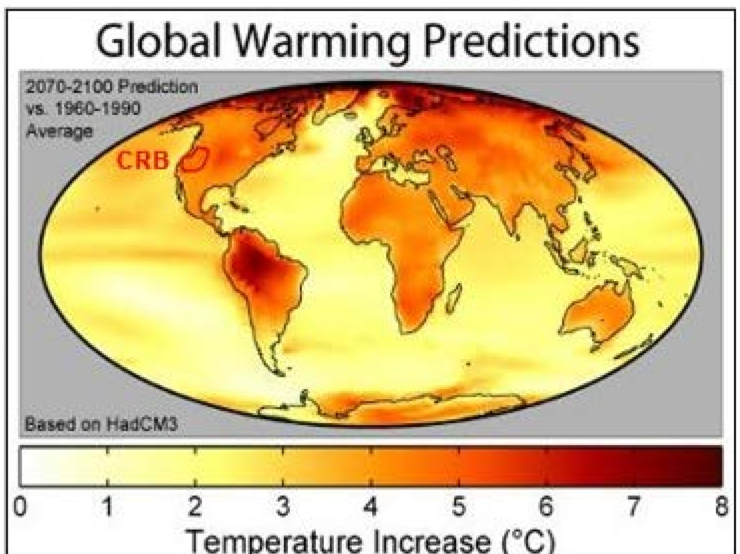
Climate change and Columbia River salmon



Dr. Laurie Weitkamp

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Newport, Oregon

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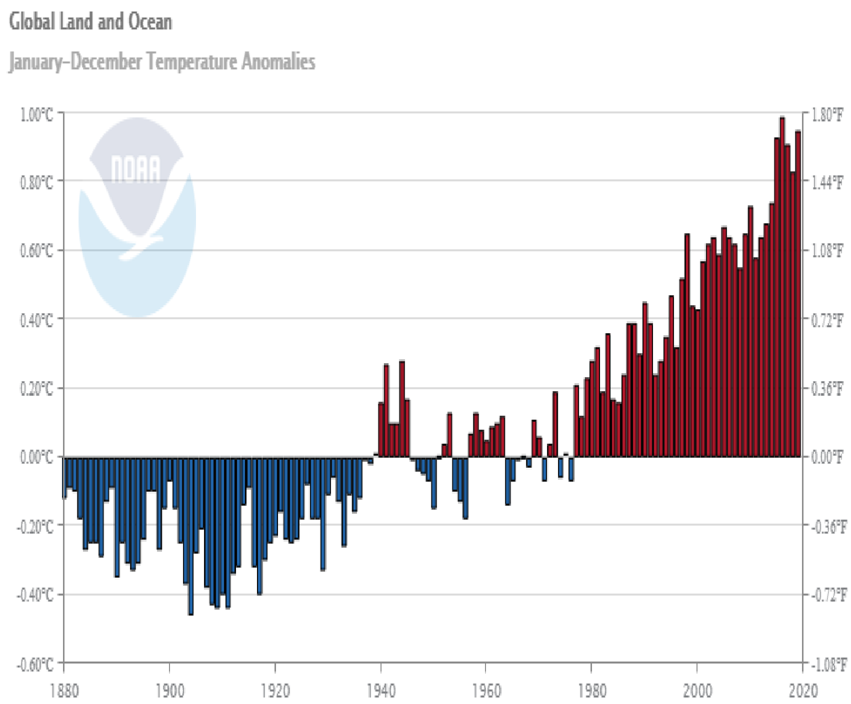
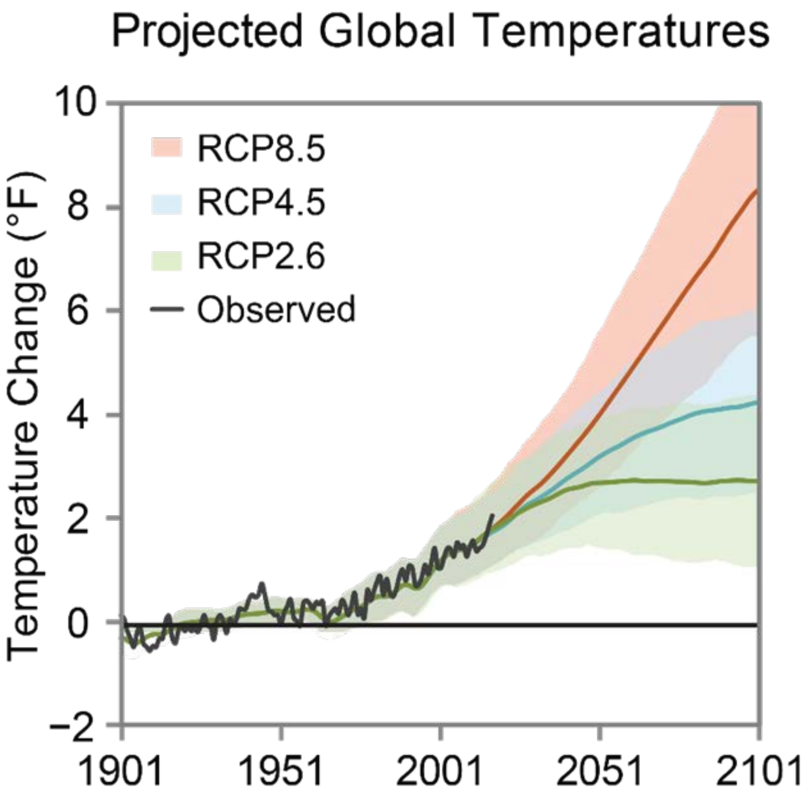
Global temperatures are and will continue to increase

Global land and ocean temperature trends
1880-2019

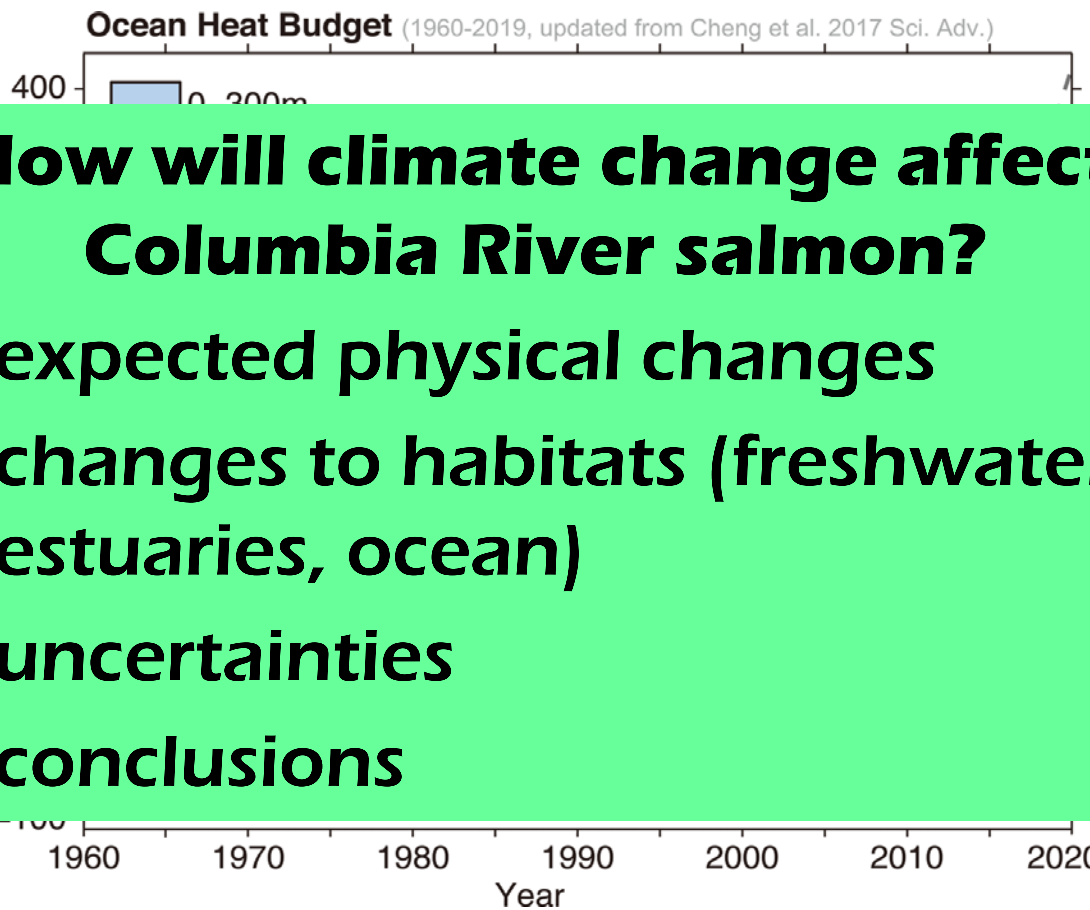


http://www.ncdc.noaa.gov/cag/



Wuebbles et al. 2017. 4th Natl. Climate Assessment, science2017.globalchange.gov

The world's oceans have absorbed 90% of excess heat, warming at all depths



How will climate change affect Columbia River salmon?

- *expected physical changes*
- *changes to habitats (freshwater, estuaries, ocean)*
- *uncertainties*
- *conclusions*

Cheng et al. 2020, Adv. Atmosph Sci 37:137-142

Direct effects of temperature on salmon

Salmon are 'cold blooded', therefore water temperature regulates their metabolic rate

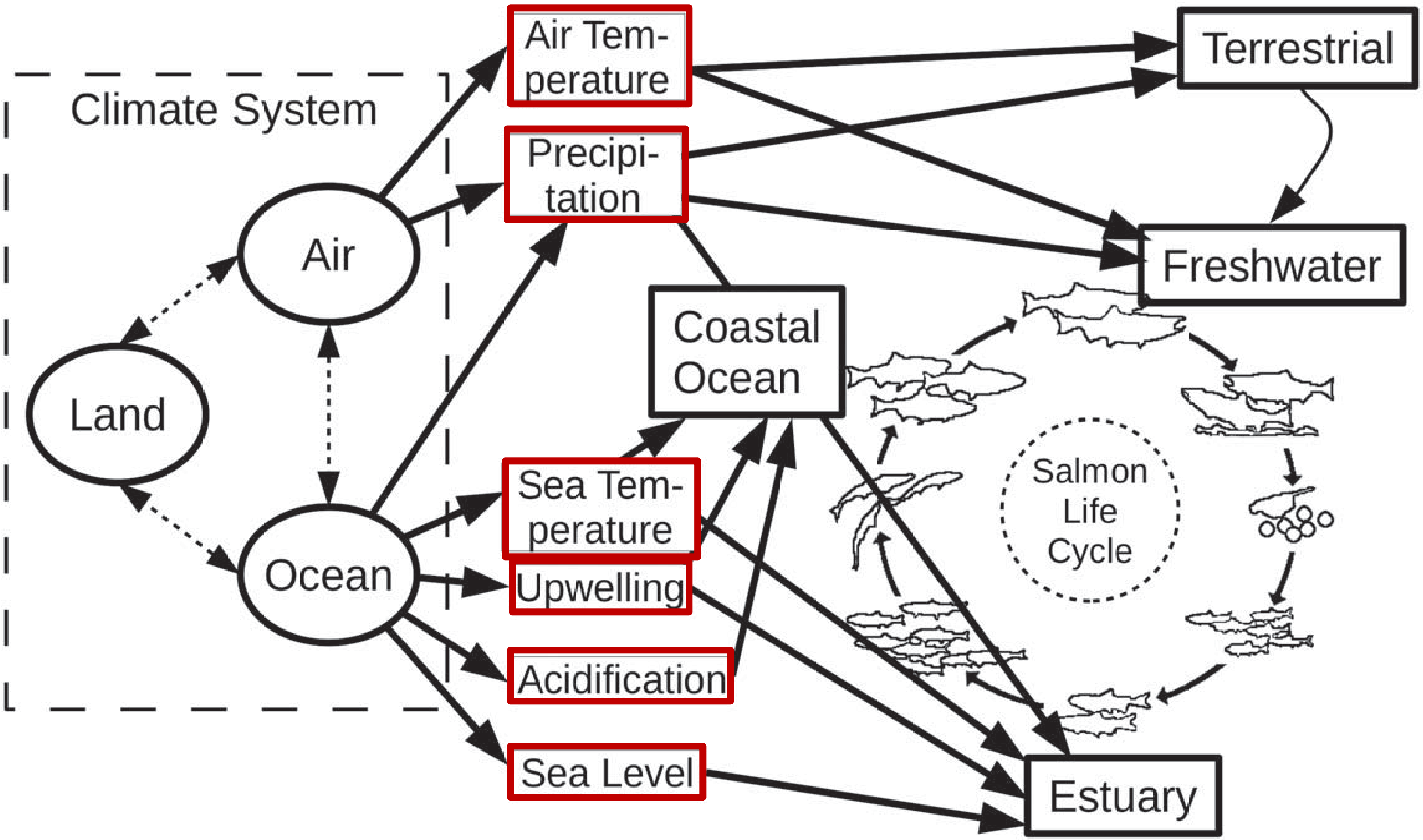
Increasing water temperatures will generally increase:

- metabolic rate
- physiological stress
- Egg incubation rates

And therefore decrease:

- disease resistance
- growth
- swim speed

Climate influences all parts of the salmon life cycle



Wainwright and Weitkamp 2013

In the Pacific Northwest

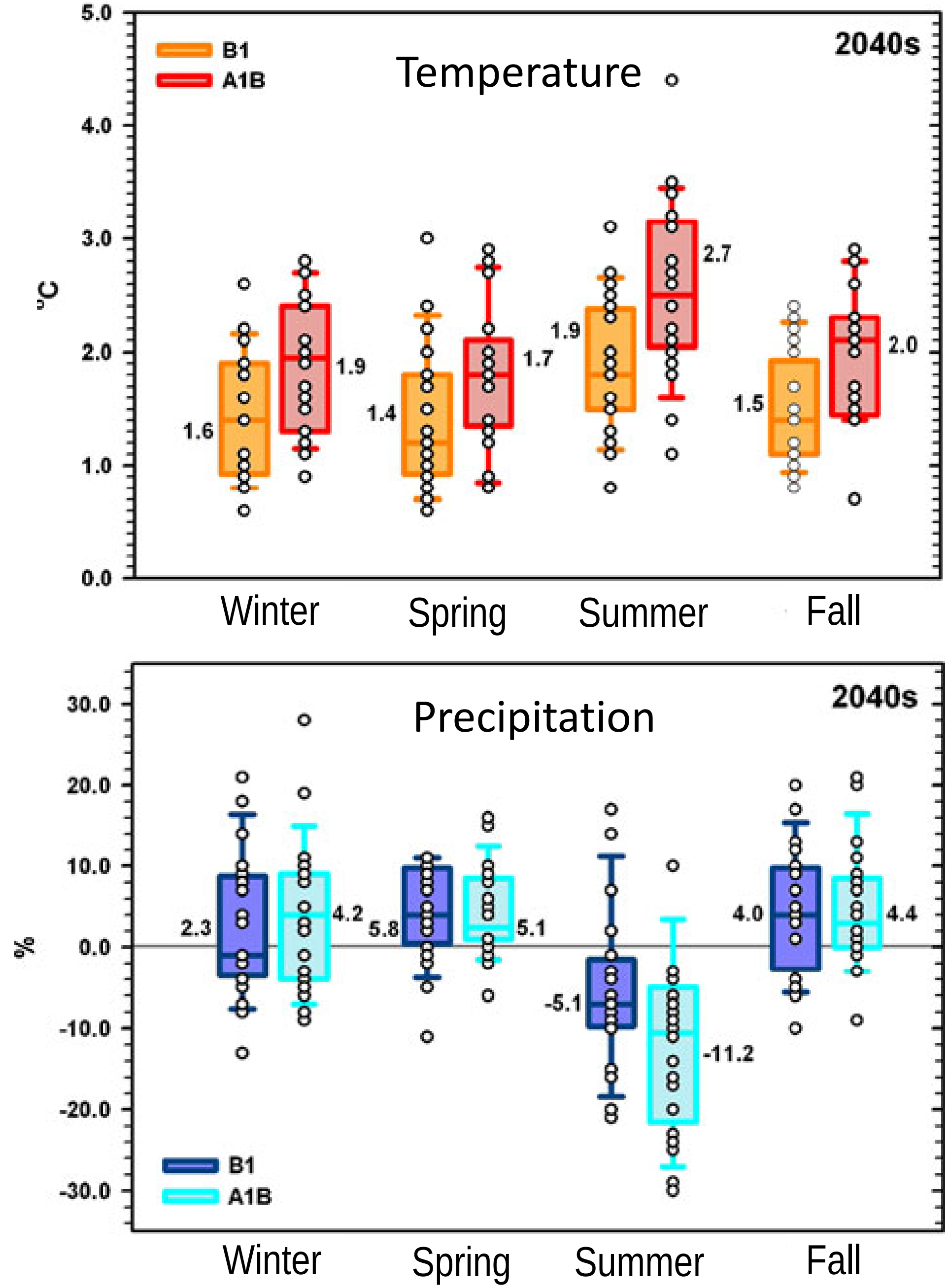
By 2040 expect:

Air and stream temps to increase by 2°C.

Drier summers and wetter winters.

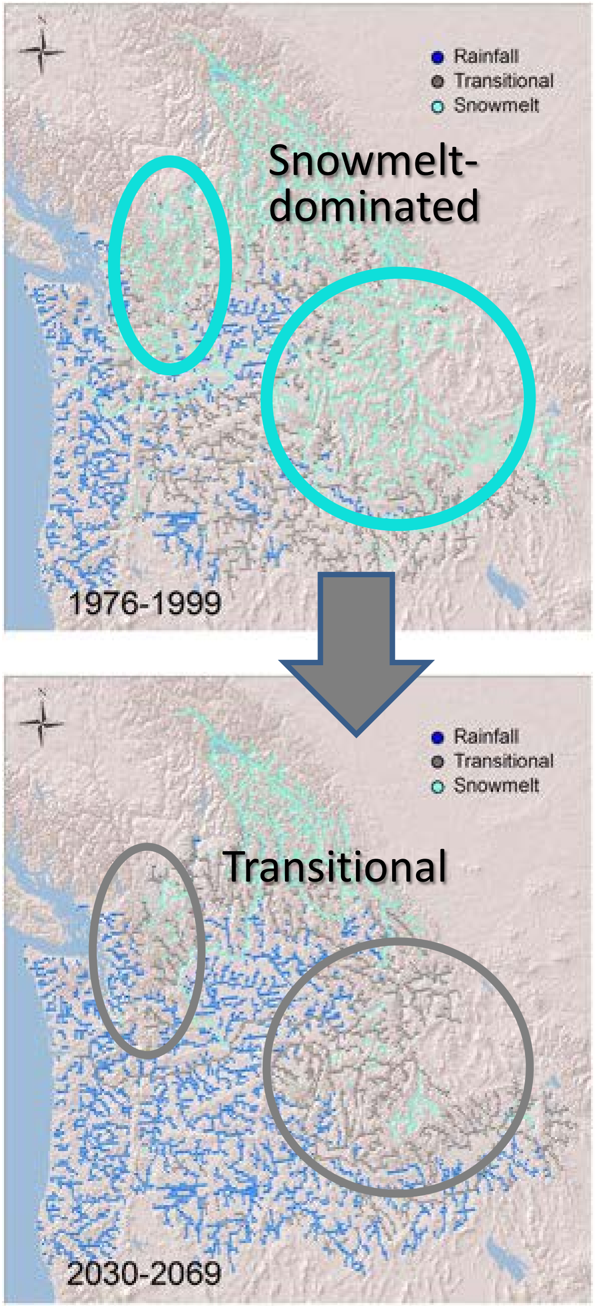
Ocean temps will rise by 1.2 to 2°C.

Mote and Salathé 2010



Indirect effects of temperature: Freshwater

More basins become rain- rather than snow -dominated.



Beechie et al. 2013, Schnorbus et al. 2014

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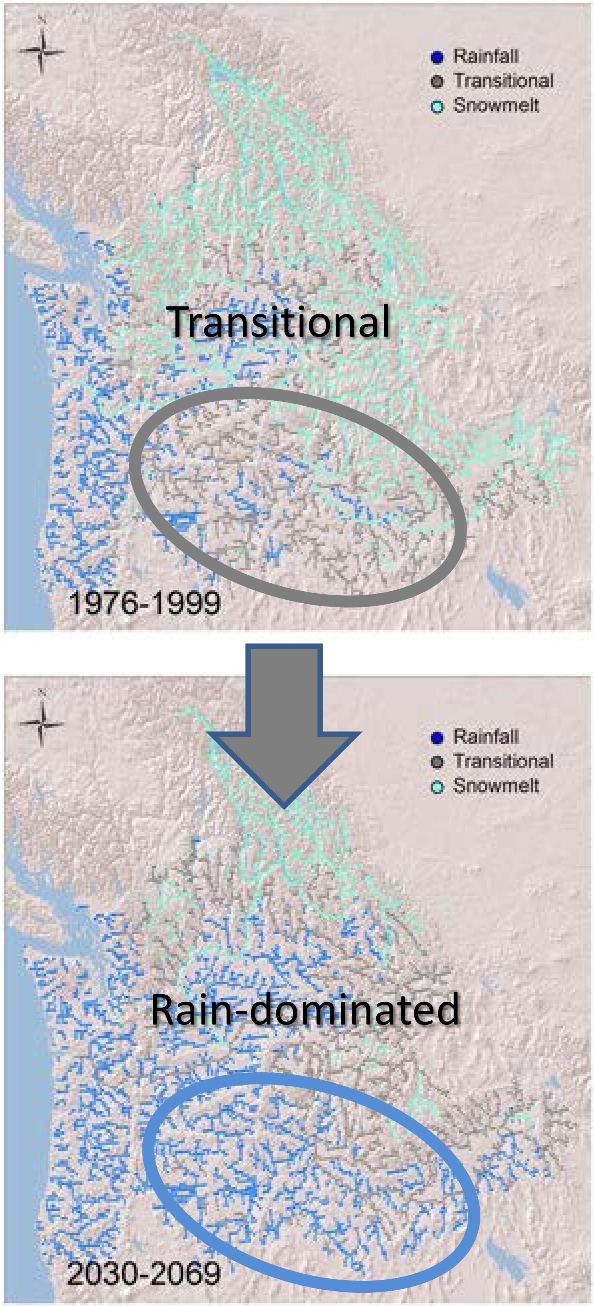


Beechie et al. 2013, Schnorbus et al. 2014

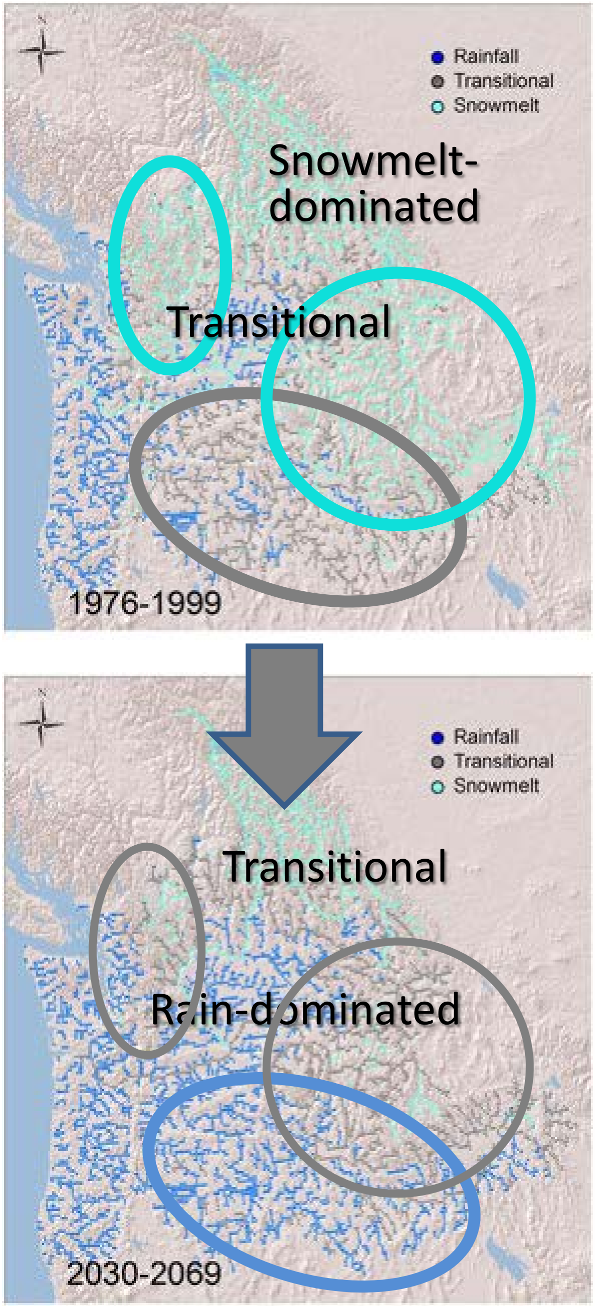
Indirect effects of temperature: Freshwater

More basins become rain- rather than snow -dominated.

This will result in:

- ↑ summer stream temperatures and ↓summer flows at low-middle elevations (less snowpack)

Beechie et al. 2013, Schnorbus et al. 2014



Indirect effects of temperature: Freshwater

More basins become rain- rather than snow -dominated.

This will result in:

- ↑ summer stream temperatures and ↓summer flows at low-middle elevations (less snowpack)
- ↑ intense high flows at all elevations (from more rain + intense storms)
- ↑ summer flows at high elevations (greater snowpack)

Warmer winter temps
shorter incubation, higher fry growth

Warmer summer temps
Increased thermal stress

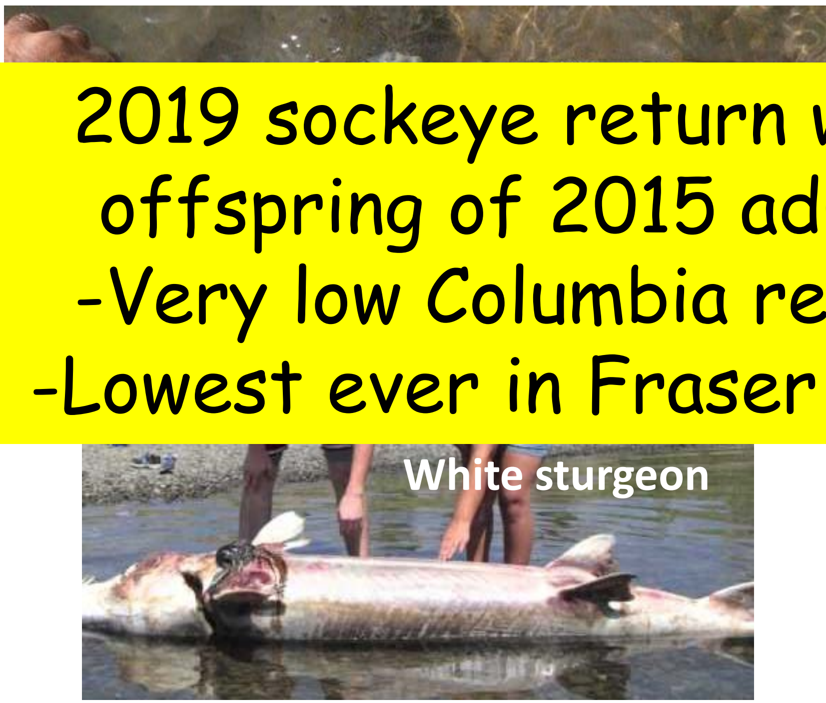
Higher fall/winter flows
Increased egg scour, juvenile displacement, access to spawning habitat

Flow alteration
reduced summer rearing, migration timing mismatch

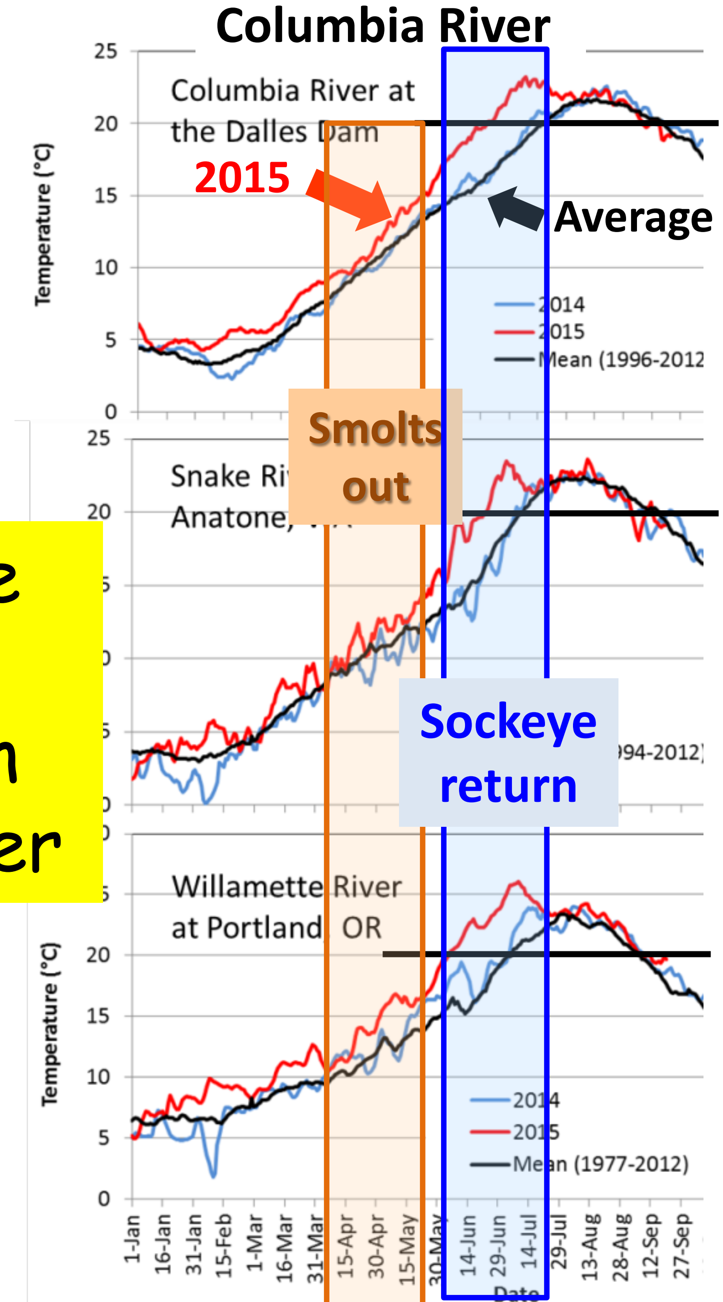
Beechie et al. 2013, Schnorbus et al. 2014

Summer 2015

Low river flow+ hot spring = high river temperatures & fish kills



2019 sockeye return were offspring of 2015 adults
-Very low Columbia return
-Lowest ever in Fraser River



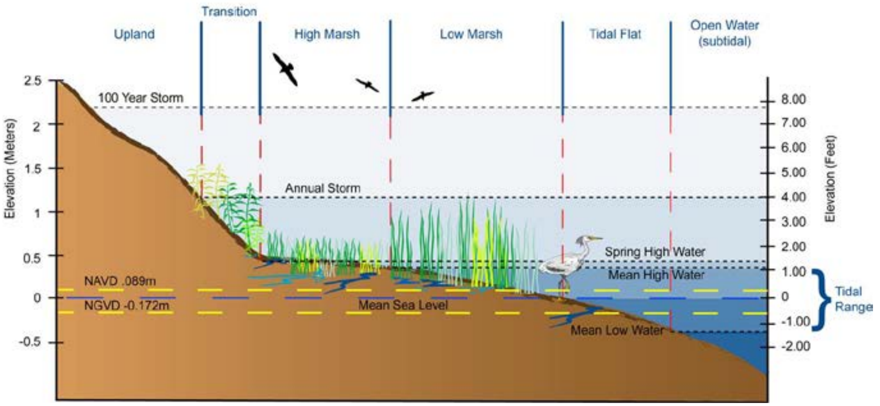
Climate impacts to estuaries

Impacts

- Higher sea level

  Loss of tidal wetlands

  Increased salinity intrusion



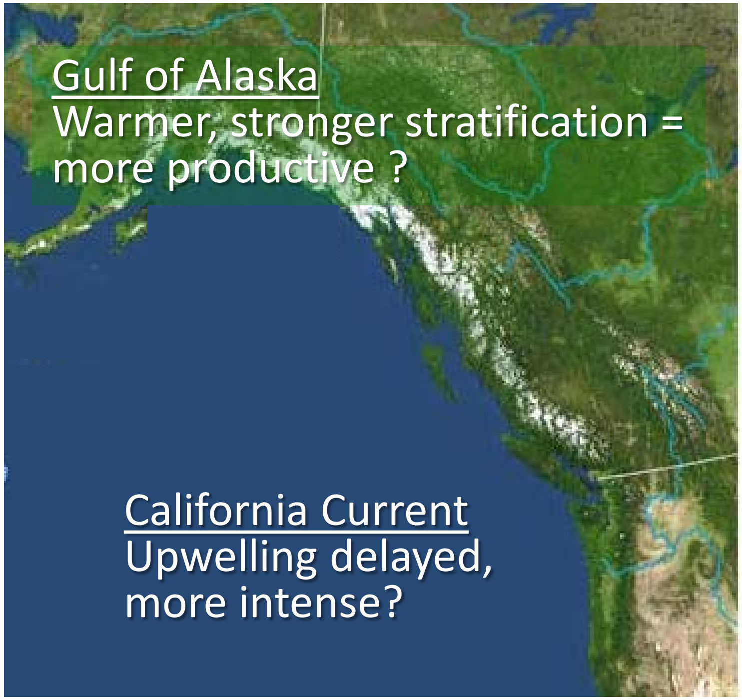
- Higher temperatures

  Stress, disease, predation

- Ecosystem restructuring
  - Changes in species composition

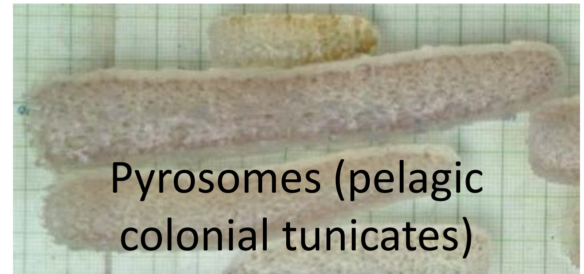
Climate impacts to oceans

- Rising temperature
  Physiological stress, range shifts
- Regional impacts to productivity
  -recent warming increasing Bering Sea productivity
  -Big uncertainty about future of upwelling in California current
  - No impact or delayed
- Acidification
  Changes in food supply (impact to salmon prey)
- Combined effects
  Change in ecosystem structure
  Not clear how well it will support salmon

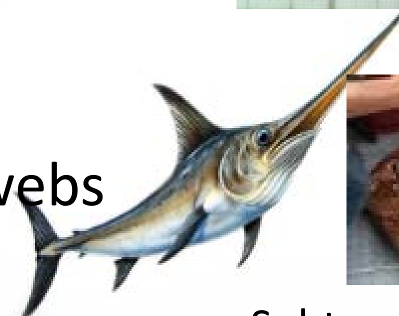


Hot water across North Pacific since 2014 (the Blob) has resulted in:

- Species range extensions across NE Pacific
- Changes in productivity (↑↓)
- Changes in seasonal timing (e.g., spawning)
- Dramatic changes to food webs
- Record low salmon returns



Pyrosomes (pelagic colonial tunicates)



Subtropical species in Oregon

Dramatic changes to base of food web

Commercial squid fishery in Oregon!

Domoic acid closes crab and clam fisheries

Climate vulnerability assessment for Pacific salmon and steelhead in the California Current Large Marine Ecosystem

Lisa G. Crozier[1*¶], Michelle M. McClure[1,2¶], Tim Beechie[1§], Steven J. Bograd[3¶], David A. Boughton[4§], Mark Carr[5§], Thomas D. Cooney[1§], Jason B. Dunham[6§], Correigh M. Greene[1§], Melissa A. Haltuch[1], Elliott L. Hazen[3¶], Damon M. Holzer[1&], David D. Huff[1], Rachel C. Johnson[4,7§], Chris E. Jordan[1§], Isaac C. Kaplan[1§], Steven T. Lindley[4§], Nathan J. Mantua[4§], Peter B. Moyle[8§], James M. Myers[1§], Mark W. Nelson[9¶^], Brian C. Spence[4§], Laurie A. Weitkamp[1§], Thomas H. Williams[4§], Ellen Willis-Norton[5§&]

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[3] Southwest Fisheries Science Center, Monterey, California, USA

[4] Southwest Fisheries Science Center, Santa Cruz, California, USA

[5] Department of Ecology and Evolutionary Biology, UC, Santa Cruz

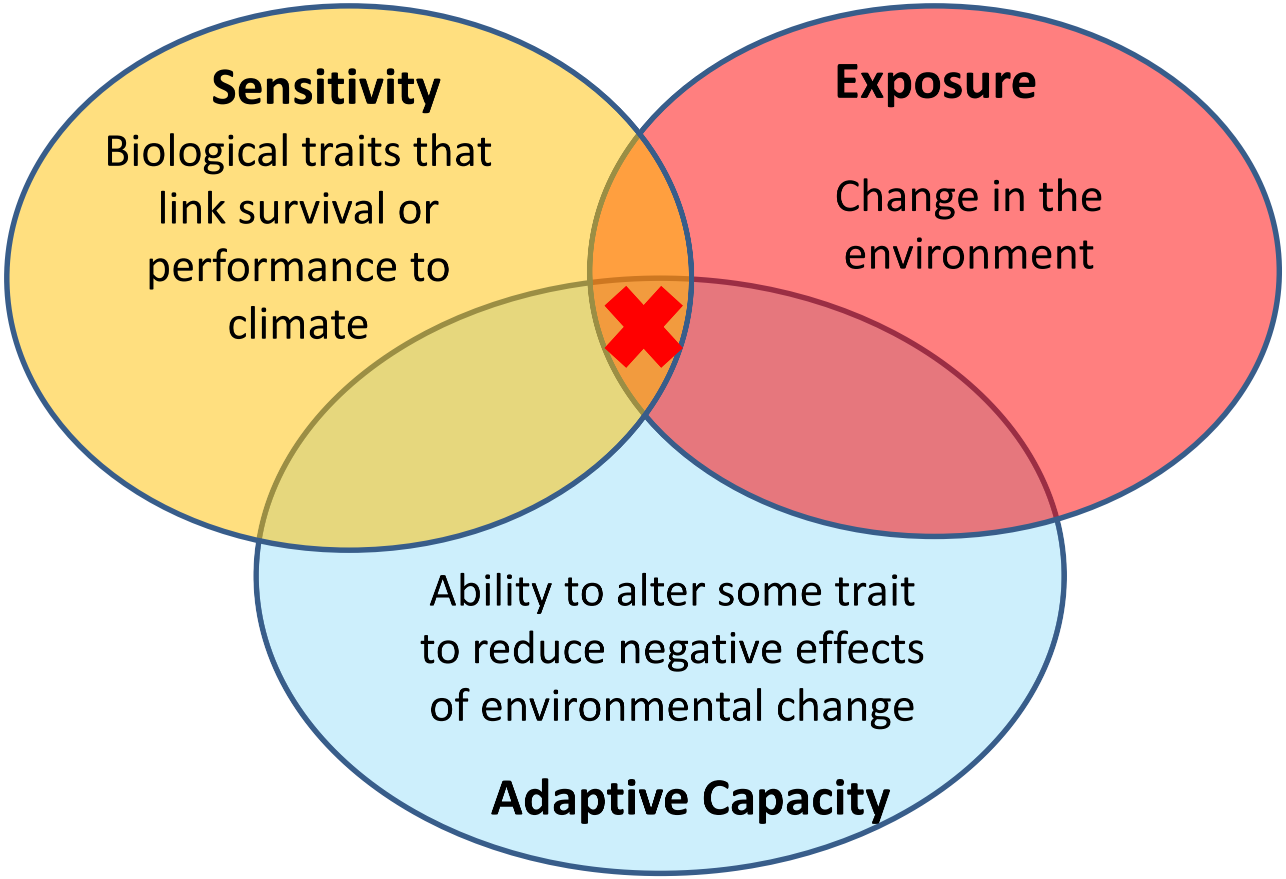
[6] U.S. Geological Survey, Forest & Rangeland Ecosystem Science Center

[7] Center for Watershed Sciences, UC, Davis

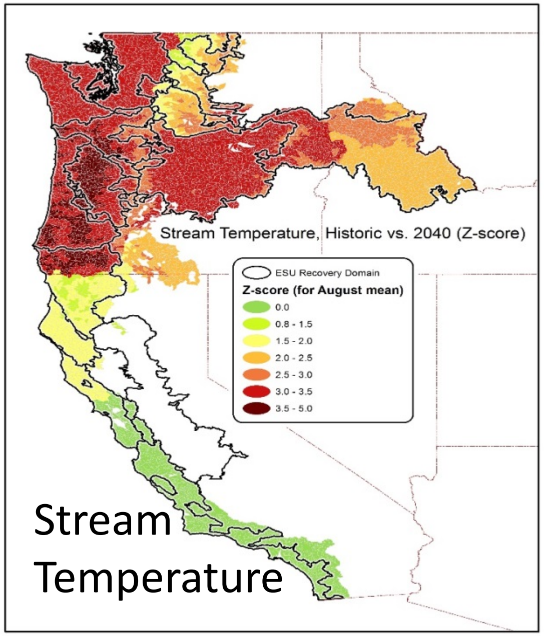
[8] Department of Wildlife, Fish and Conservation Biology, UC, Davis,

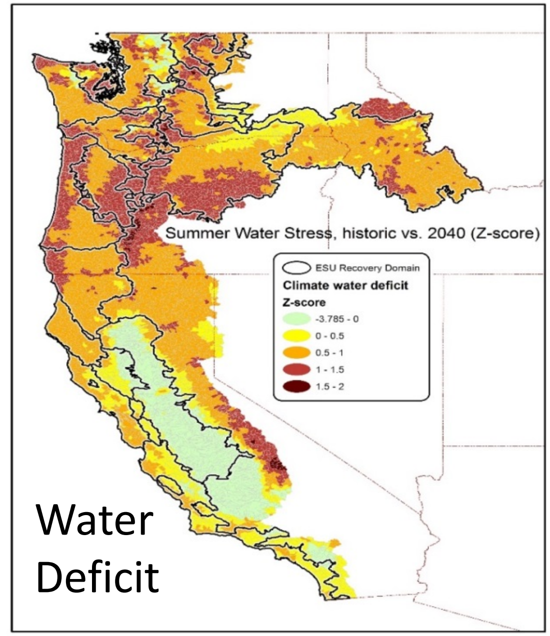
[9] ERT, Inc. Under Contract to Office of Sustainable Fisheries, NMFS

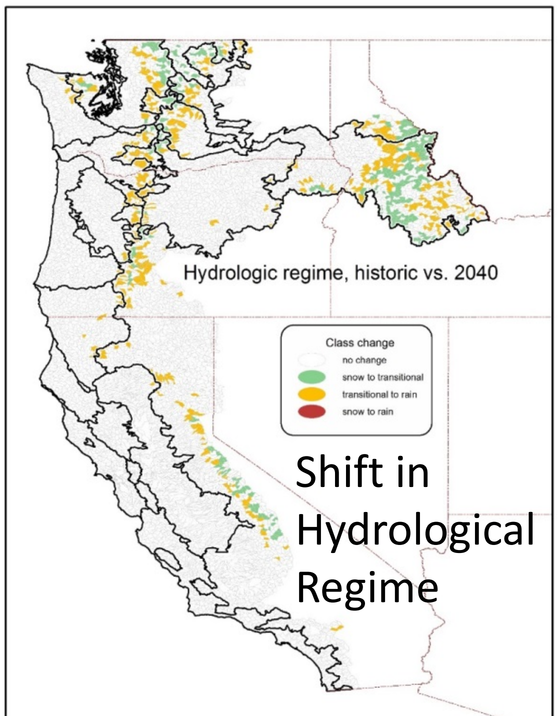
What makes a salmon population vulnerable?

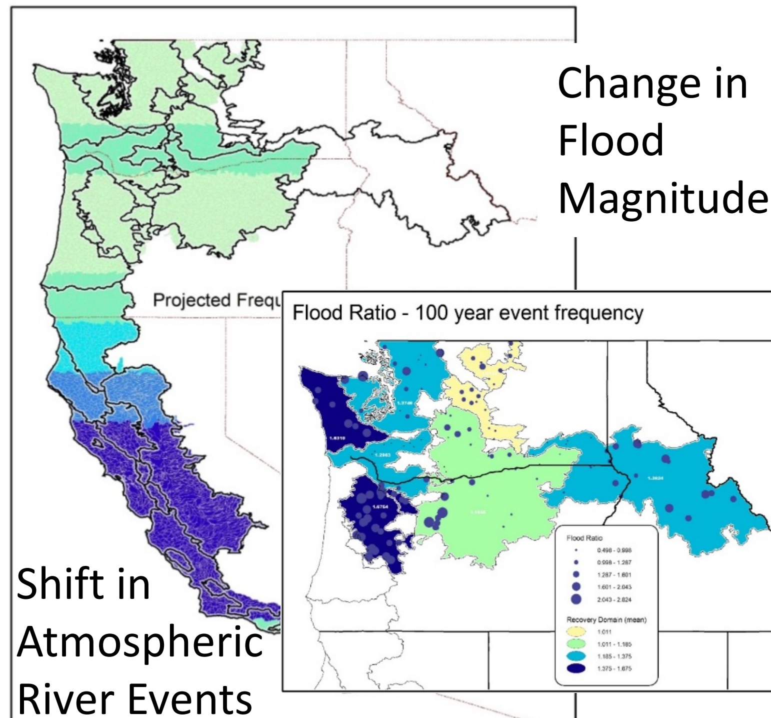


Freshwater exposure factors



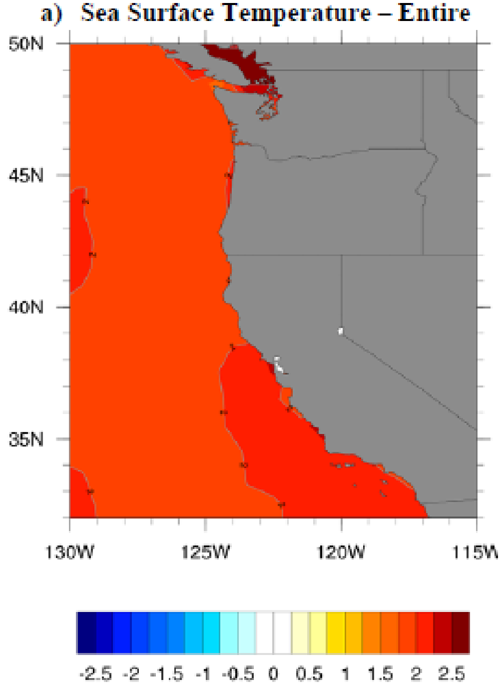




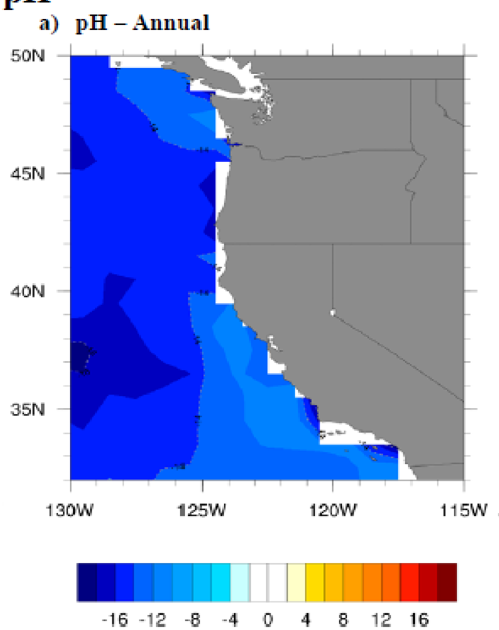


Marine Exposure Factors

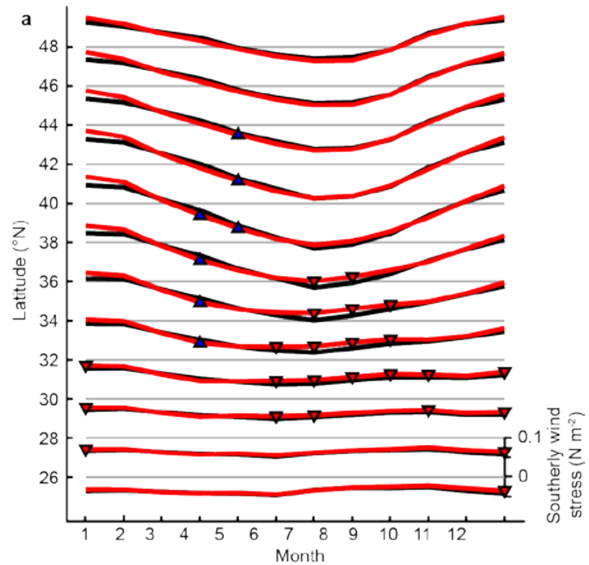
Sea Surface Temperature



pH

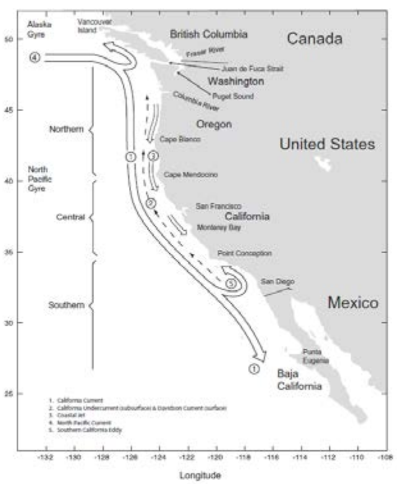


Timing of upwelling



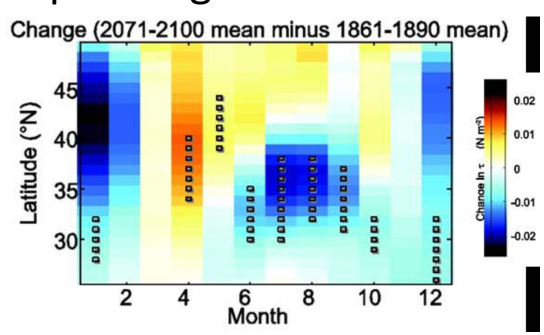
Rykaczewski et al 2015 Figure S5

Ocean currents



Checkley and Barth, 2009

Upwelling-favorable winds

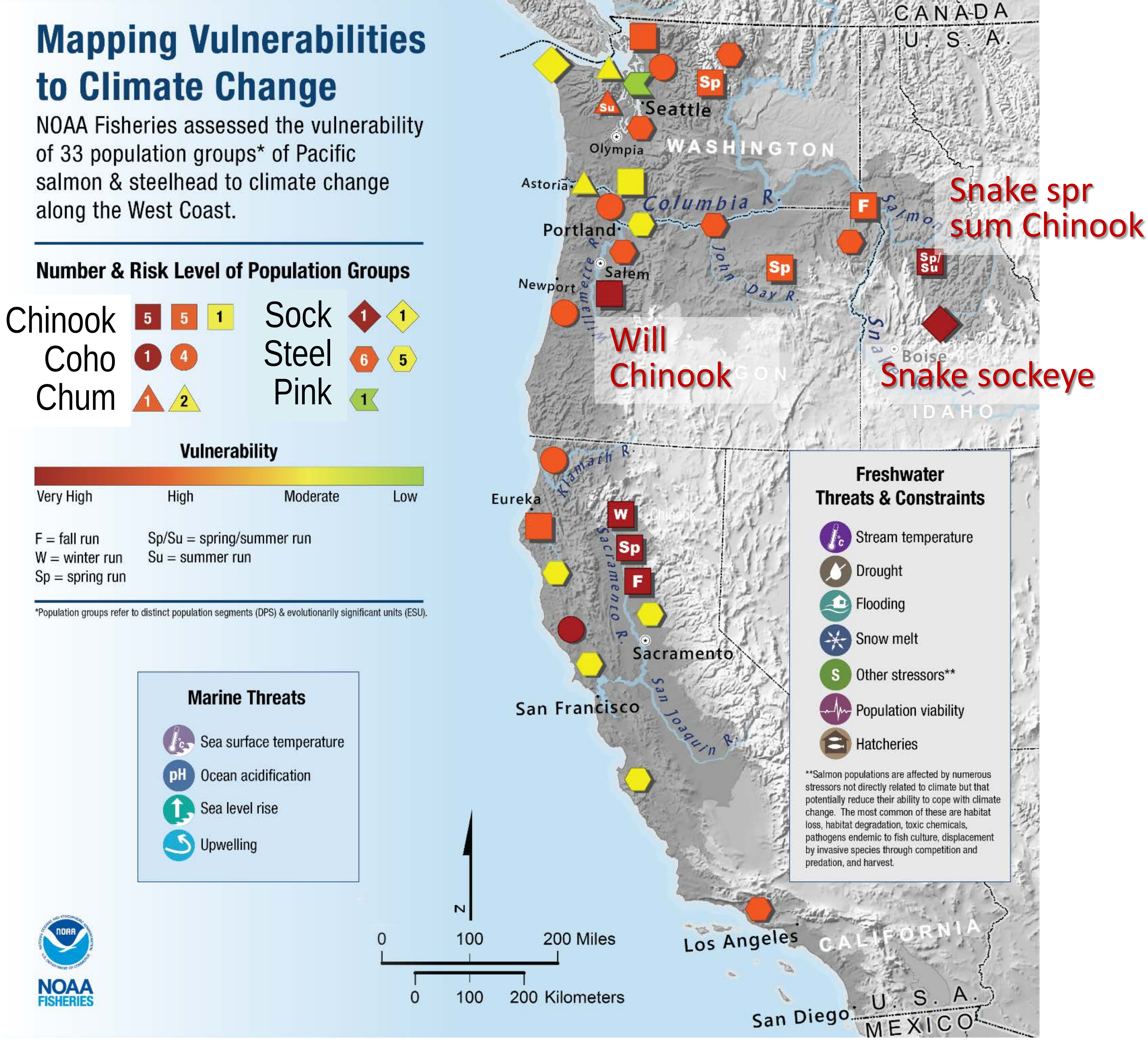


Sea Level Rise

	2030	2050	2100
South of Cape Mendocino	.04 – .3 meters	.12 – .61 meters	.42 – 1.67 meters
North of Cape Mendocino	-.04 – 23 meters	-.03 – .48 meters	.10 – 1.43 meters

Table 1: Sea level rise projections for the West Coast of the U.S. relative to the year 2000.

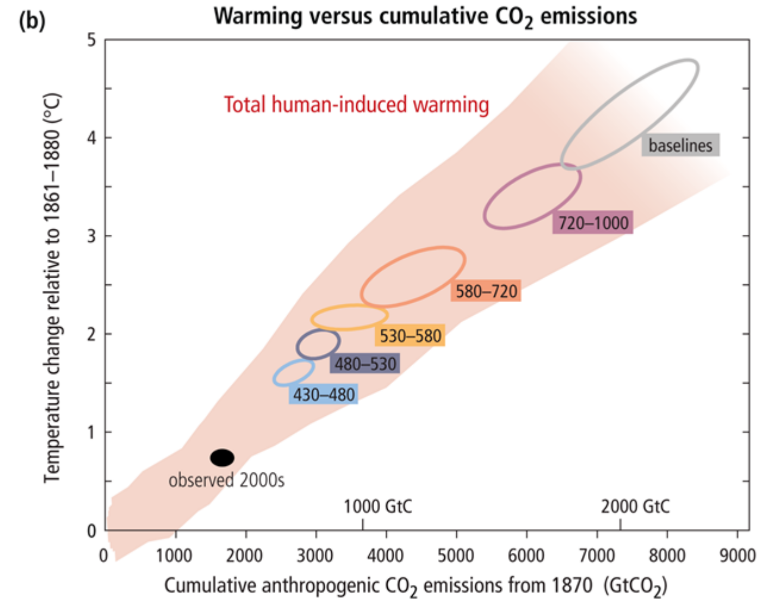
NRC 2012



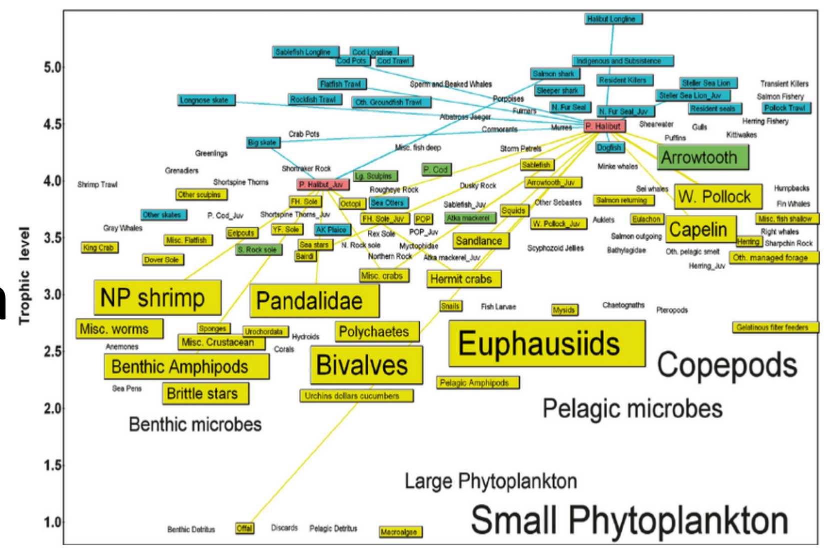
https://www.fisheries.noaa.gov/feature-story/west-coast-salmon-vulnerable-climate-change-some-show-resilience-shifting-environment

Uncertainties

- Temperature rise depends on rate of emissions
- Ability of salmon to adapt to altered conditions
- Physical changes to ocean environments (model results of upwelling vary)
- Predicting future freshwater, estuarine, and marine food webs and their value to salmon



IPCC 2015



Conclusion

Bottom line

The earth is warming, its climate becoming more variable (e.g., more intense rainfall, extreme hot weather events)

- Expect impacts to cold-water Columbia River salmon to be largely negative

Primary impacts

- Increasing temperatures in all habitats
- In freshwater, snowpack changes will affect river flow
- Expect alterations to food webs throughout life cycle
- Productivity of marine habitats will likely change

Many uncertainties

- Reduce emissions of greenhouse gases
- Salmon's ability to adapt to future habitats

1. Distributions. First summer in the ocean: 3 patterns for Columbia River salmon

Pattern 1: Rapid north-wards movement on shelf to Gulf of Alaska

Which: Spring Chinook, chum, sockeye, some coho

Pattern 2: Remain in local waters

Which: Fall Chinook, some coho

Pattern 3: Move rapidly offshore

Which: Steelhead

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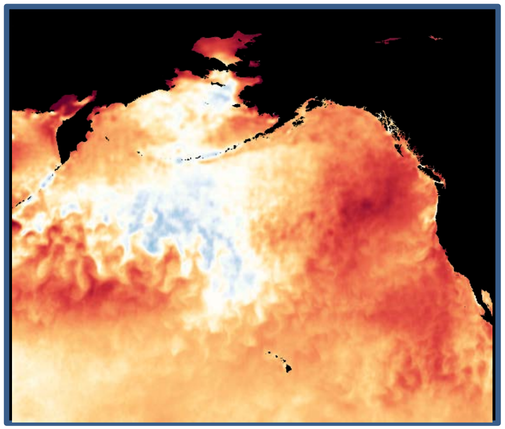
Which: Steelhead

This is when most marine mortality is thought to occur

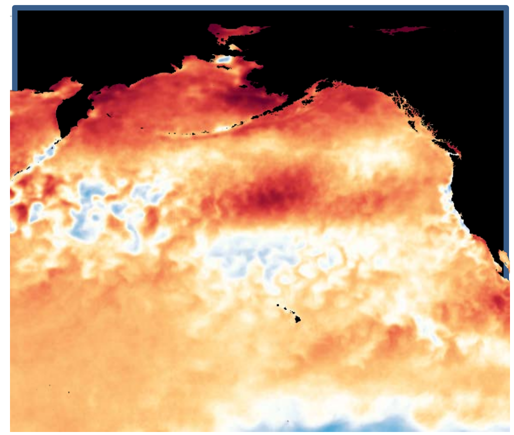
Sea surface temperature anomalies in recent Julys

(shading = monthly sea surface temperature anomalies)

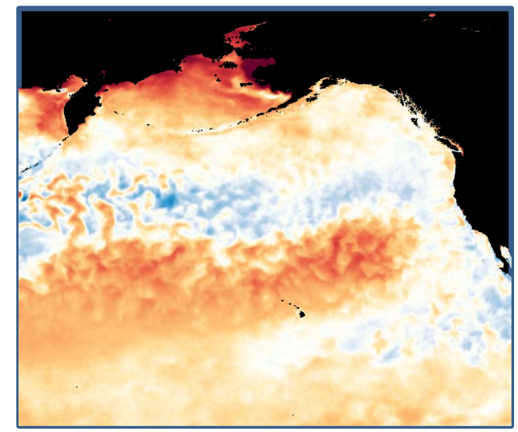
July 2015



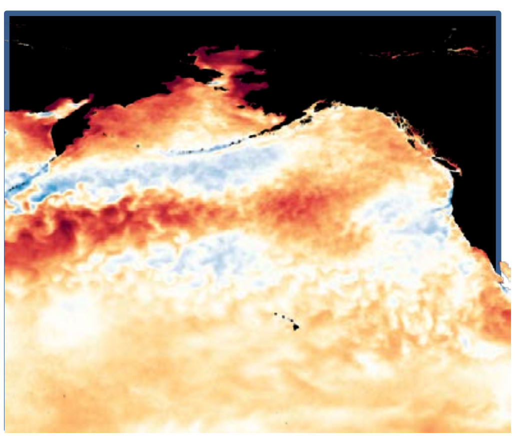
July 2016



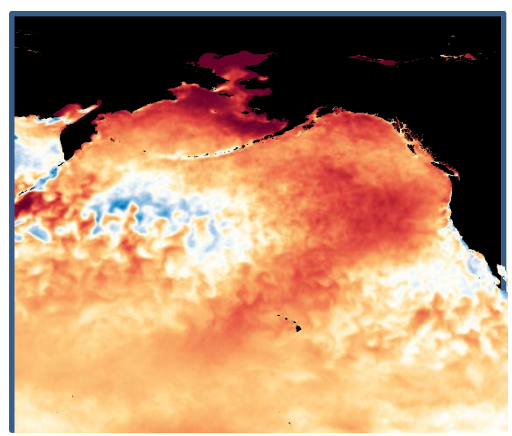
July 2017



July 2018

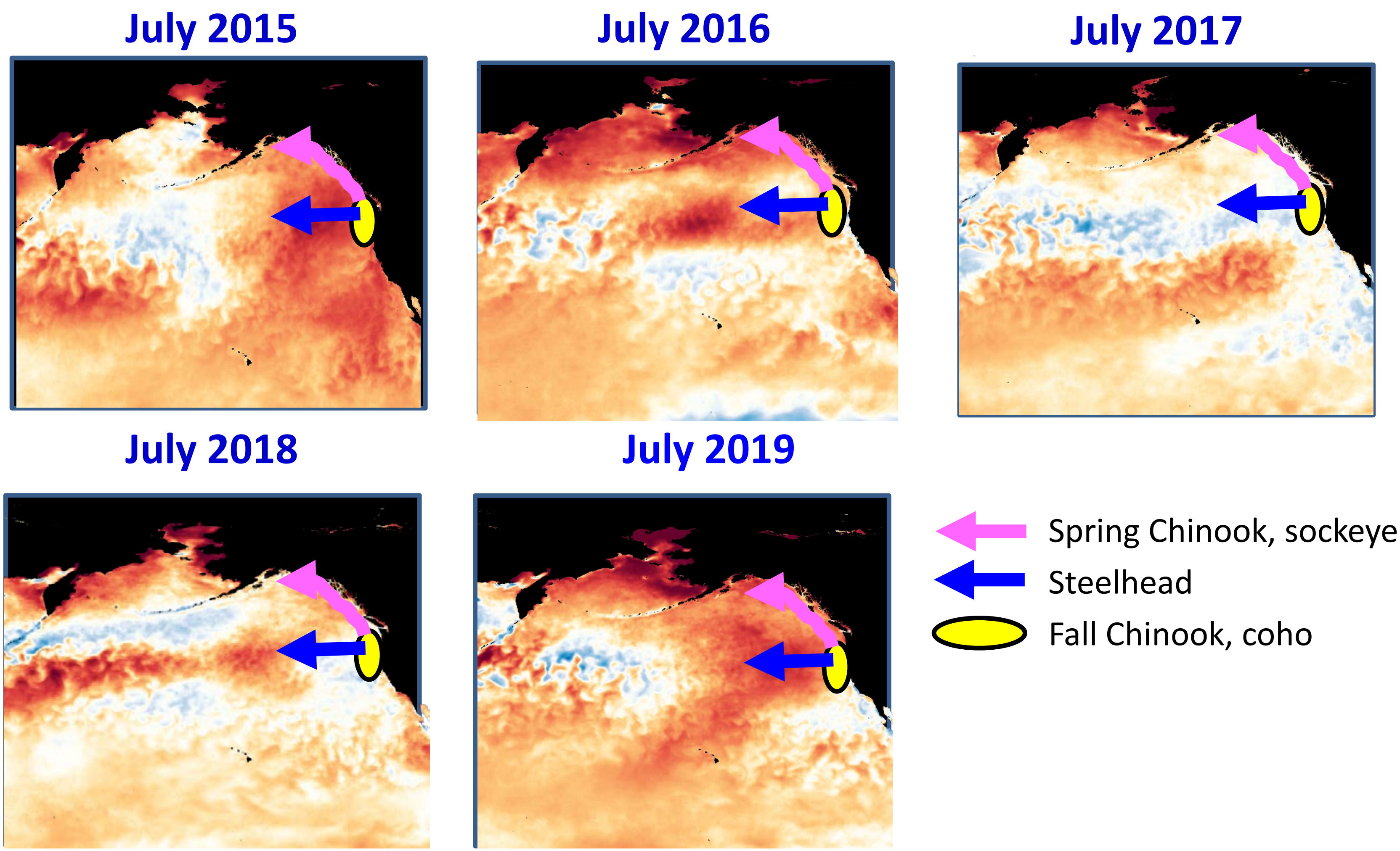


July 2019



Initial ocean migrations of Columbia River salmon in recent Julys

(shading = monthly sea surface temperature anomalies)



1. Columbia River high seas distributions

We know the least about this phase (where they are, what they're doing)

1. Adults returning to the Columbia: 3 general migration patterns

Pattern 1: Southwards movement along shelf

Which: Fall Chinook, Chum (?), sockeye (?)

Pattern 2: Northwards along California & Oregon Coasts

Which: Coho

Pattern 3: Move rapidly onshore (or unknown)

Which: Steelhead, Spring Chinook