A lifecycle perspective of climate impacts on West Coast salmon, and why it matters for salmon recovery planning

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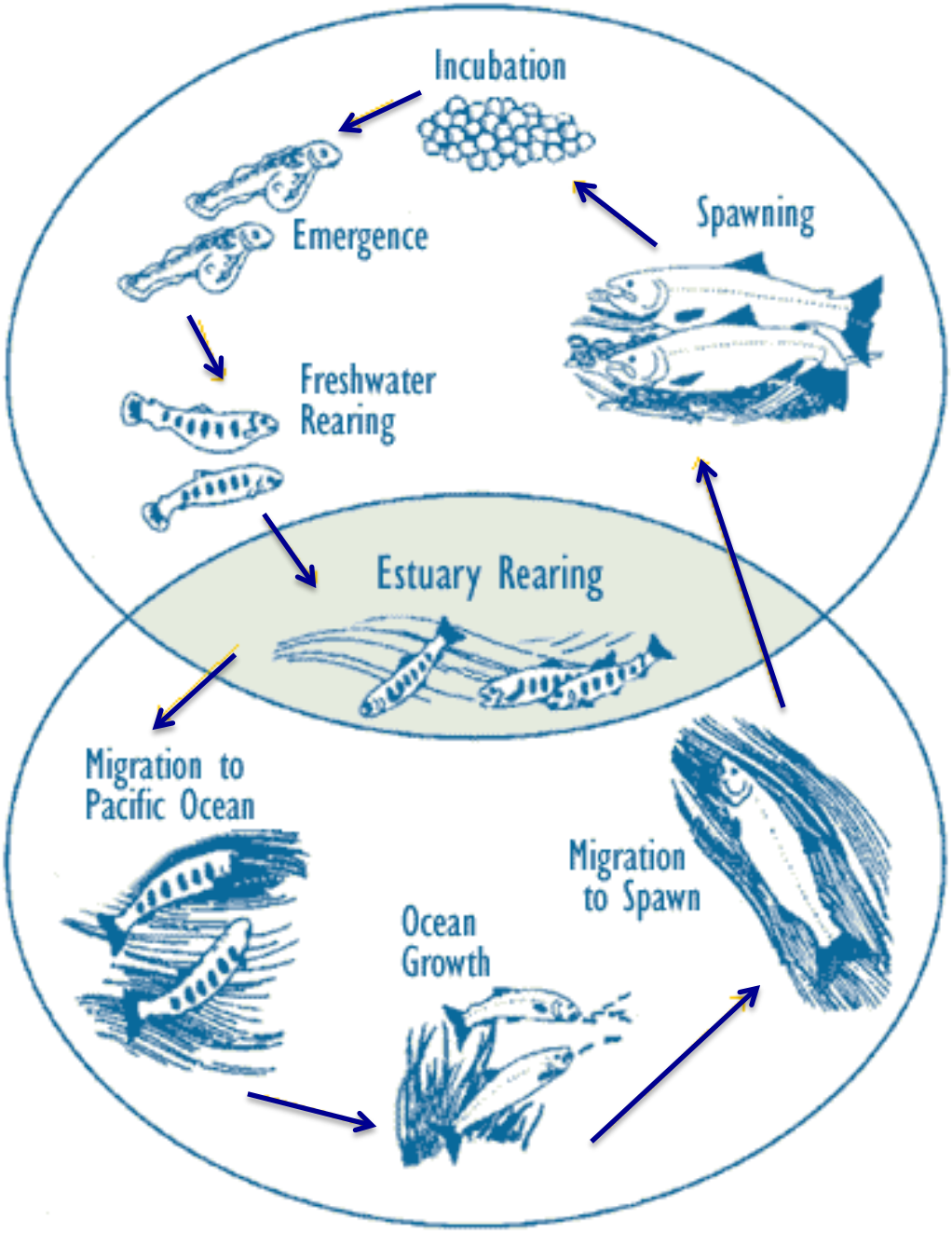
River Herring Tech Expert WG meeting

December 15, 2014



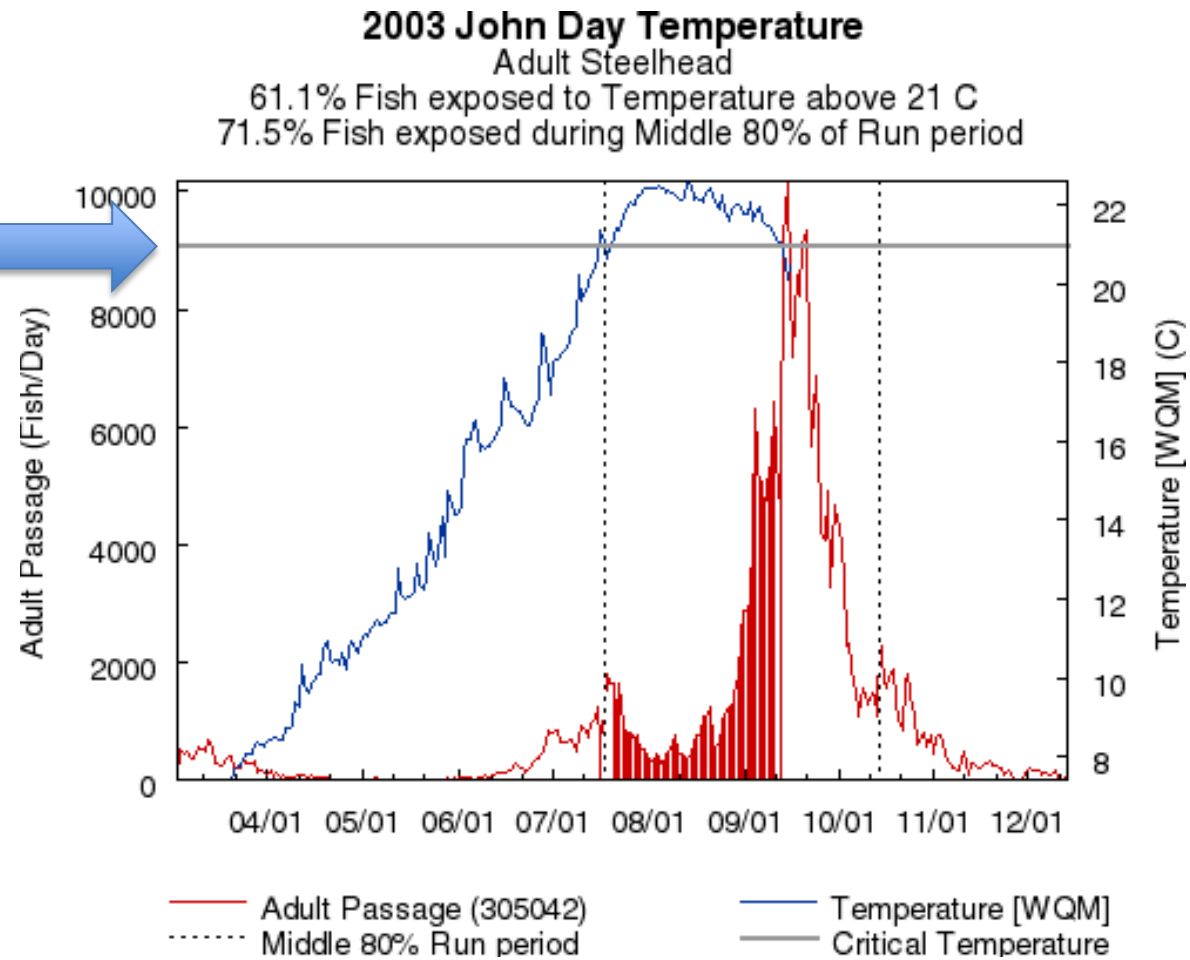
Why are salmon so climate-sensitive?

Their complex lifecycle includes freshwater spawning and rearing, (sometimes) estuary rearing, and an extended ocean life for growth and maturation puts them in highly dynamic climate-driven habitats.

- flow and temperature are critical climate pressure points in freshwater habitats
- marine food-web is critical for ocean growth and survival

Adult Chinook salmon migration and water temperature in the Lower Columbia River

- **For many West Coast salmon populations adult spawning migrations are sensitive to water temperatures > ~21ºC**



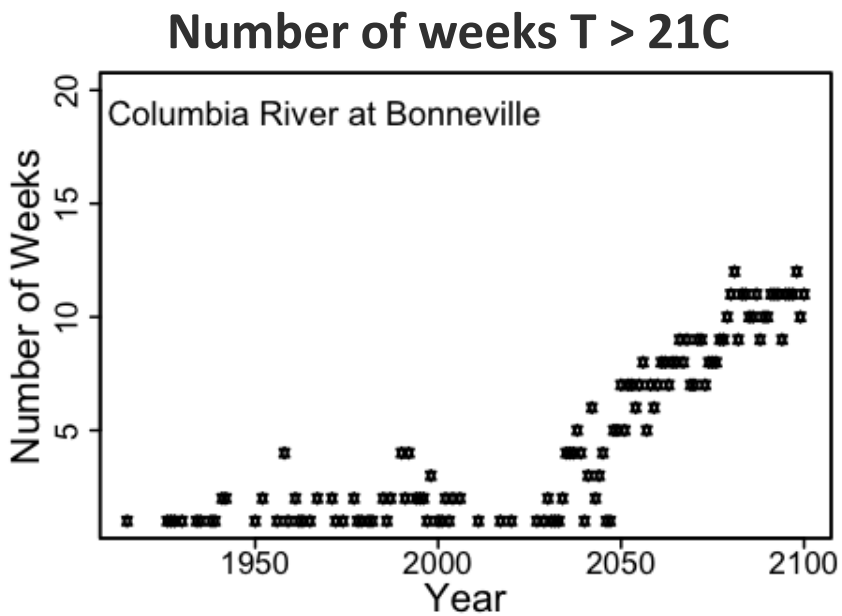
UW SAFS Columbia Basin DART: http://www.cqs.washington.edu/

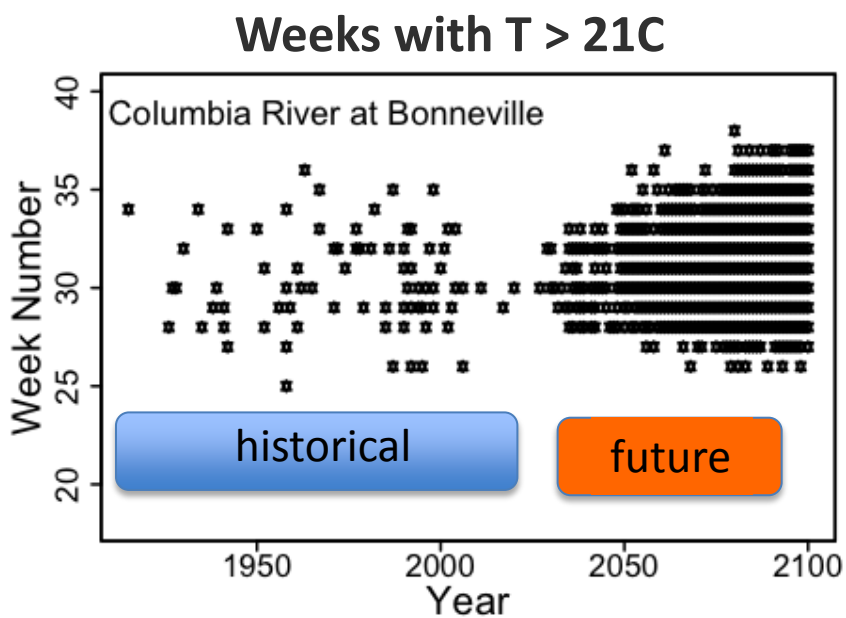
Klamath River fish kill 2002 – a case where a short-term drought amplified existing stresses on cold water

- **Disease, high fish densities, low flows and a very warm river combined to result in a massive kill of adult chinook salmon in the lower Klamath River**

Conservation concerns over the offspring from the 2002 returns led to a curtailed CA/OR chinook season in 2005, and sharp restrictions in 2006

Thermal stress season

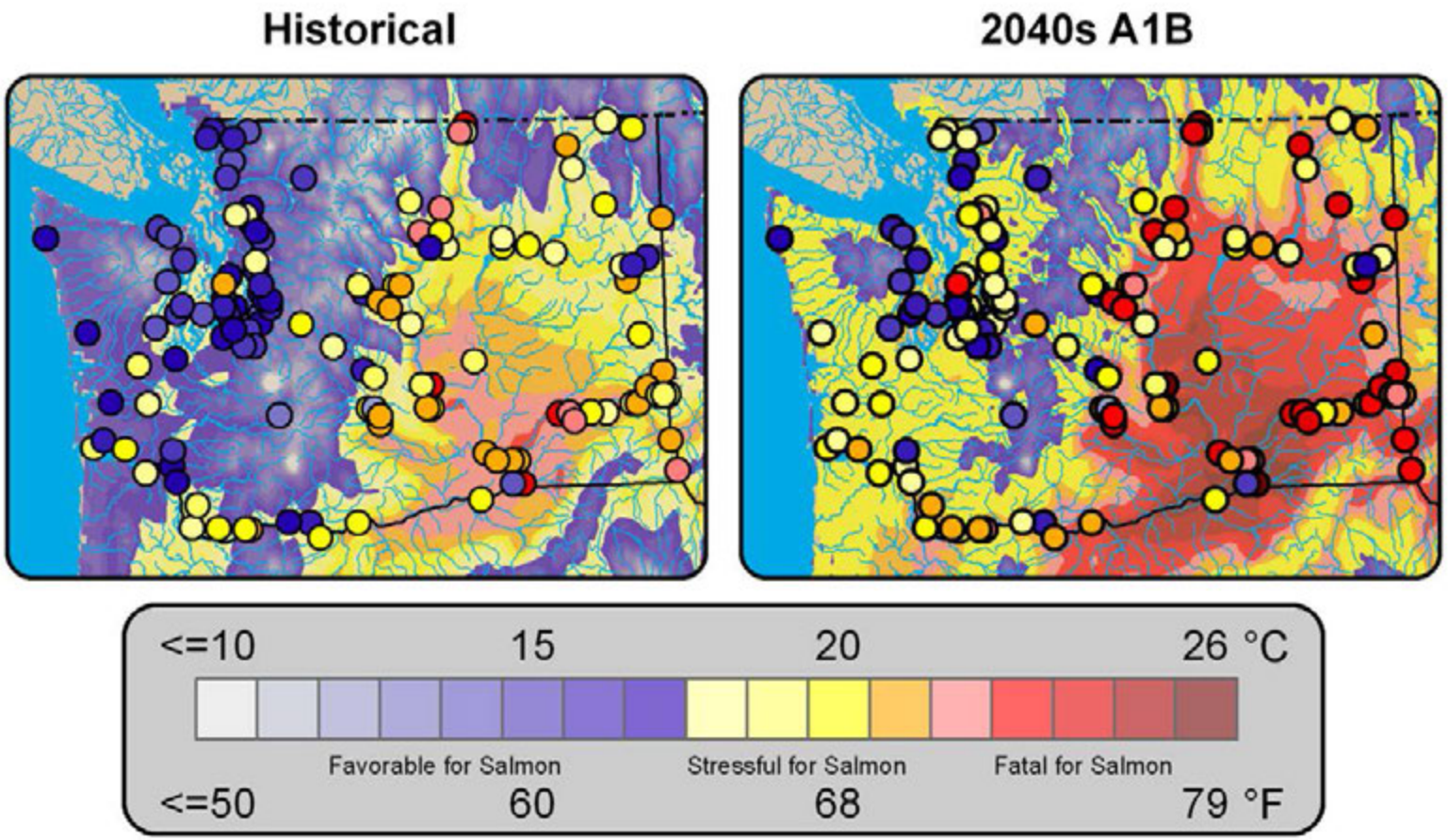




- Use a simple regression model to translate future air temperature scenarios into stream temperature scenarios
- Extended periods with weekly average water temperatures > 21C
  - the season of thermal migration barriers for migrating salmon predicted to last up to 12 weeks in the mainstem Columbia River

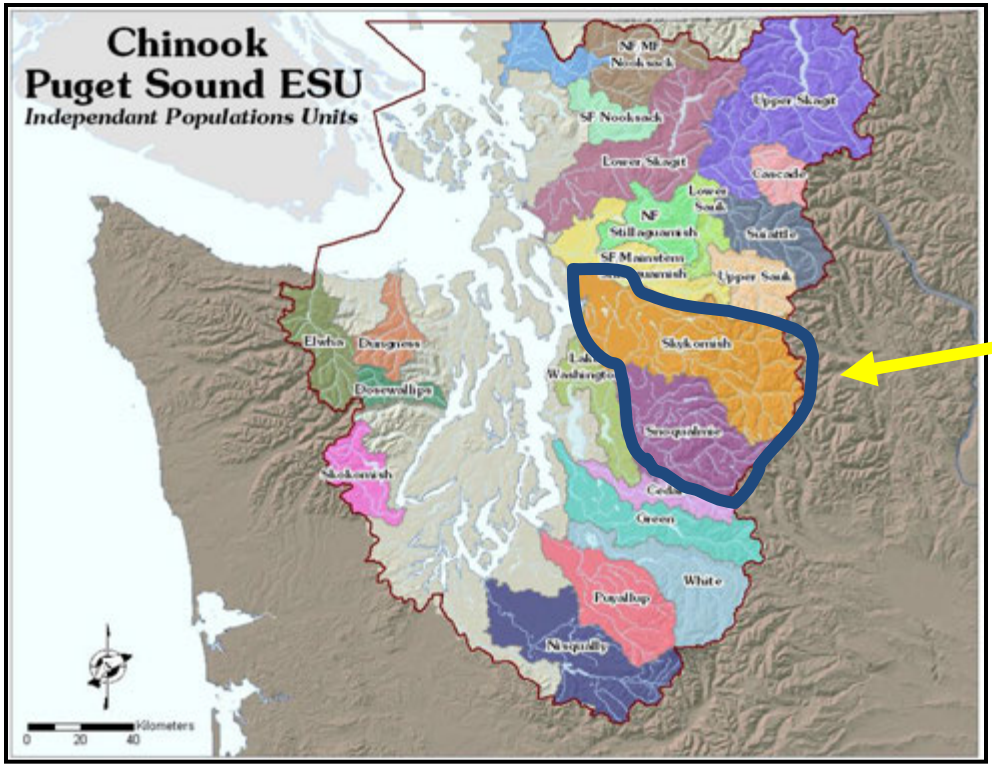
Mantua et al. 2010: Climatic Change

Western Washington's "maritime" summer climate becomes as warm as today's interior Columbia Basin, temperatures in the interior Columbia Basin become as warm as today's Central Valley in California



Mantua et al. 2010: Climatic Change

Snohomish R. Chinook Recovery Planning Case Study



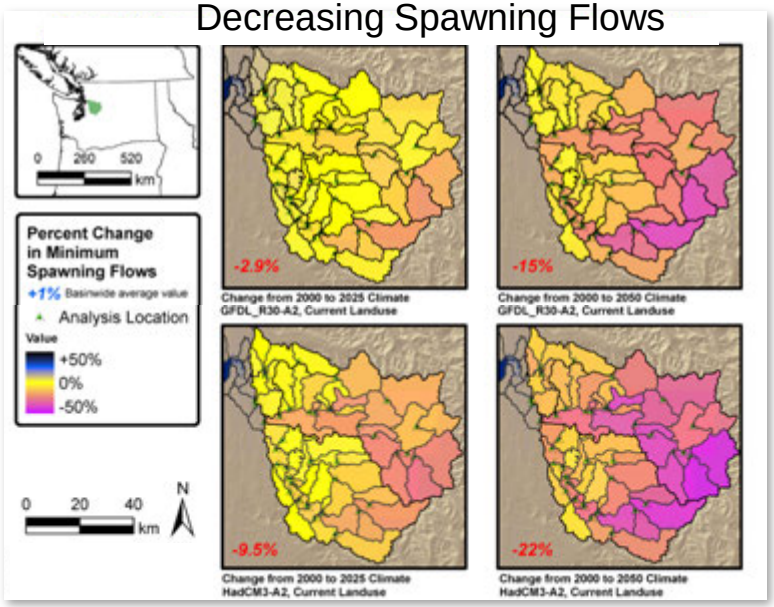
Snohomish R.

- Evaluate the benefits of alternative habitat restoration plans under different future climate scenarios using linked hydrologic and salmon-lifecycle models

Battin et al. 2007: PNAS

Impacts of Climate Change on Salmon Recovery in the Snohomish River (Battin et al. 2007: PNAS)

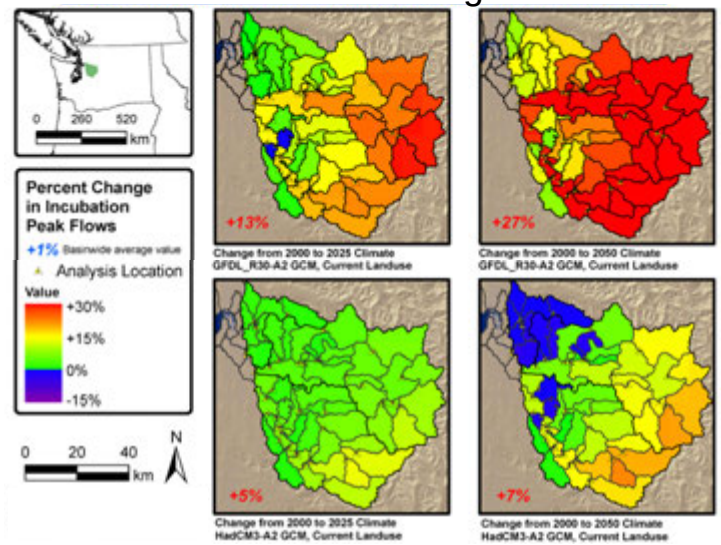
Decreasing Spawning Flows



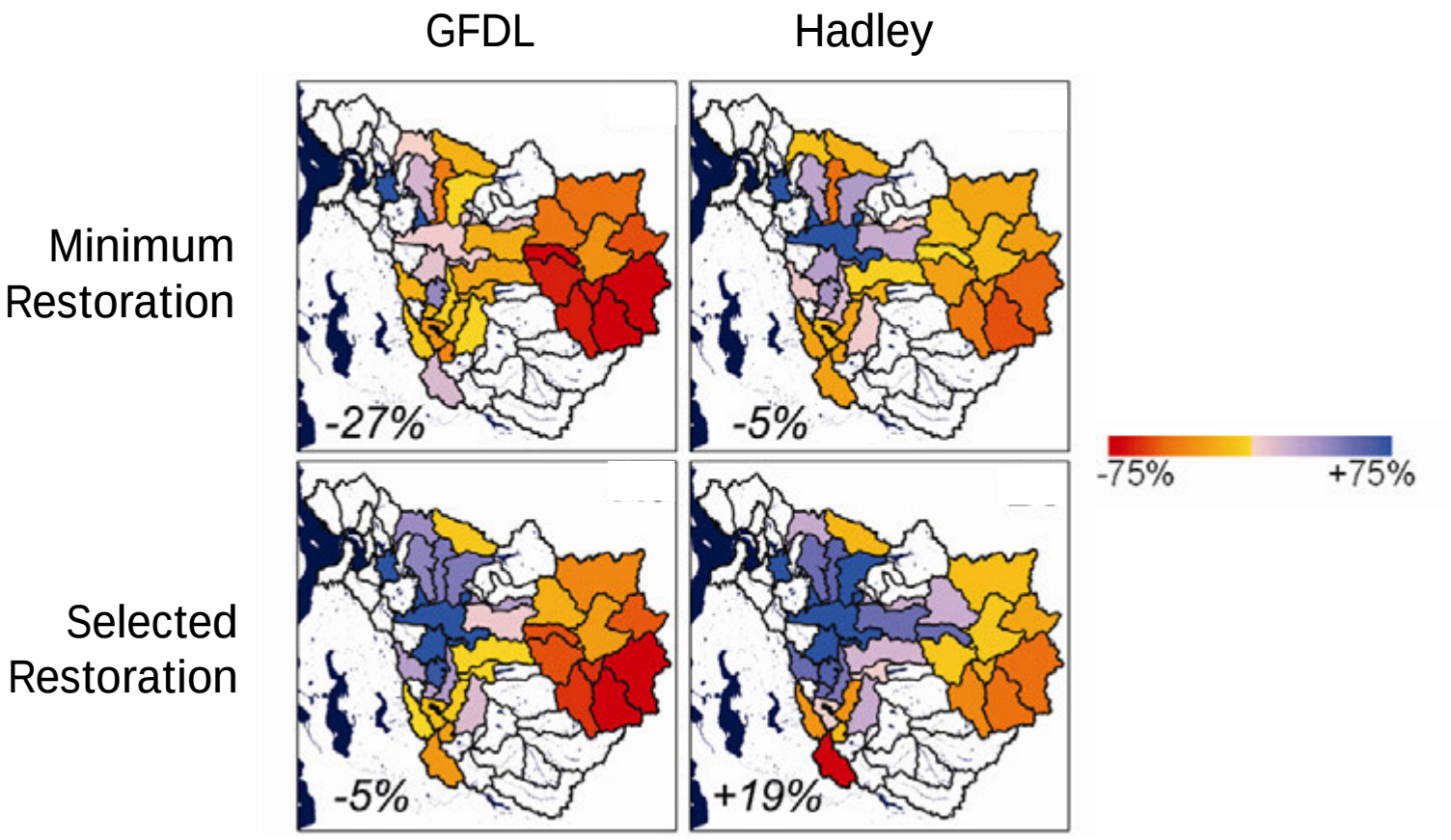
Climate Change will make salmon restoration more difficult:

- Decreasing Summer Low Flows
- Increasing Winter Peak Flows
- Increasing water temperatures in critical periods

Increasing Winter Flows



Predicted change in the distribution of wild spawners by 2050



- Negative effects of climate change are concentrated at higher elevations
- Positive effects of restoration are concentrated at lower elevations
- Effects are likely to increase the proportion of Chinook spawning at lower elevations

50 YEARS WITH IMPACT
Journal of Applied Ecology
British Ecological Society

Journal of Applied Ecology 2013, 50, 1093–1104 doi: 10.1111/1365-2664.12137

Steelhead vulnerability to climate change in the Pacific Northwest

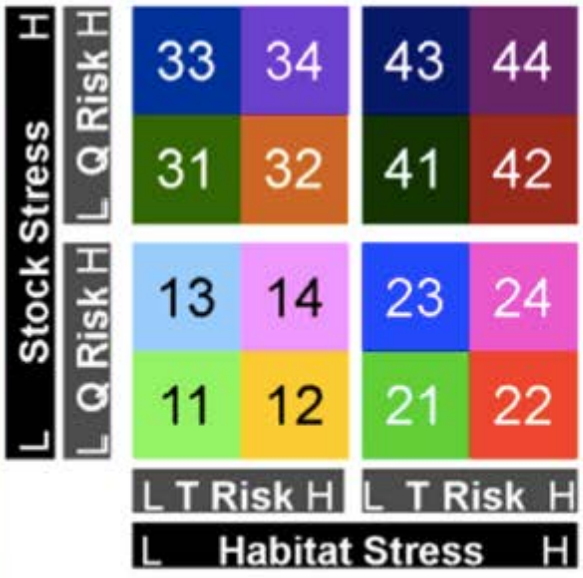
Alisa A. Wade[1*,†], Timothy J. Beechie[2], Erica Fleishman[3], Nathan J. Mantua[4], Huan Wu[5‡], John S. Kimball[5], David M. Stoms[6] and Jack A. Stanford[5]

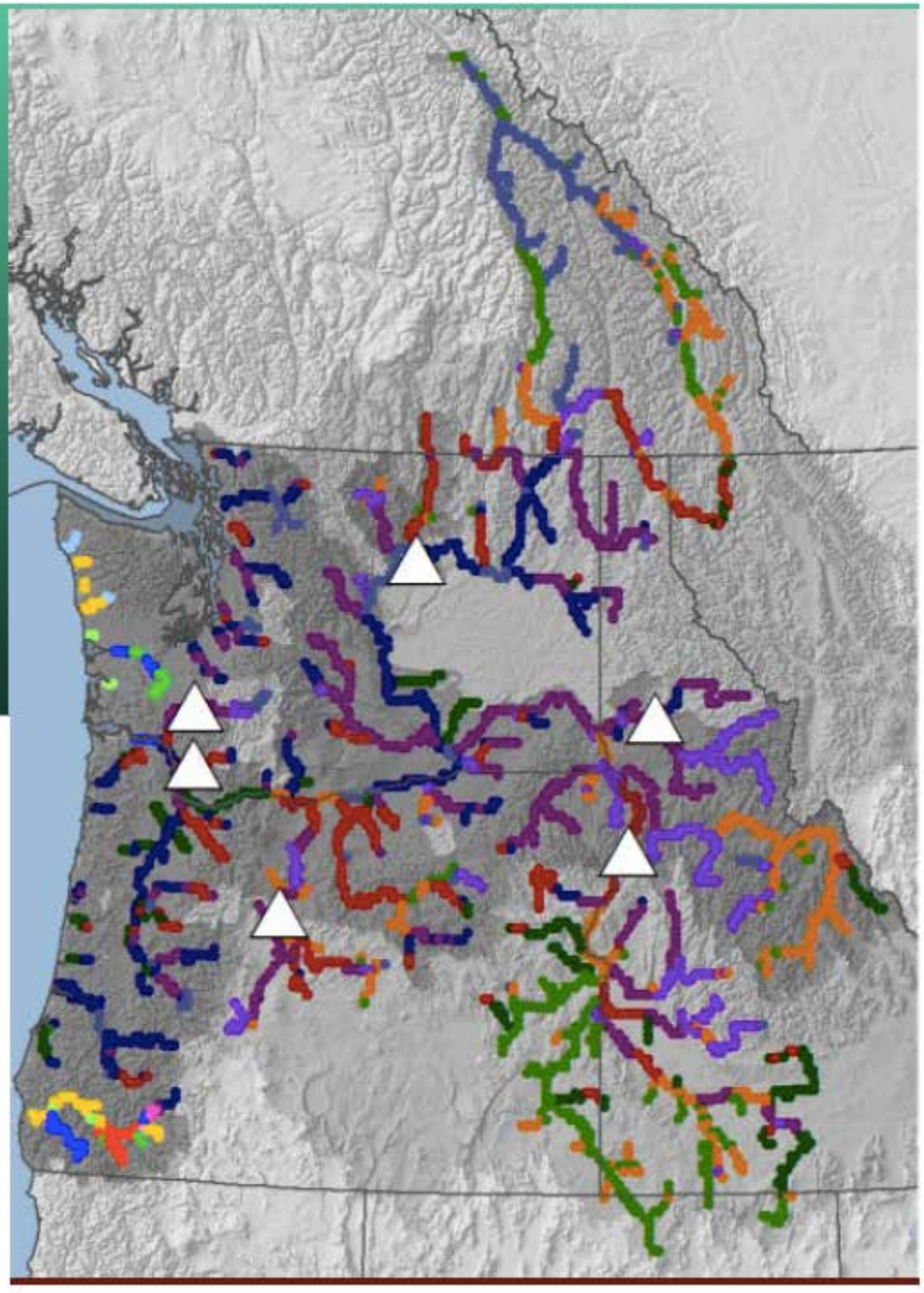
- Vulnerability = sensitivity x exposure
- "*Exposure*" informed by future stream flow and stream temperature scenarios
- "*sensitivity*" informed by habitat and stock condition (VSP parameters and NMFS status reviews)
- Allowed for a spatially and population specific assessment of key factors underlying vulnerability
    - For some cases, assessment highlights vulnerability related to increased spawning flows, or warming migration temperatures … in others, key factor is poor habitat and/or stock status leading to very high sensitivity

PNW Steelhead Vulnerability

exposure x sensitivity

(2080)





RESTORING SALMON HABITAT FOR A CHANGING CLIMATE

T. BEECHIE[a*], H. IMAKI[a], J. GREENE[a], A. WADE[b], H. WU[c,d], G. PESS[a], P. RONI[a], J. KIMBALL[e], J. STANFORD[e], P. KIFFNEY[a] AND N. MANTUA[f]

River Research and Applications (2012)

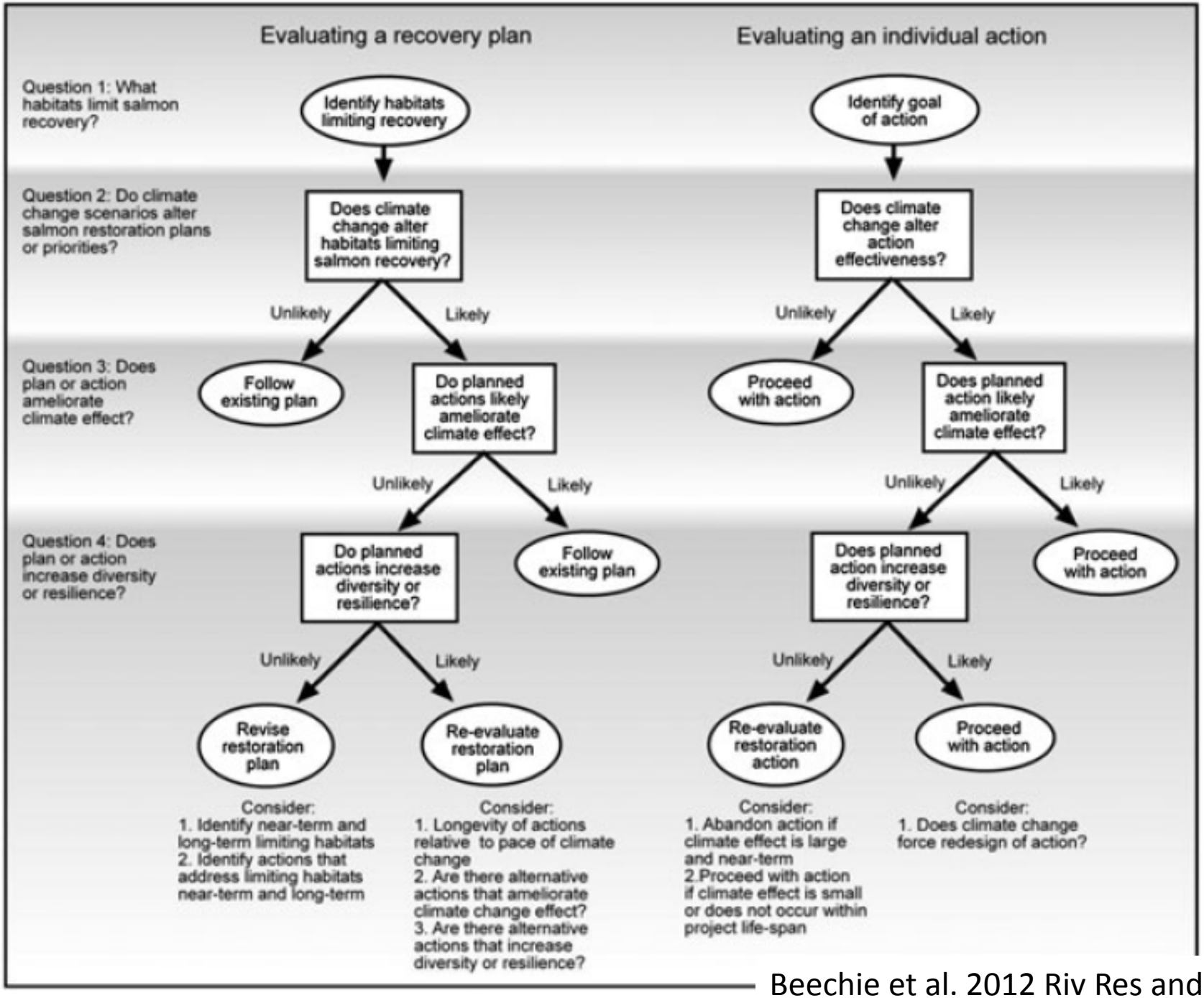
How should habitat restoration plans be altered to accommodate climate change effects on stream flow and temperature?

- We developed a decision-support process for adapting recovery plans that incorporates (1) local habitat factors limiting salmon recovery, (2) scenarios of climate change impacts on flow and temperature, (3) the ability of restoration actions to ameliorate climate change effects, and (4) the ability of restoration actions to increase habitat diversity and salmon population resilience

Restoration actions and their ability to ameliorate climate impacts

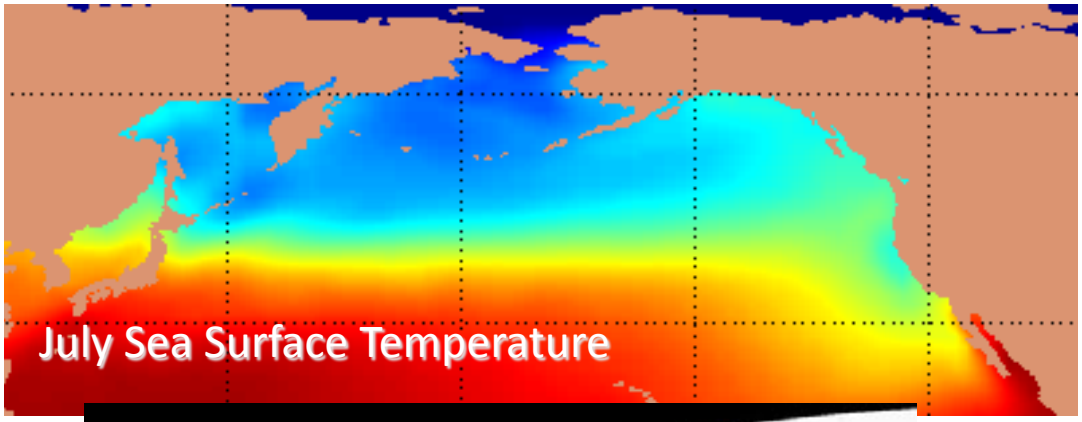
Category	Common techniques	Ameliorates temperature increase	Ameliorates base flow decrease	Ameliorates peak flow increase	Increases salmon resilience
Longitudinal connectivity (barrier removal)					
	Removal or breaching of dam	●	●	○	●
	Barrier or culvert replacement/removal	○	○	○	●
Lateral connectivity (floodplain reconnection)					
	Levee removal	●	○	●	●
	Reconnection of floodplain features (e.g. channels, ponds)	●	○	●	●
	Creation of new floodplain habitats	●	○	●	●
Vertical connectivity (incised channel restoration)					
	Reintroduce beaver (dams increase sediment storage)	●	●	●	●
	Remove cattle (restored vegetation stores sediment)	●	●	●	○
	Install grade controls	●	●	●	○
Stream flow regimes					
	Restoration of natural flood regime	●	●	○	◒
	Reduce water withdrawals, restore summer baseflow	●	●	○	○
	Reduce upland grazing	○	◒	◒	○
	Disconnect road drainage from streams	○	○	●	○
	Natural drainage systems, retention ponds, other urban stormwater techniques	○	◒	●	○

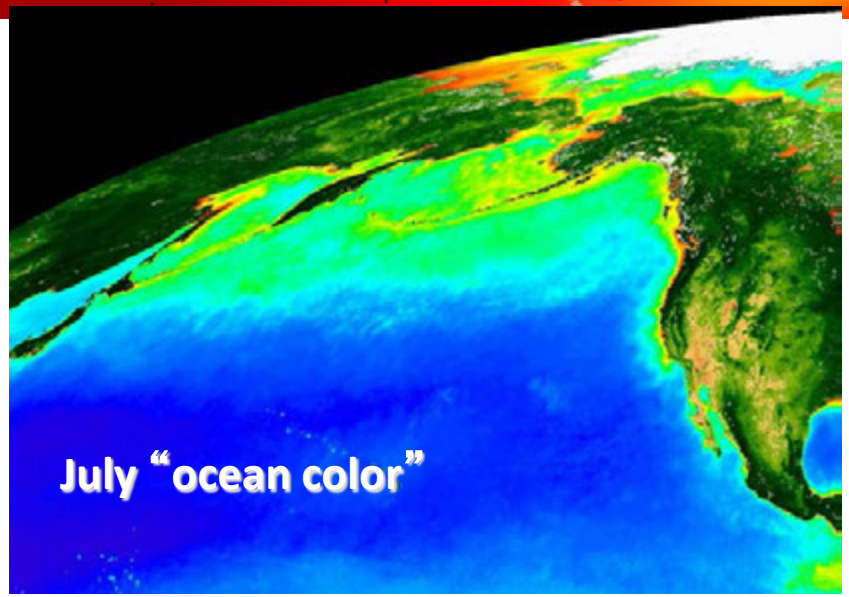
Beechie et al. 2012: Riv. Res. and Appl.

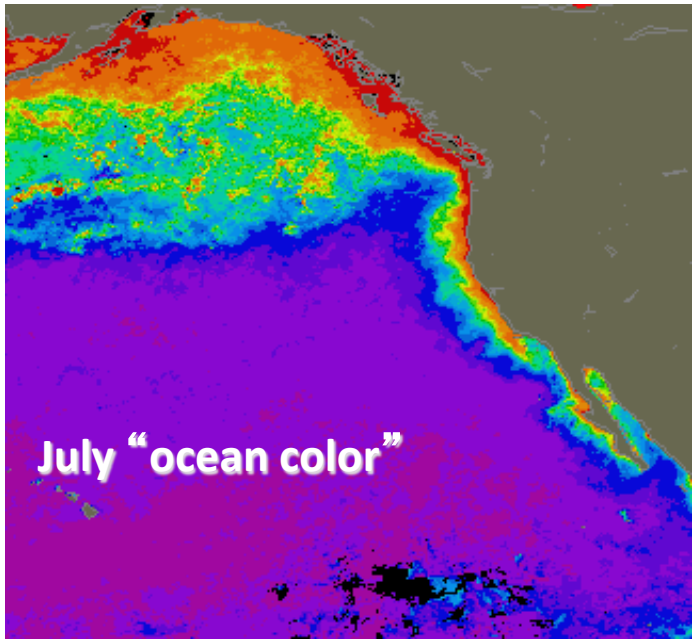


Beechie et al. 2012 Riv Res and Appl

Salmon and steelhead habitat: productive sub-arctic (cool-fresh-nutrient rich) waters from Japan to California -- coastal upwelling extends this habitat south to S. Cal.

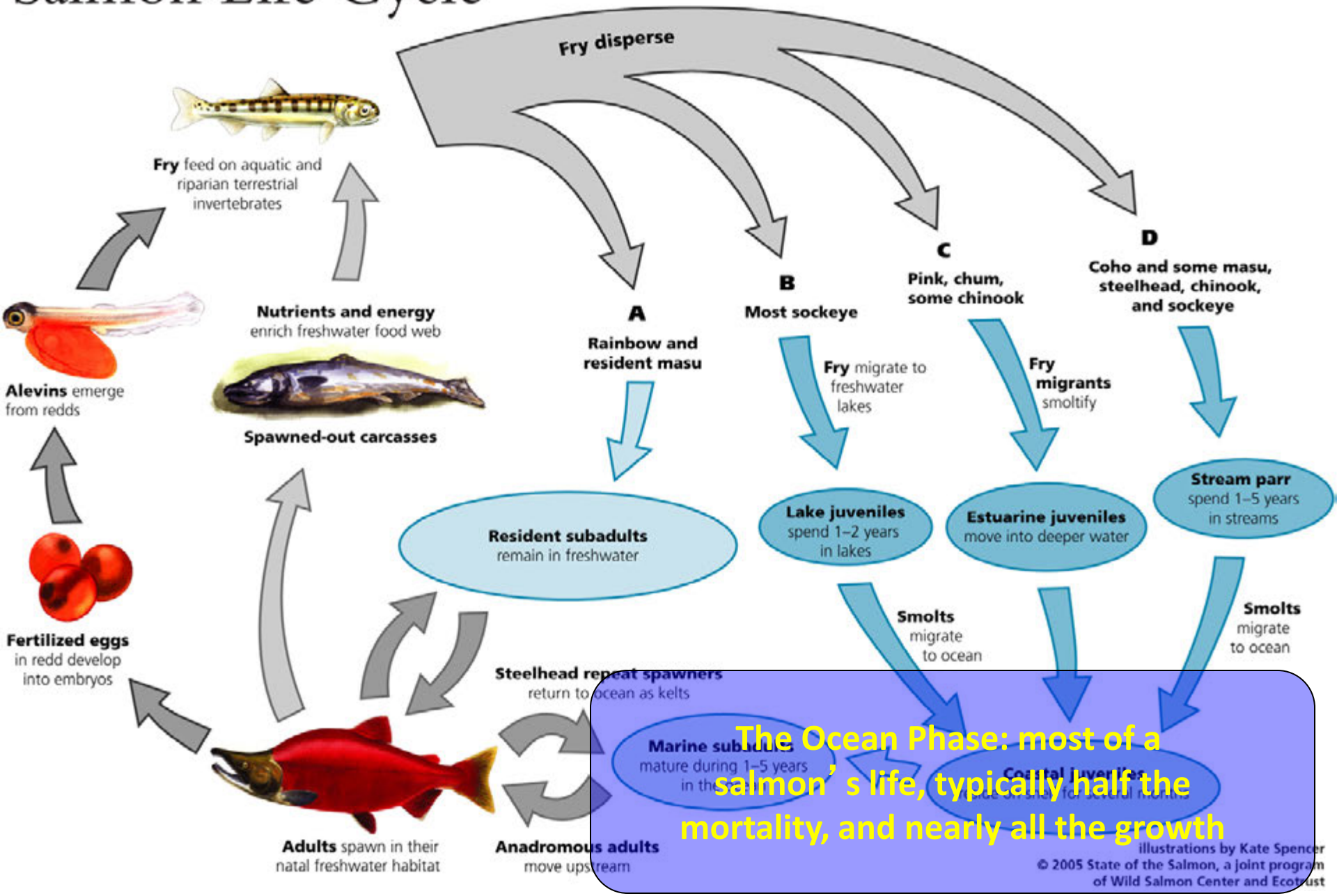






SeaWiFS images from NASA's Goddard Space Flight Center
http://seawifs.gsfc.nasa.gov/SEAWIFS.html

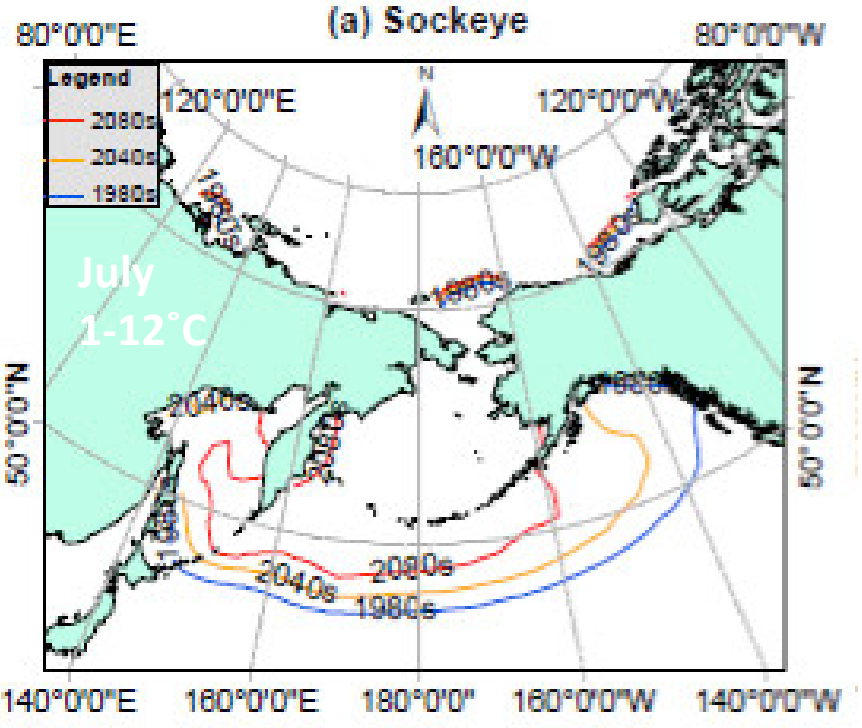
Salmon Life Cycle

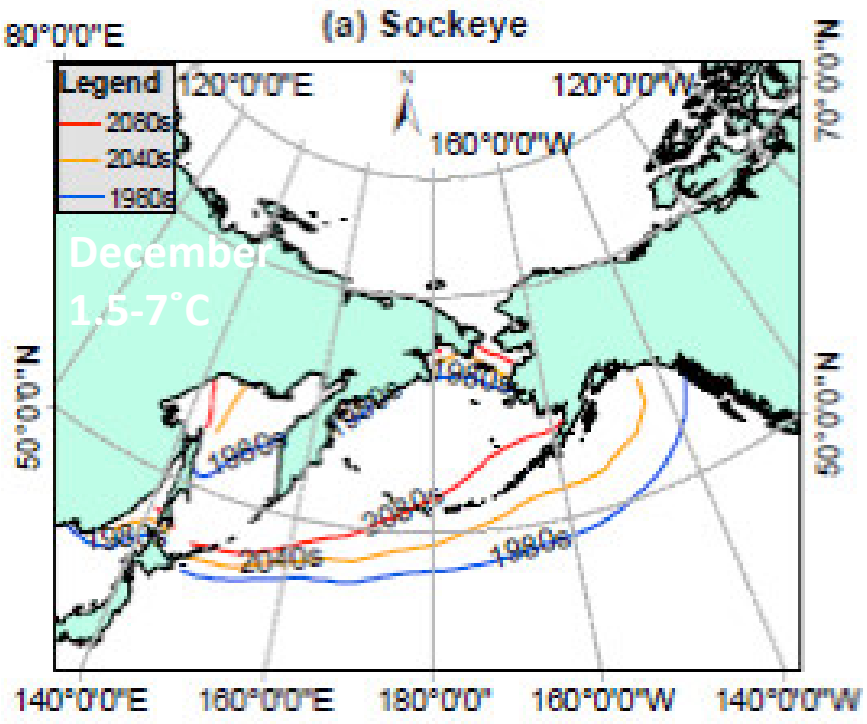


The Ocean Phase: most of a salmon's life, typically half the mortality, and nearly all the growth

thermal habitat projections – Sockeye

Aziz et al. 2010. Can. J. Aquat. Fish. Sci.





- 2080s: sockeye habitat reduced by 45% in July, 38% in December
  - the complete loss of preferred thermal habitat in the Gulf of Alaska due in part to a relatively low upper thermal limit (surveys show GoA sockeye found at SST<15˚C)