Climate Change and Pacific Salmon

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Santa Cruz, CA

Environmental Indicators Workshop

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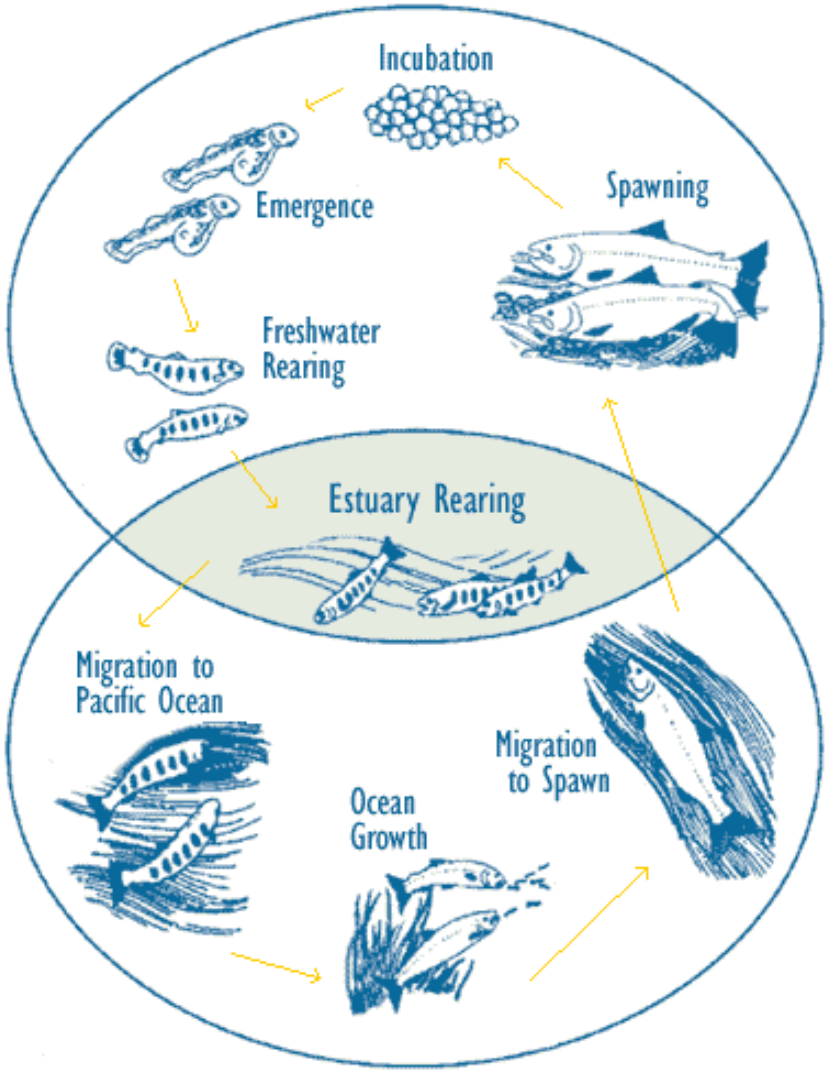
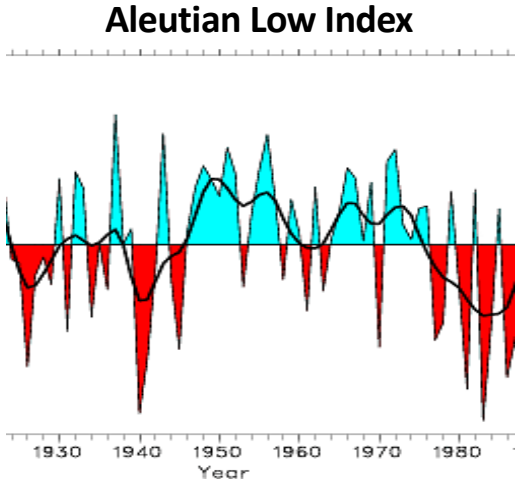


Climate is a key part of salmon habitat

Their complex lifecycle puts them in mostly highly dynamic climate-driven habitats

The Regime Concept in Pacific Salmon Production

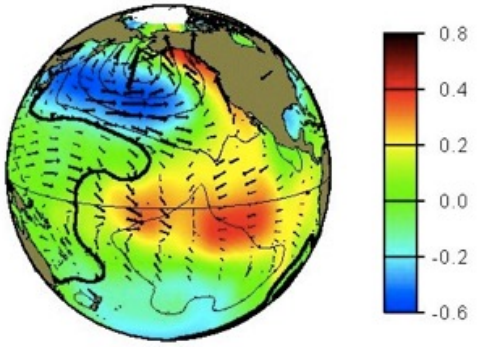
Beamish and Boullion (1991, 1993) report a relationship between the Aleutian Low Pressure system and Pacific salmon production – prolonged periods of stability separated by rapid shifts



Catch figure from npafc.org

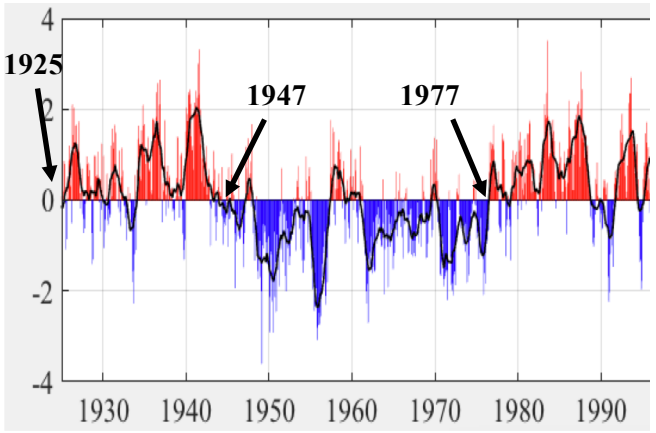
The Pacific Decadal Oscillation and Salmon Production Regimes

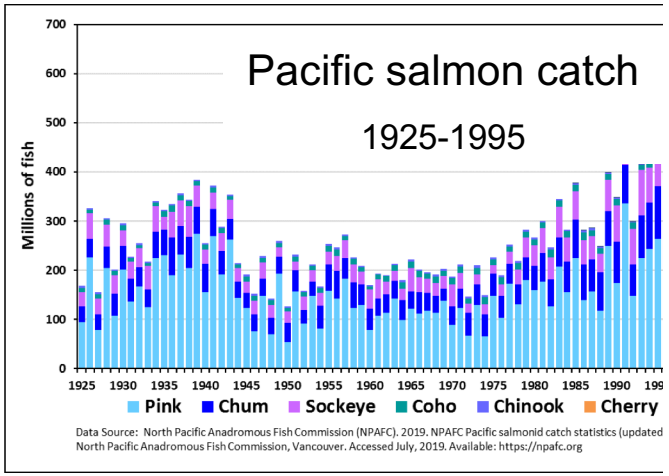
Pacific Decadal Oscillation (PDO)



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

PDO Index: 1925-1995





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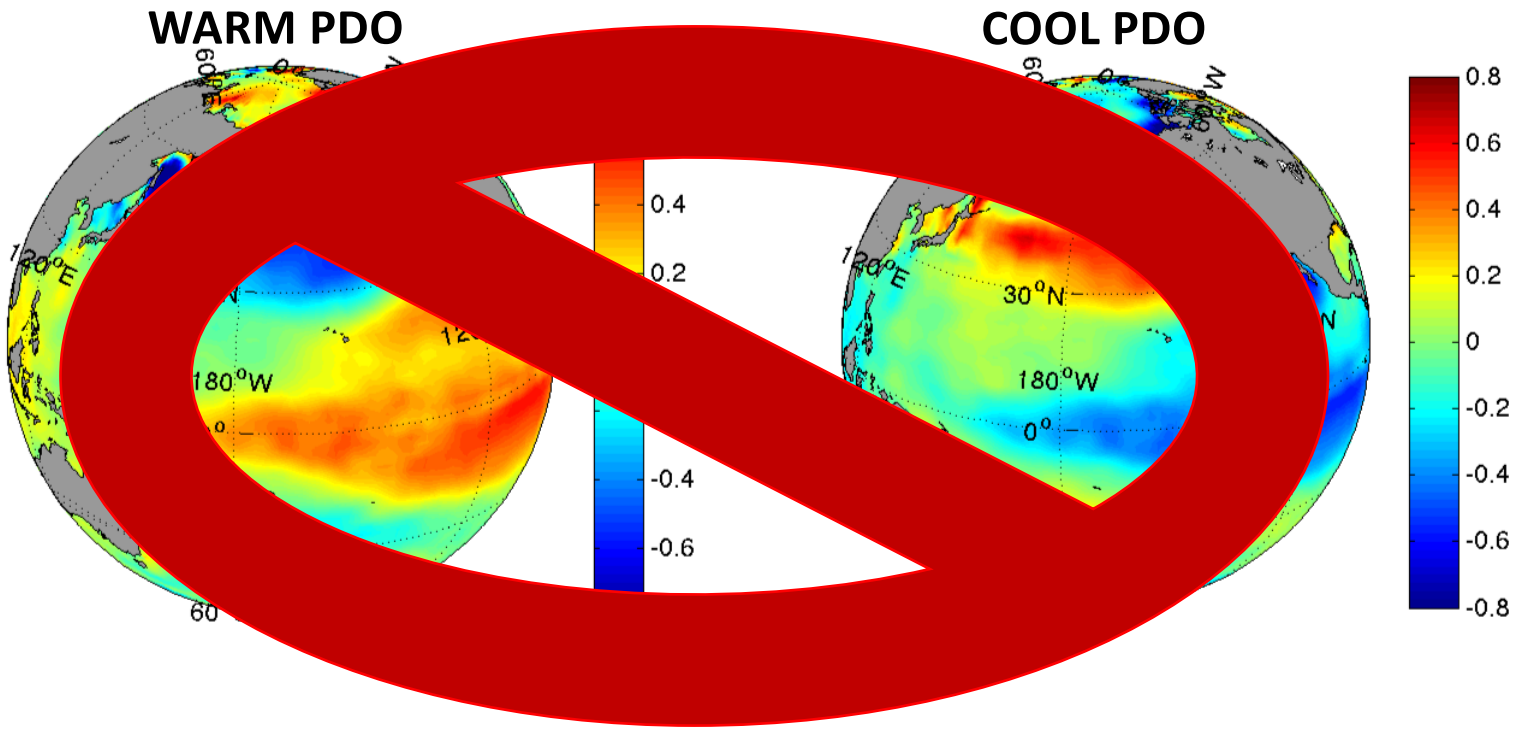
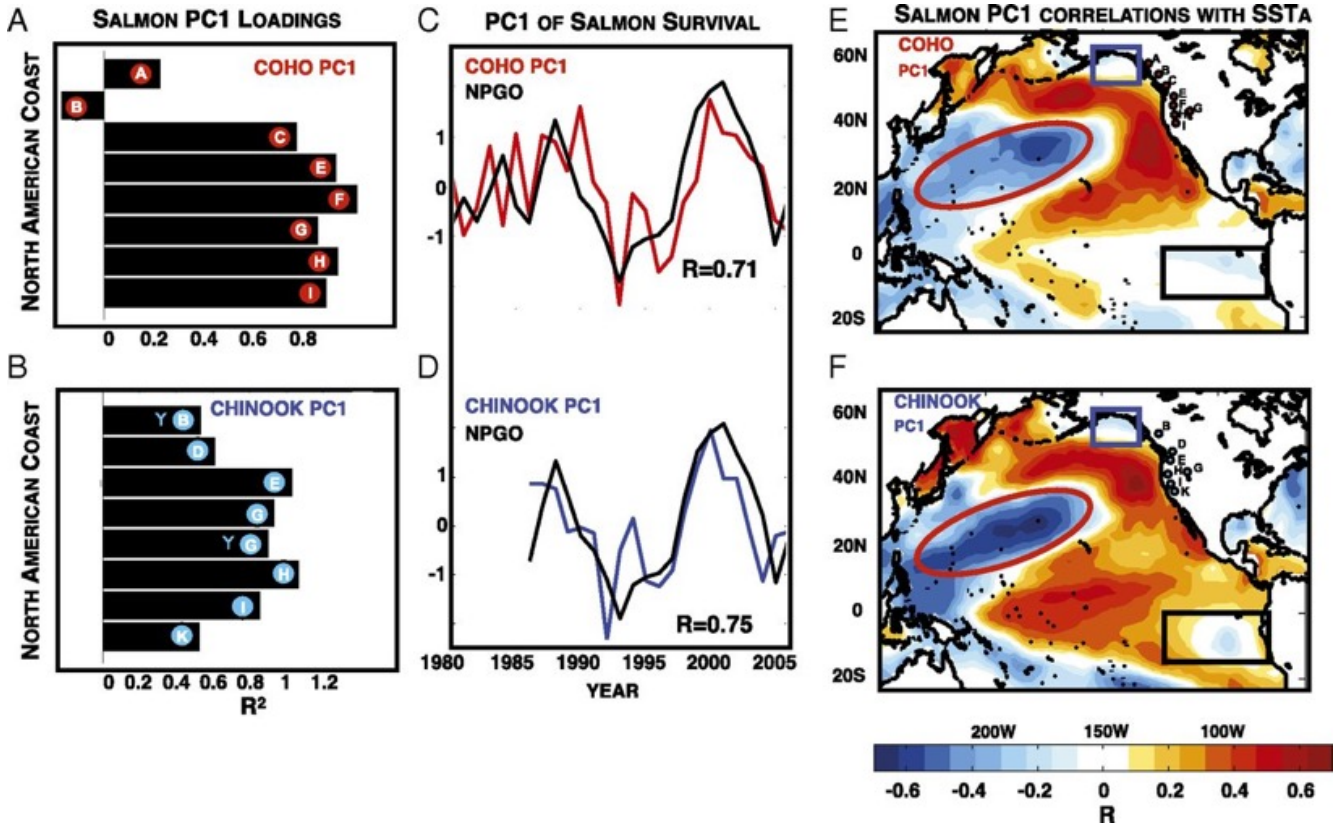
Two regimes in the North Pacific?

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



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

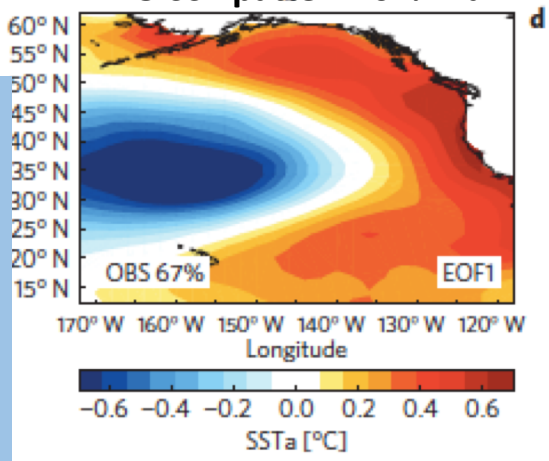


D. Patrick Kilduff et al. PNAS 2015;112:35:10962-10966

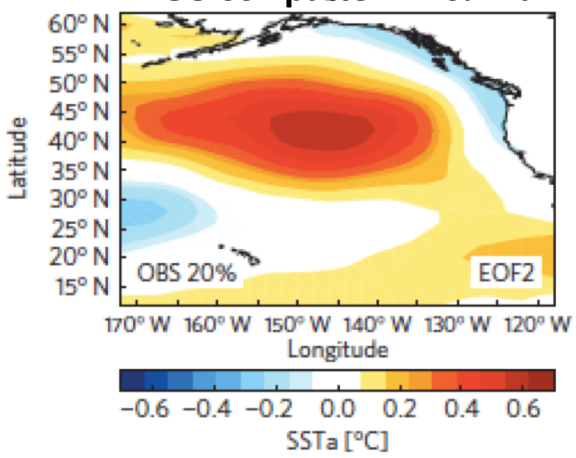
The two leading patterns of Northeast Pacific SST variations account for most of the year-to-year variability

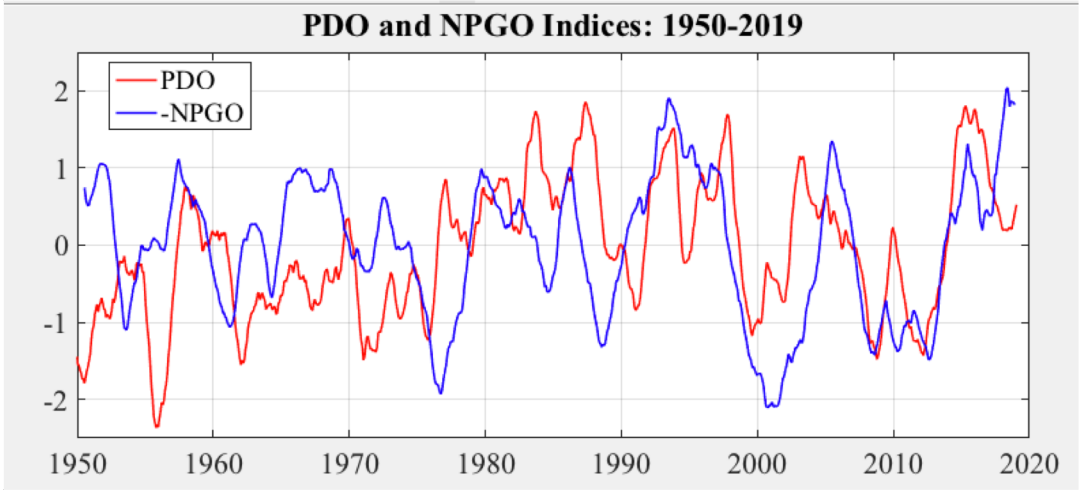
These variations aren't limited to 20-30 year regimes

PDO SST pattern: 67% var.



NPGO SST pattern: 20% var.

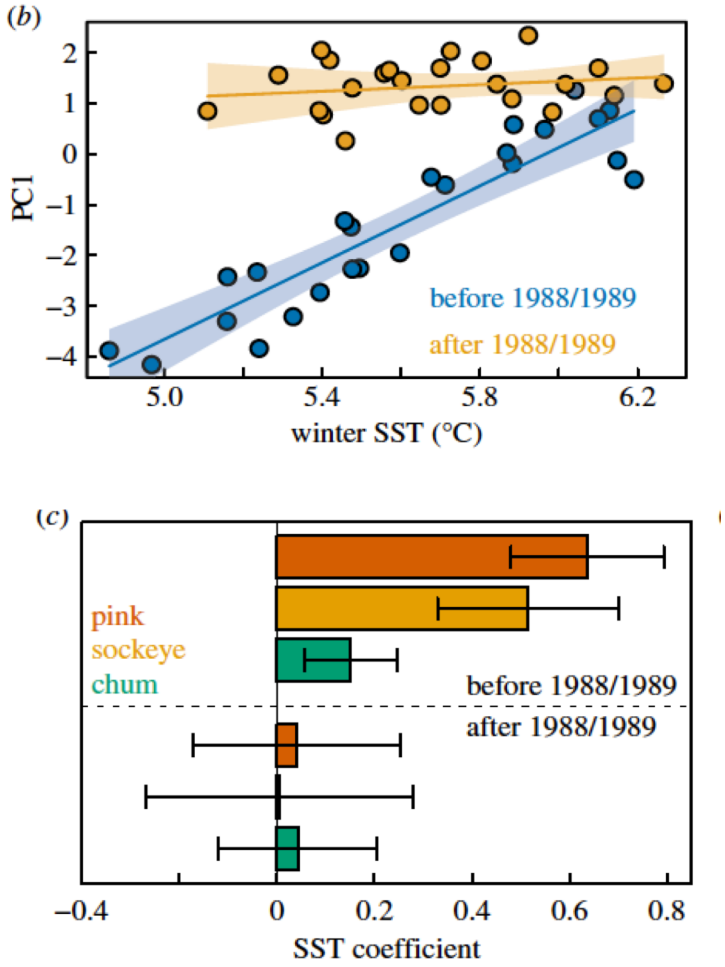




Non-stationarity in Alaska climate-salmon relationships

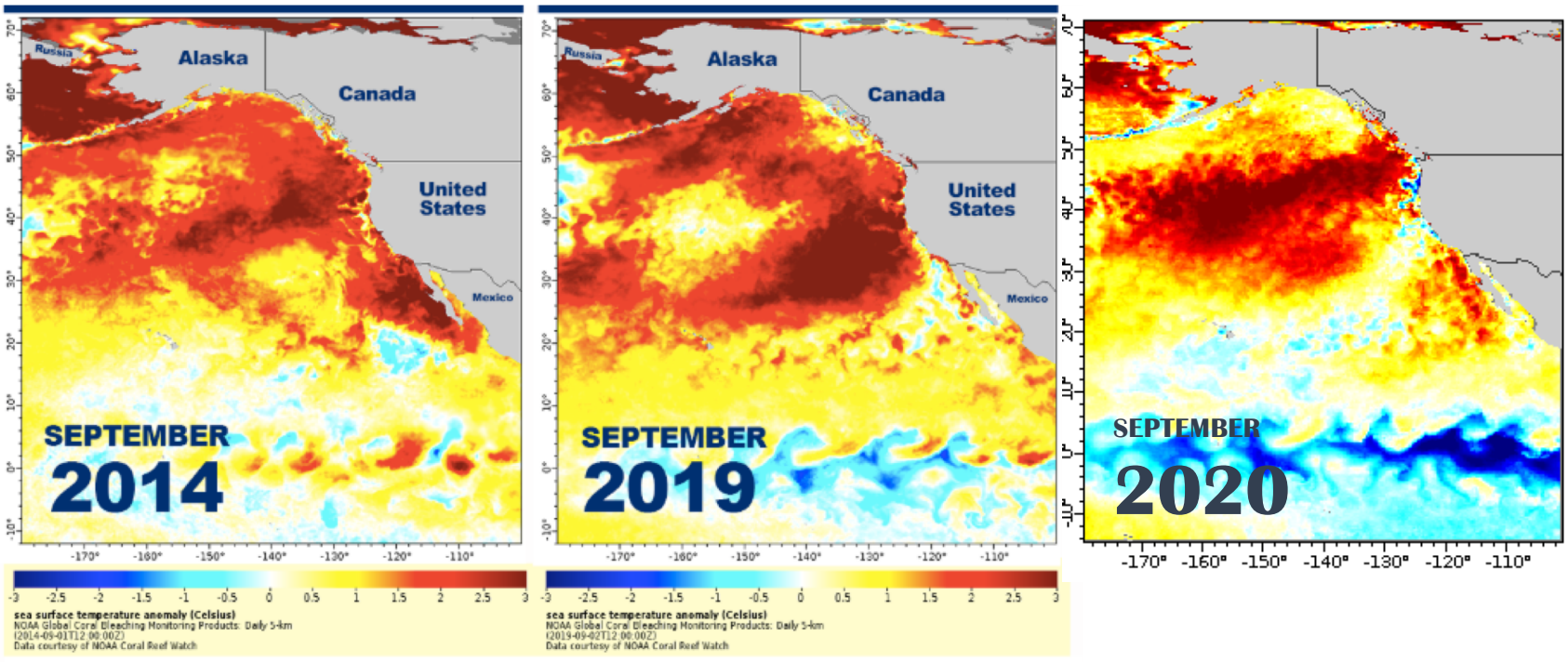
(Litzow et al. 2018, Proc. R. Soc. B.)

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



Frequent Marine Heatwaves from 2014-2020

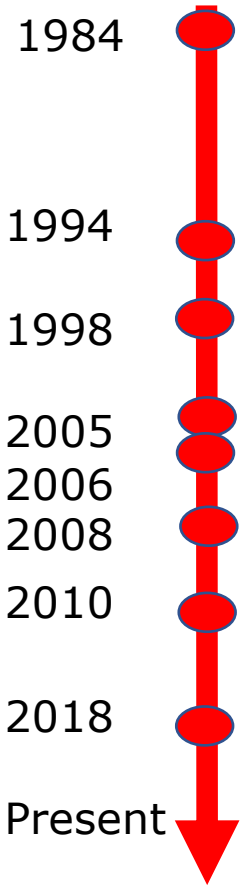
Extreme and persistent warm periods have affected the Bering and Chukchi Seas, Gulf of Alaska, and California Current, with widespread impacts on marine life and fisheries.



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

US Federal Fishery Disaster Timeline

from https://www.fisheries.noaa.gov/national/funding-and-financial-services/fishery-disaster-determinations



Severely restricted or closed salmon fisheries

Increasing frequency of:

- California Drought
- Washington Flooding
- Coastwide warm and poor ocean conditions

The Changing Climate and Context of West Coast Salmon

Climate Extremes: A **warming climate** and an era of **frequent drought**; an increased frequency of **ocean extremes**

Evolving salmon production system: **Loss and degradation of natural FW+estuary habitats**; **increasing hatchery contributions** and reliance on releases of large smolts; evidence for increased synchrony among populations

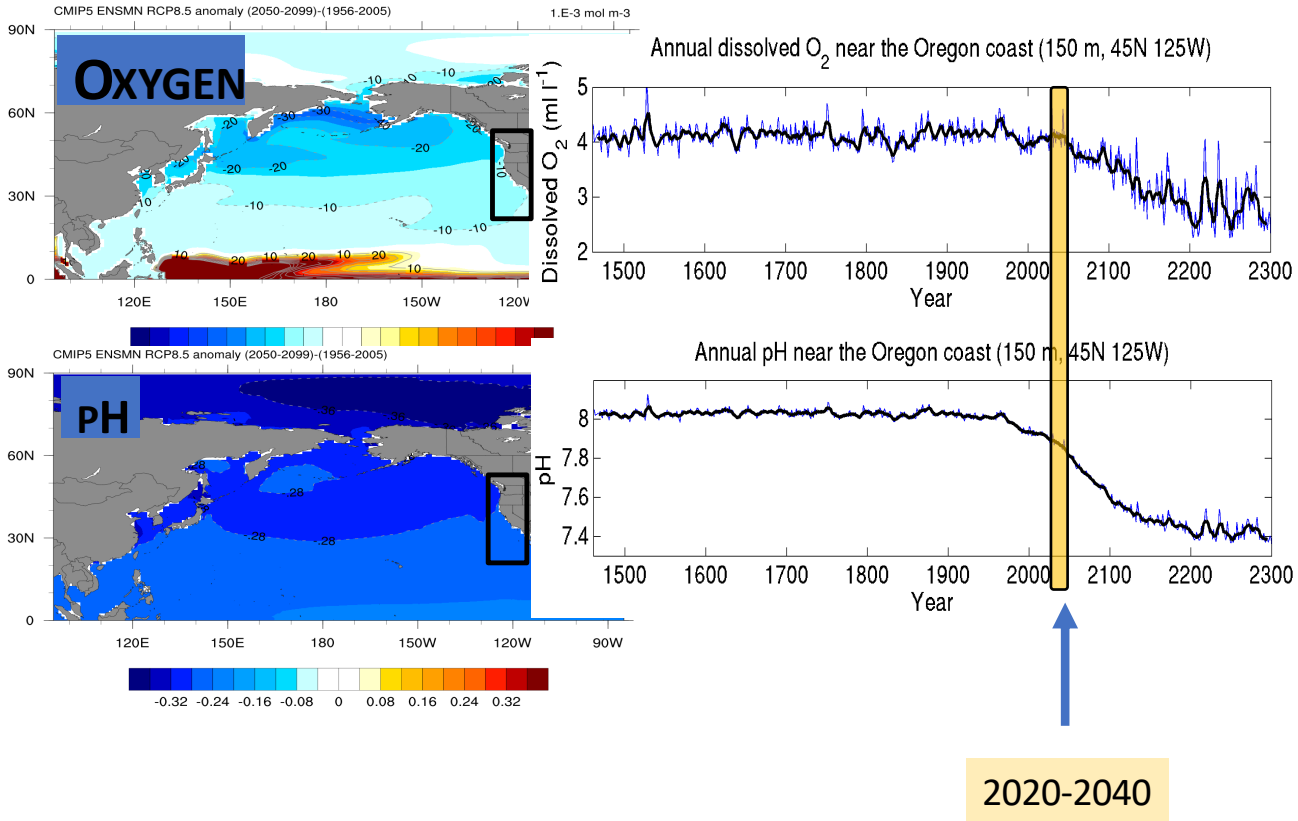
Evolving marine food webs: increases in top predators (whales, sea lions, harbor seals, and some sea birds); boom-bust cycles in key forage fish (California sardines, northern anchovy)

Era of super-abundant pink salmon: increasing evidence for competition between abundant pinks and N. American sockeye salmon, especially bad for "southern" sockeye in warm ocean years (see Connors et al. 2020, CJFAS)

A warmer and wetter future for most salmon watersheds

- More warming at the highest latitudes
- Largest precipitation increases at higher latitudes
- Ocean warming, acidification, and deoxygenation of the subarctic North Pacific Ocean

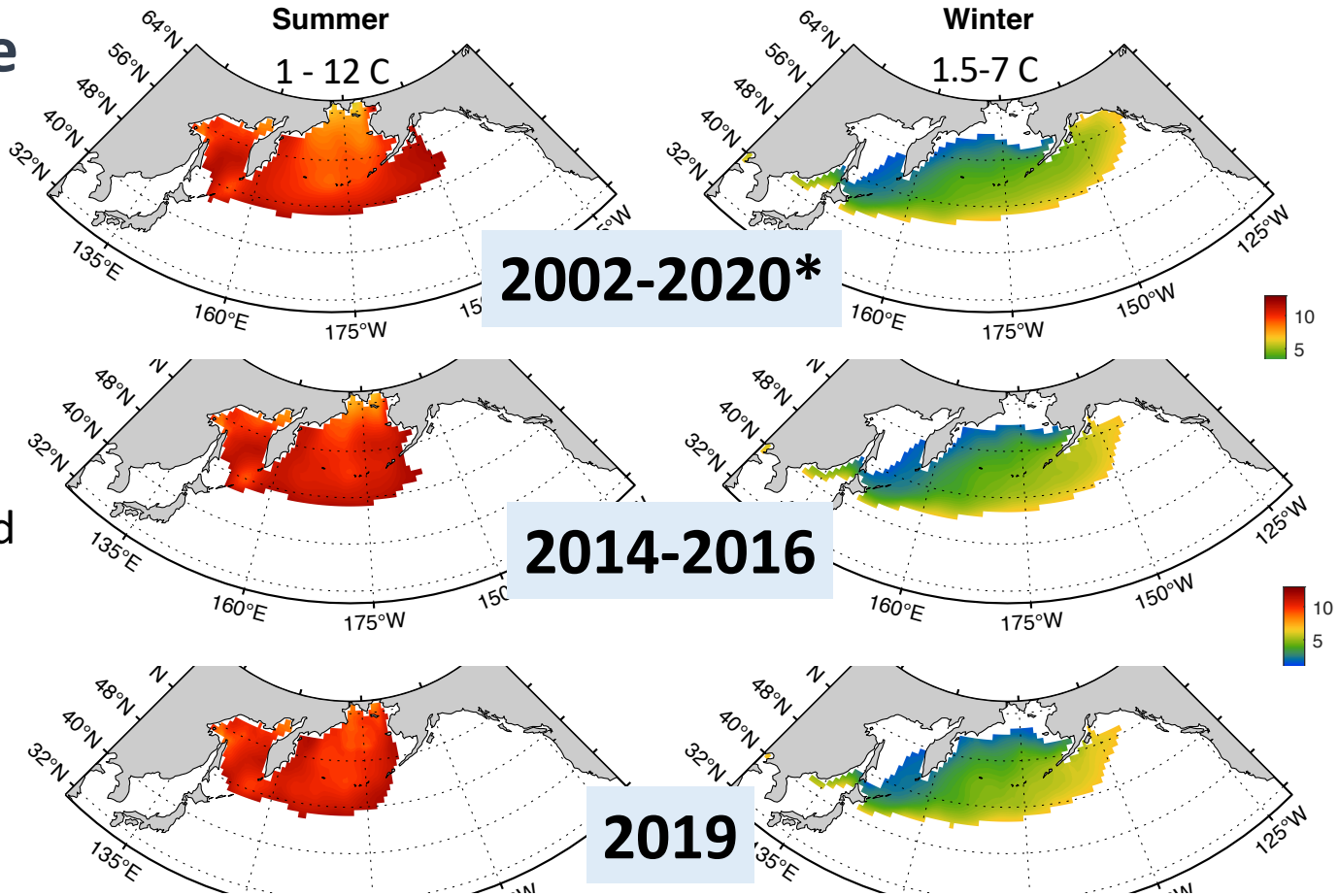
CLIMATE PROJECTIONS: OXYGEN, PH



Shrinking sockeye salmon thermal habitat

- 10-20% area reductions observed in recent MHW years
- Habitat area projected to decline ~38% in winter, and 45% in summer, under A1B emissions by late 21st century

(Welch et al. 1998, CJFAS; Aziz et al., 2011, CJFAS)



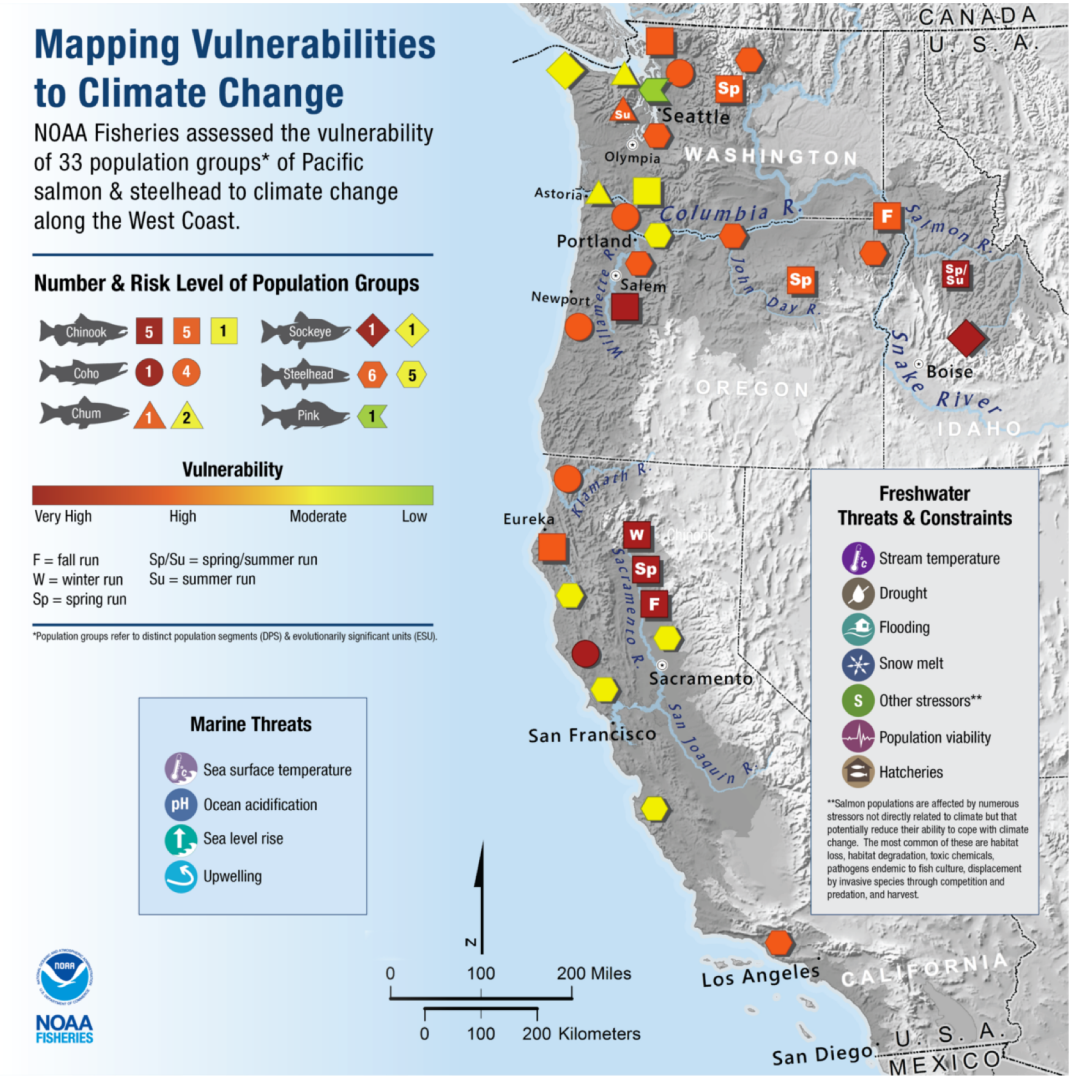
Lindley et al, NPAFC/IYS poster 2021

West Coast Climate Change Vulnerability Assessment for salmon

(Crozier et al. 2019: PLoS ONE)

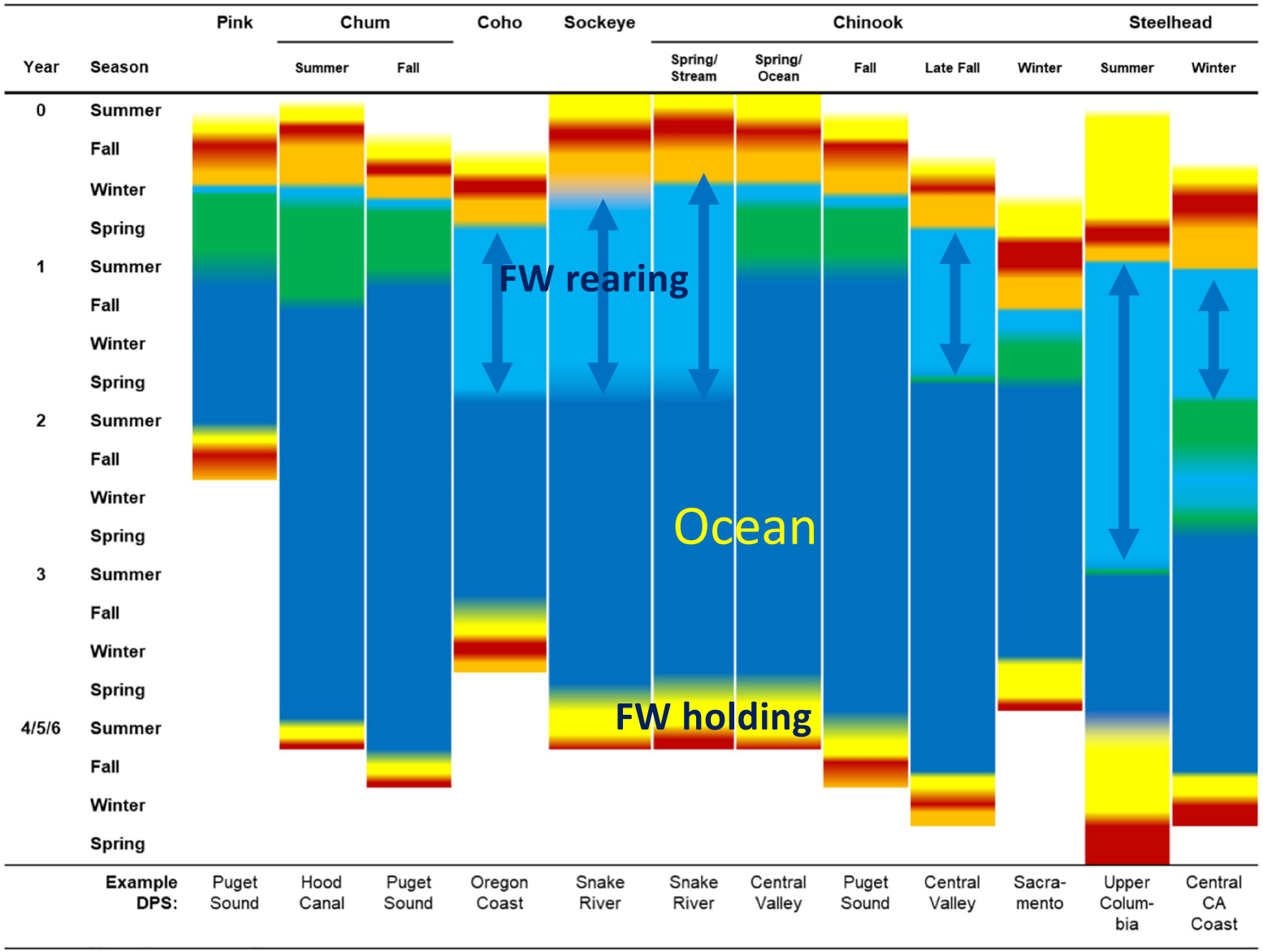
warmer, bigger floods, lower summer low-flows, less snowpack, ocean warming and acidification

- adding climate stress to already stressed ESA-listed salmon/steelhead populations
- Recovery and adaptation or extirpation?



Salmon life histories for example ecotypes

(from Crozier et al. 2019: PLoS ONE)



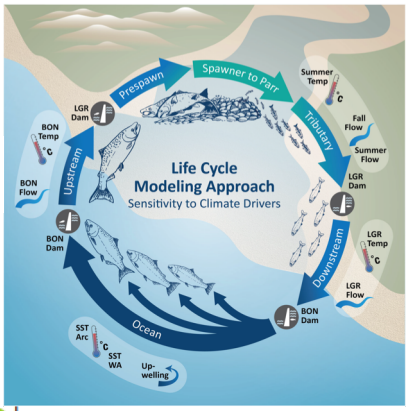
communications biology (Nature, 2021)

ARTICLE

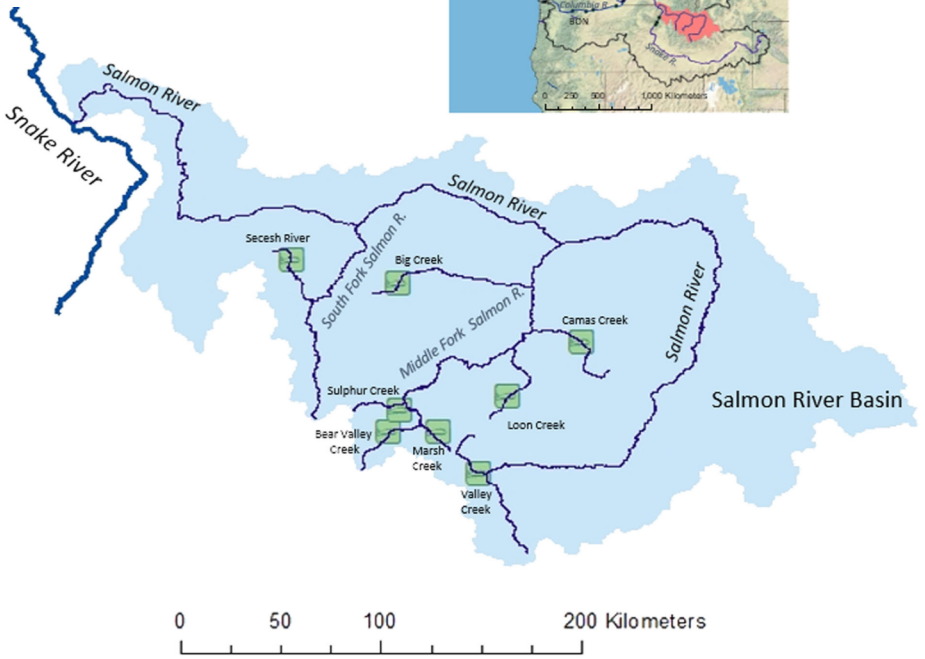
https://doi.org/10.1038/s42003-021-01734-w OPEN

Climate change threatens Chinook salmon throughout their life cycle

Lisa G. Crozier[1✉], Brian J. Burke[1], Brandon E. Chasco[1], Daniel L. Widener[2] & Richard W. Zabel[1]



- Climate change impacts were found to be most dramatic in the marine stage – with rising SST especially important
  - this study focused on populations using high-elevation, high-quality spawning and rearing habitat in Idaho's Salmon River
- Freshwater or marine limiting factors need to be addressed for these 8 populations to persist in a warming ocean



Summary of Ocean Changes

We are entering an era of rapid ocean change:

- High frequency of extreme warm events in the NE Pacific since the 1980s caused widespread ecosystem and fishery impacts
- Climate models predict ocean extremes will become more frequent and intense as warming trends accelerate
- 2014-16, 2019, 2020 marine heatwaves were not predicted in advance!

Ecosystem responses to future climate change:

- In the next decade or two, slower trends in the ocean may still be hard to detect in the presence of large year-to-year variations
- Chronic, climate-sensitive fishery challenges likely to become more frequent and intense (*West Coast Chinook salmon)
- A “no-analog future”? As we move deeper into ocean states without historical analogs, expect novel and surprising ***ecosystem impacts*** and fishery management challenges

Climate Insurance for salmon requires actions that promote resilience

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**

Protect intact salmon habitat and resilient populations