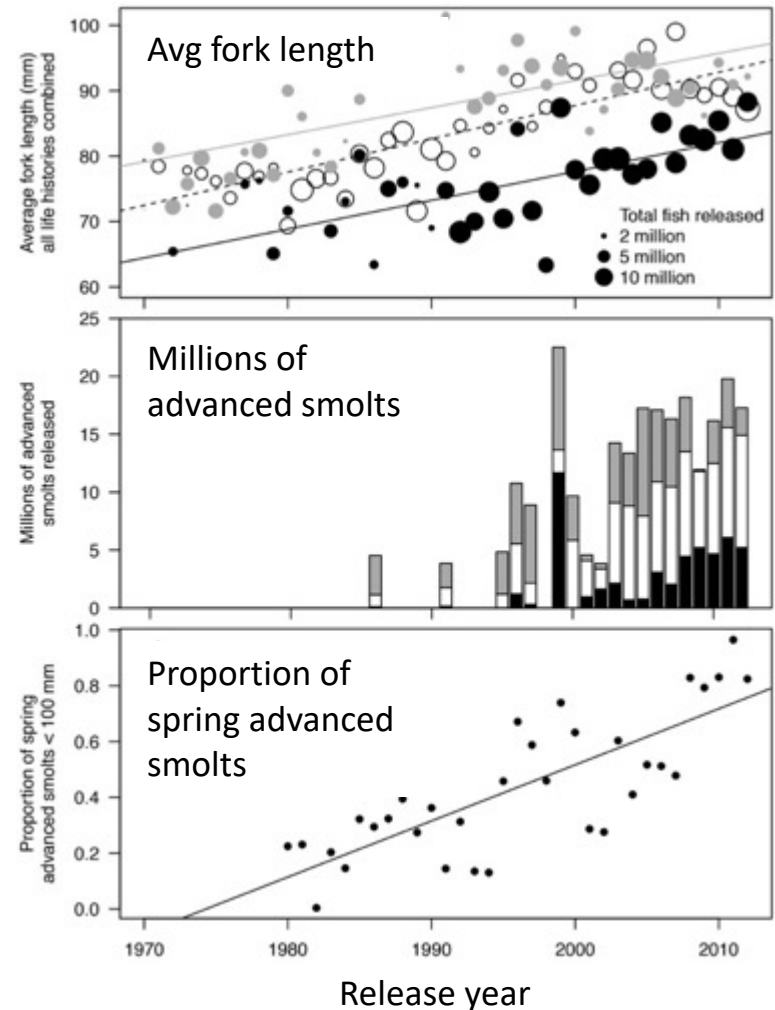
Peak warm SST years in the CCS had large numbers of California sea lions in the lower Columbia River



Declining portfolio effects

Increased synchrony in Chinook salmon population dynamics among stocks has been noted for West Coast basins (Moore et al 2010; Carlson and Satterthwaite 2011; Griffiths et al. 2014)

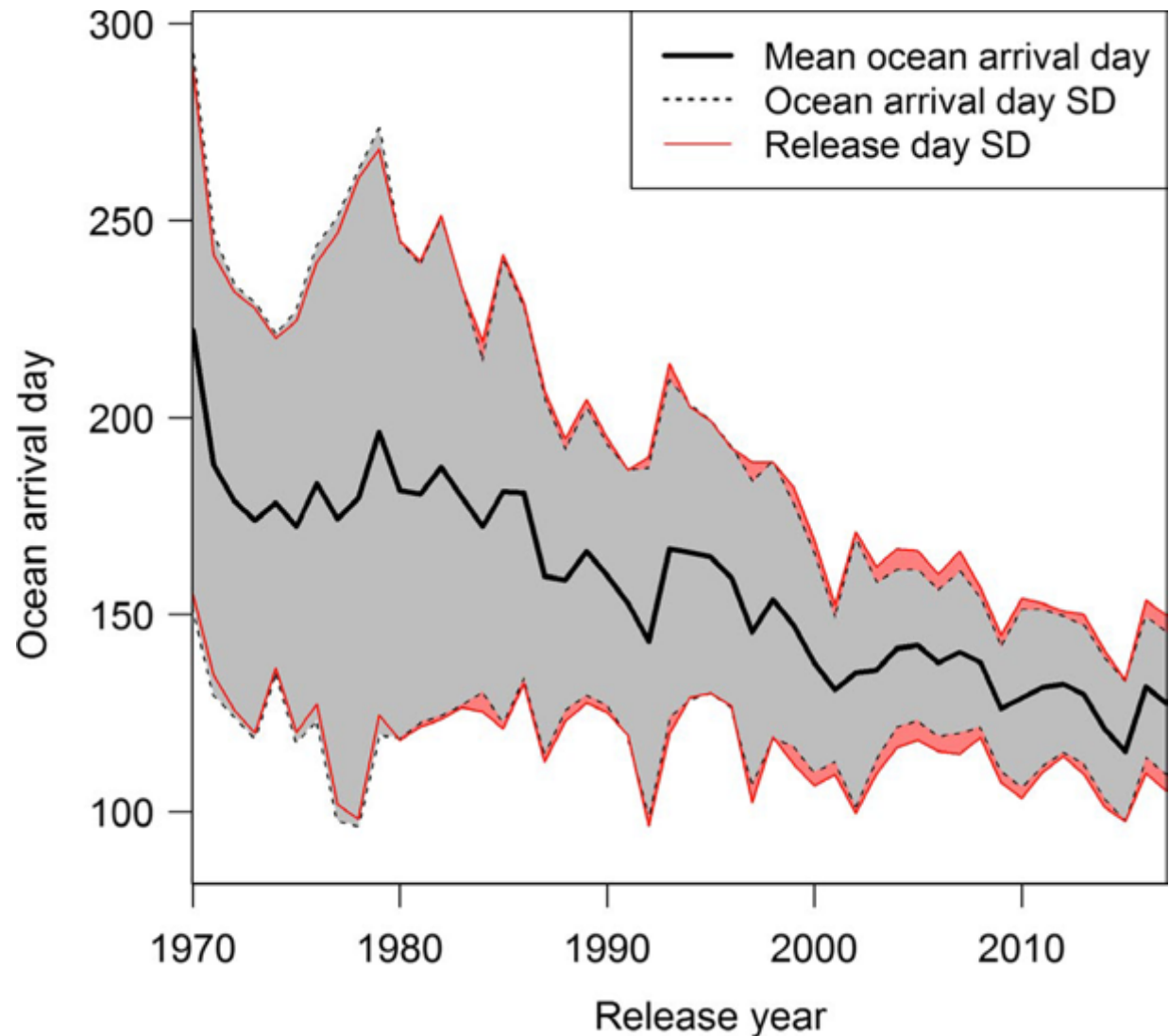
California Chinook hatchery rearing and release practices are likely contributing to these declines – more eggs are going into fewer and fewer baskets (Huber and Carlson 2015; Satterthwaite and Carlson 2015; Willmes et al. 2018)



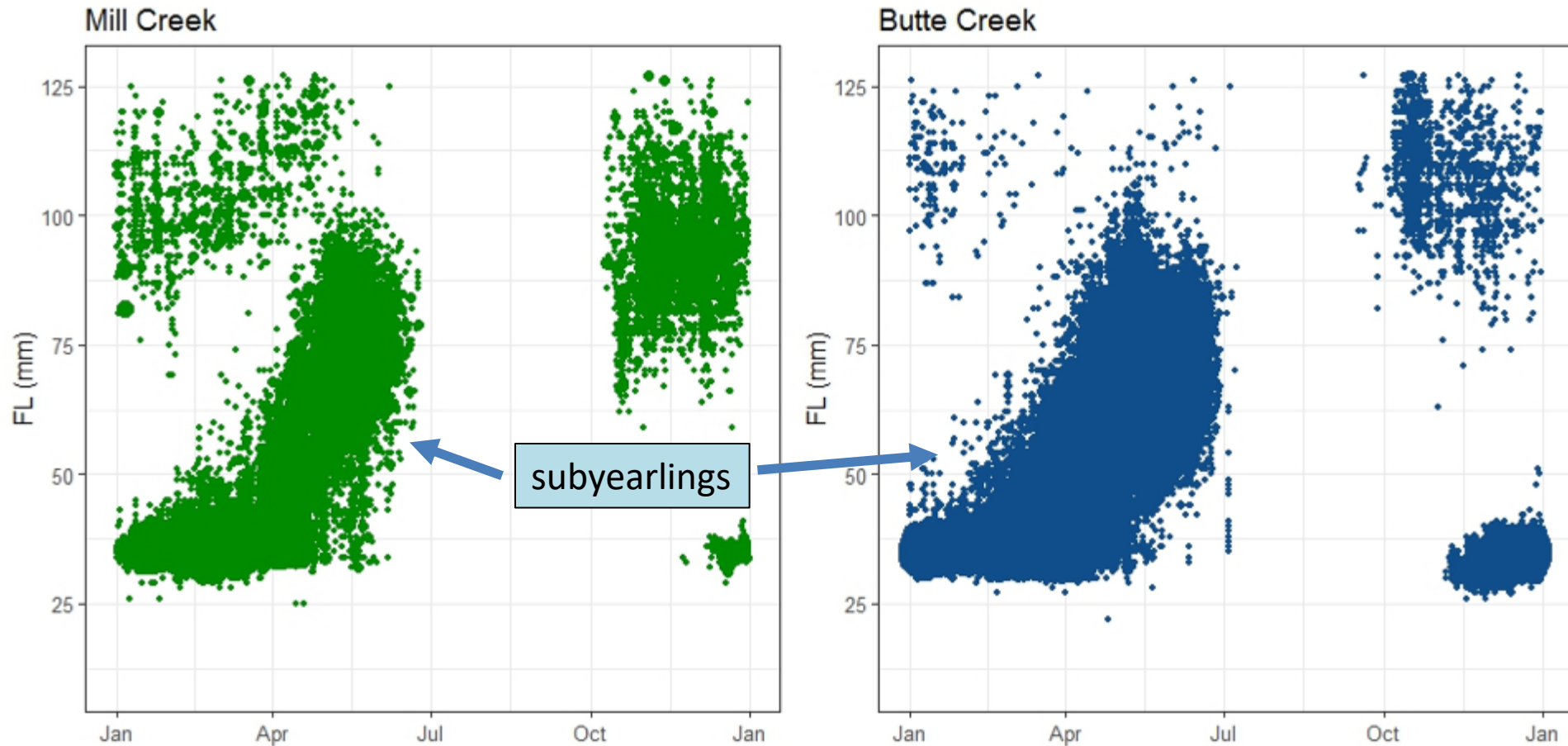
June
May
April

Figure from Huber and Carlson, 2015

Central Valley
hatchery Fall
Chinook salmon
release and ocean
entry timing have
narrowed
dramatically since
the 1970s-80s



wild Central Valley Spring Chinook outmigrant trap data

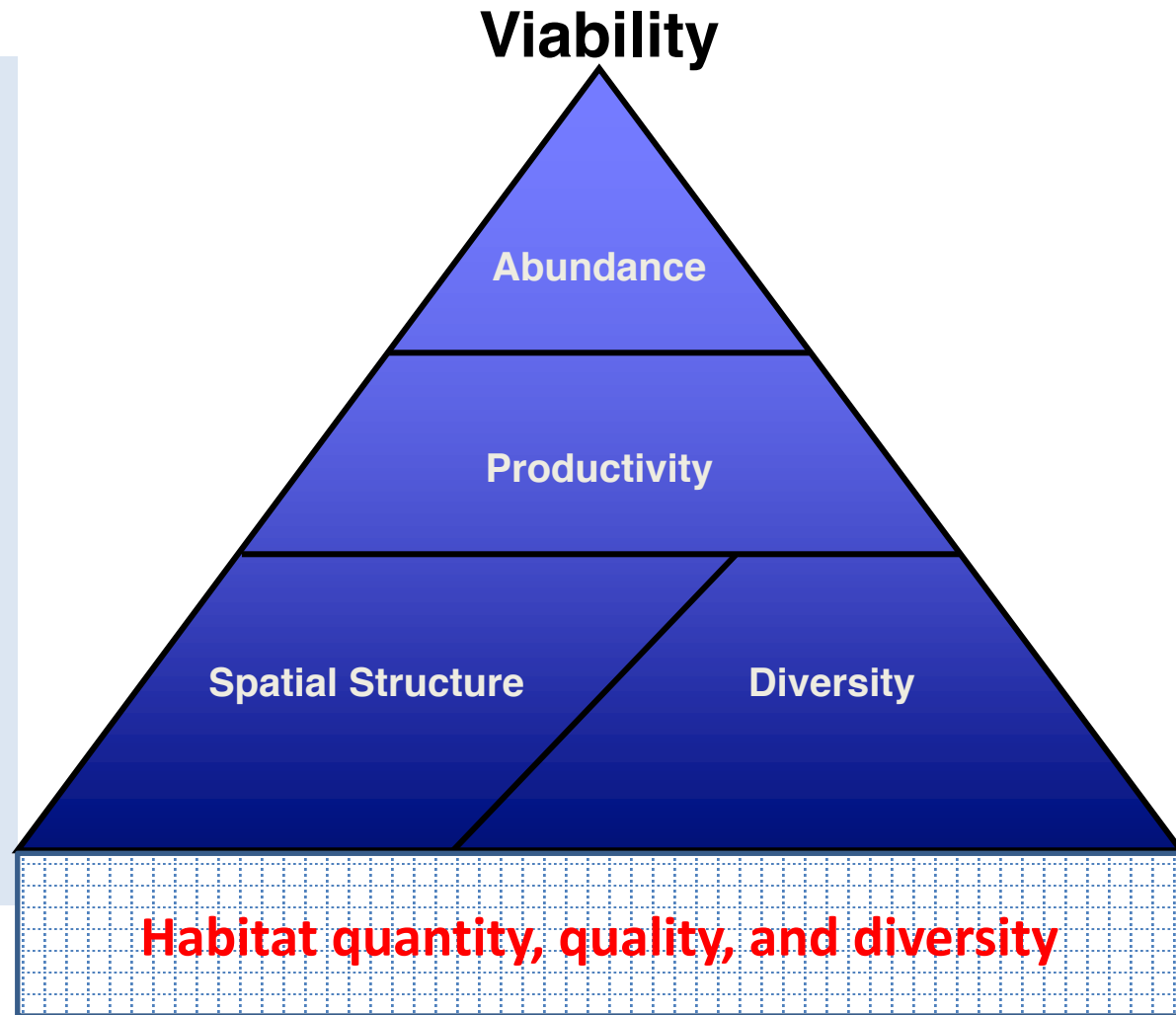


Salmon conservation in an era of a rapidly changing ocean

Promote diversity in salmon
populations by increasing the
complexity of salmon
watersheds

Increase the odds for success
when juveniles go to sea

Enable adaptation by
maintaining or restoring
diversity in genetics, life-
histories, and high-quality
habitat options



McElhany et al. 2000; modified by T. Williams,
NMFS/SWFSC

Climate Insurance requires actions that promote resilience

Protect intact salmon habitat and viable populations

Reduce existing stressors to make space for climate change before it is too late

- This means undoing the 4-H's that have put many salmon populations on the brink **without climate change**

Questions?