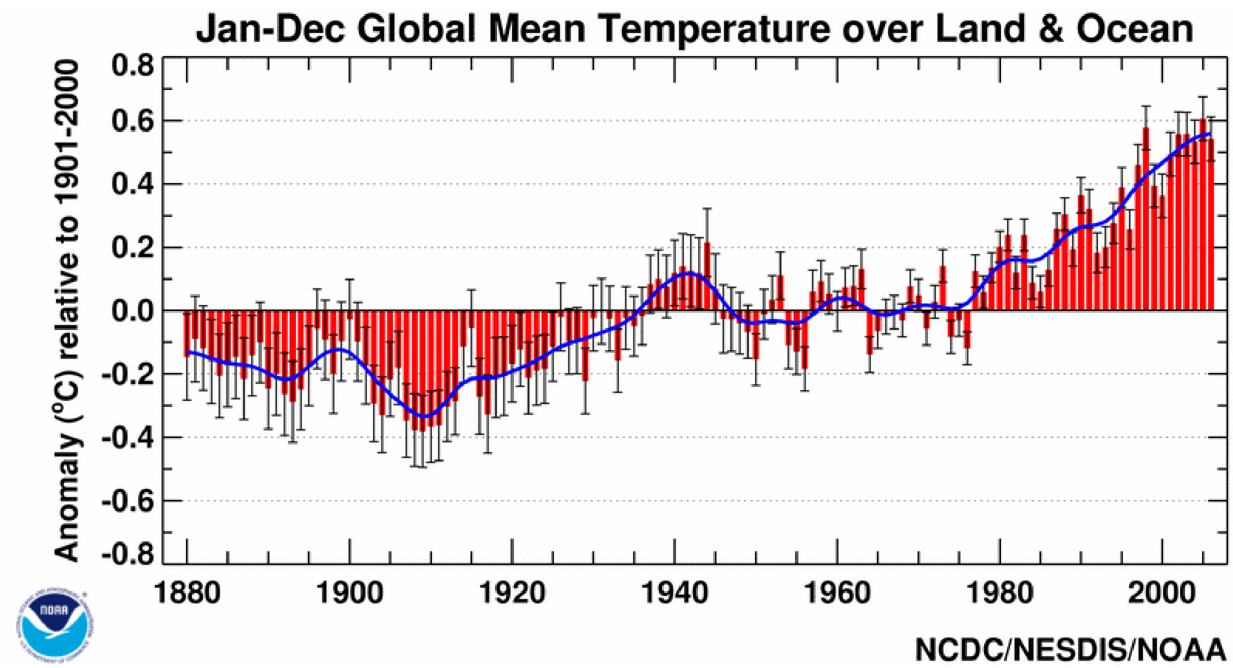
California Salmon in a Changing Climate

Steve Lindley, NOAA Fisheries



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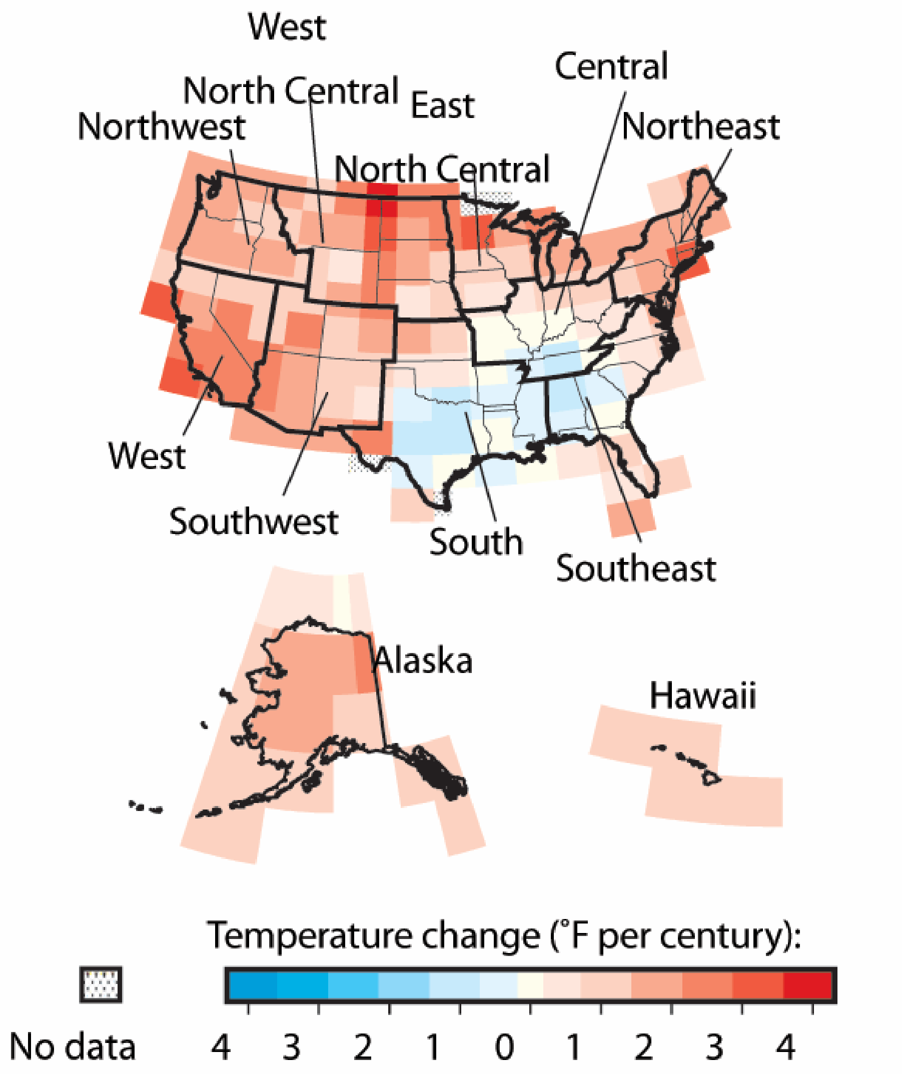

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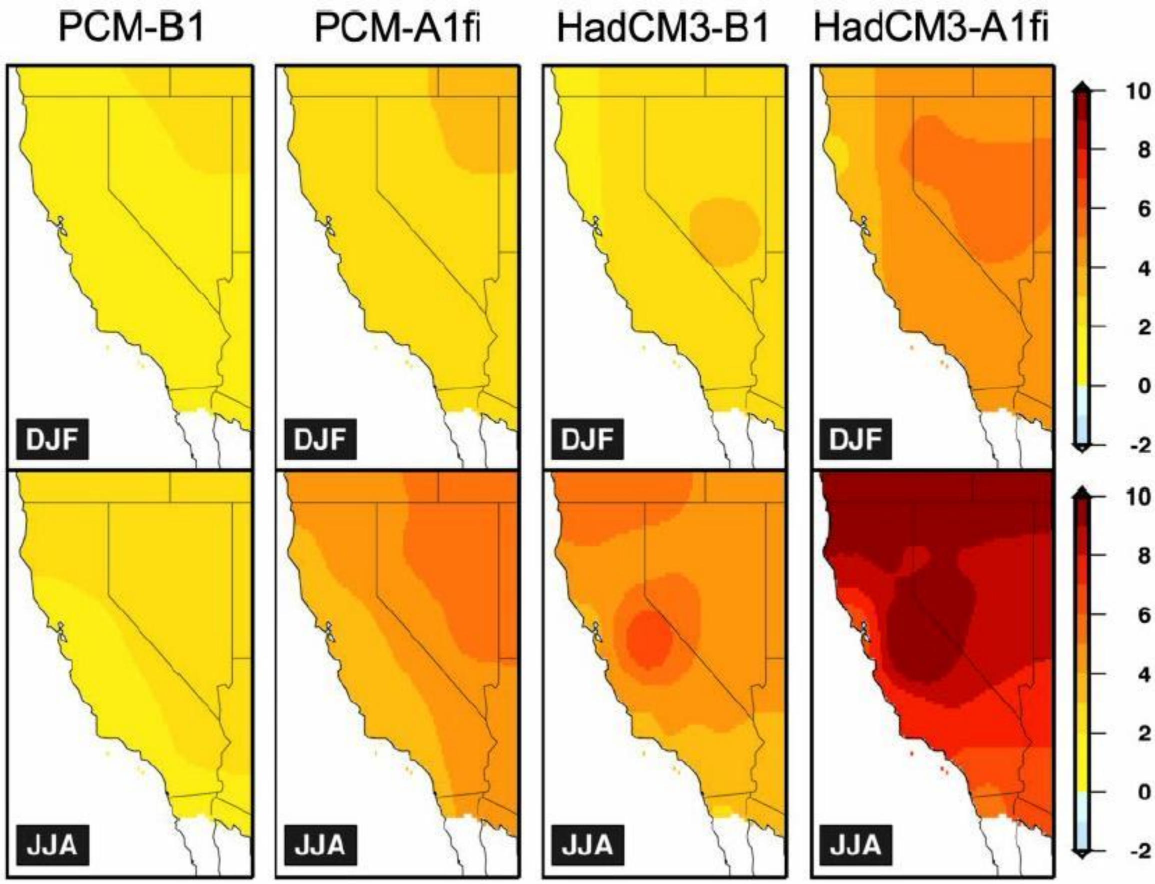
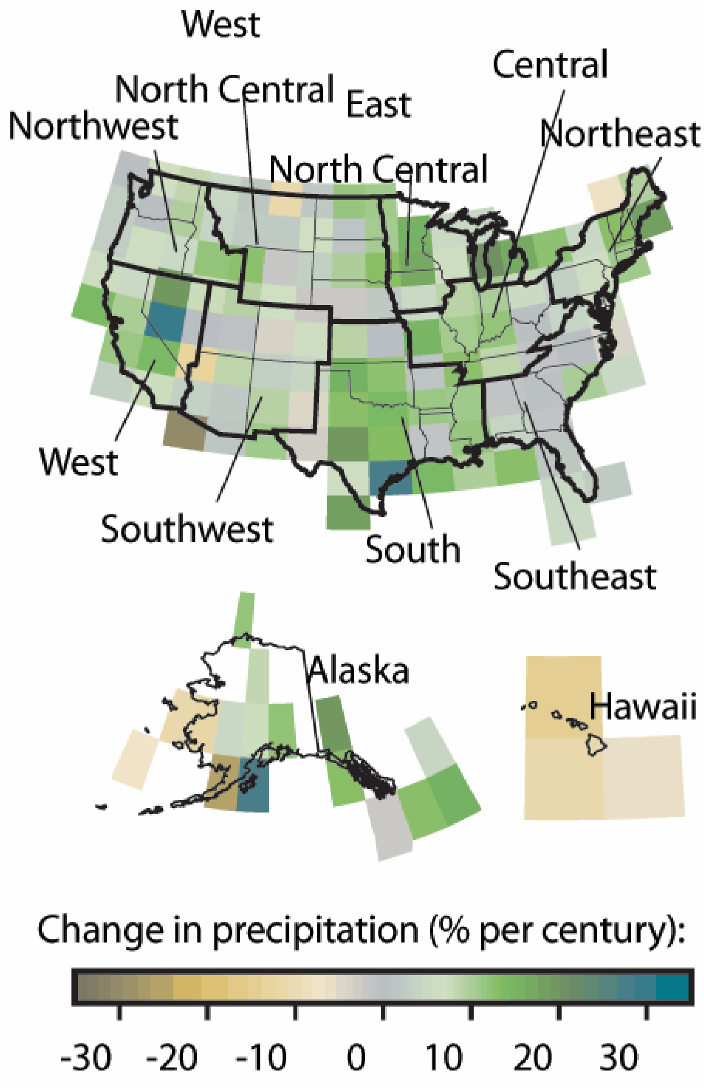


Fig. 1. Downscaled winter (DJF) and summer (JJA) temperature change (°C) for 2070–2099, relative to 1961–1990 for a 1/8° grid. Statewide, SRES B1 to A1fi winter temperature projections for the end of the century are 2.2–3°C and 2.3–4°C for PCM and HadCM3, respectively, compared with previous projections of 1.2–2.5°C and 3–3.5°C for PCM and HadCM2, respectively. End-of-century B1 to A1fi summer temperature projections are 2.2–4°C and 4.6–8.3°C for PCM and HadCM3, respectively, compared with previous projections of 1.3–3°C and 3–4°C for PCM and HadCM2, respectively (11–14).

Hayhoe, K., D. Cayan, C. B. Field, P. C. Frumhoff, E. P. Maurer, N. L. Miller, S. C. Moser, S. H. Schneider, K. N. Cahil, E. E. Cleland, L. Dale, R. Drapek, R. M. Hanemann, L. S. Kalkstein, J. Lenihan, C. K. Lunch, R. P. Neilson, S. C. Sheridan, and J. H. Verville. 2004. Emissions pathways, climate change, and impacts on California. Proceedings of the National Academy of Sciences, USA **101**:12442--12427.



West
North Central
East
Central
Northwest
Northeast
North Central
West
Southwest
South
Southeast
Alaska
Hawaii
Change in precipitation (% per century):
-30
-20
-10
0
10
20
30

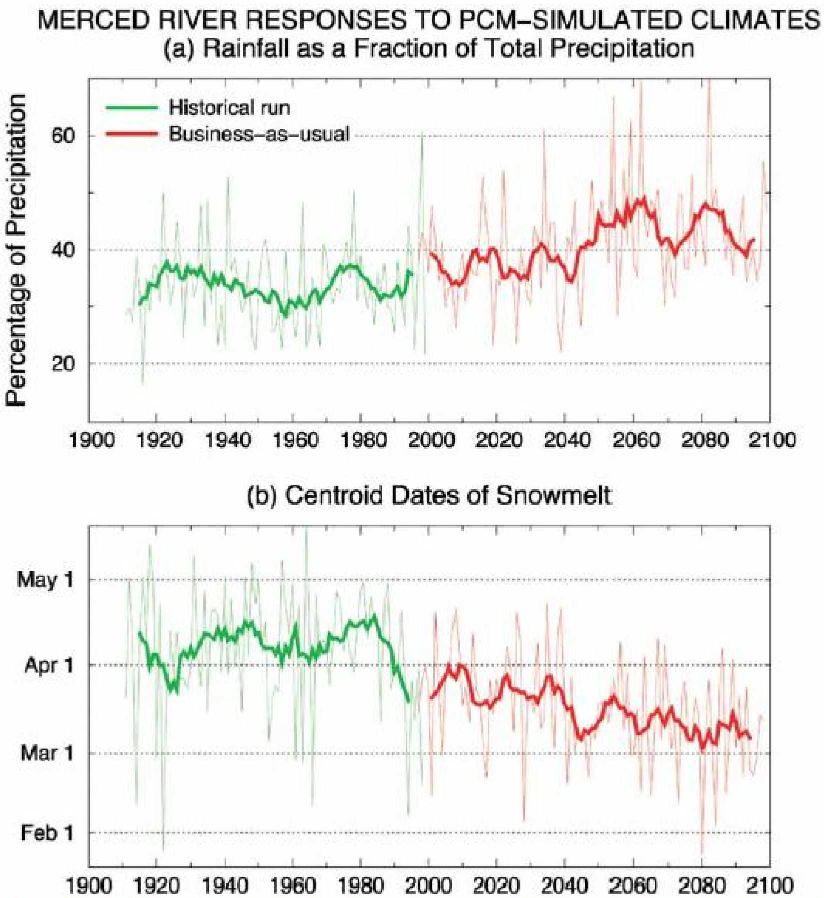
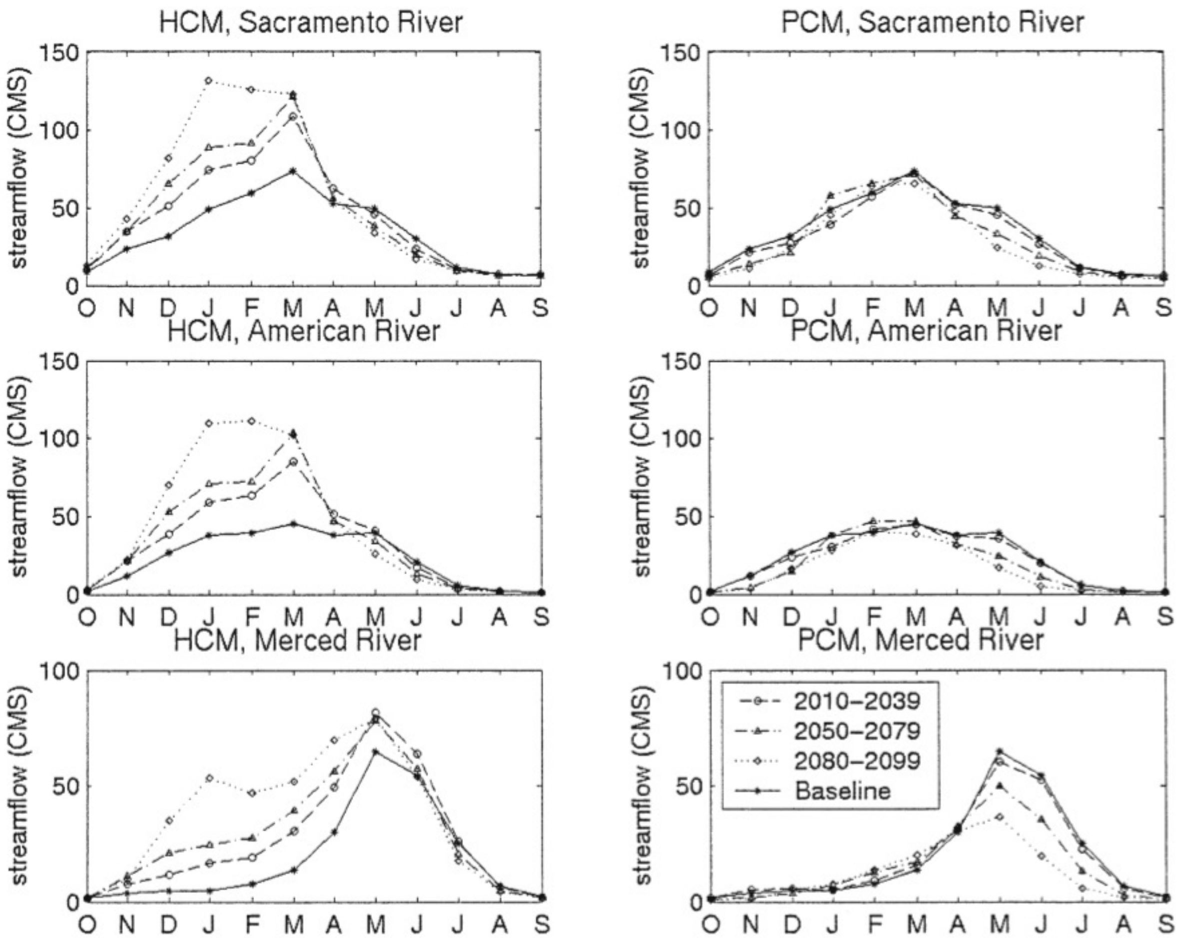
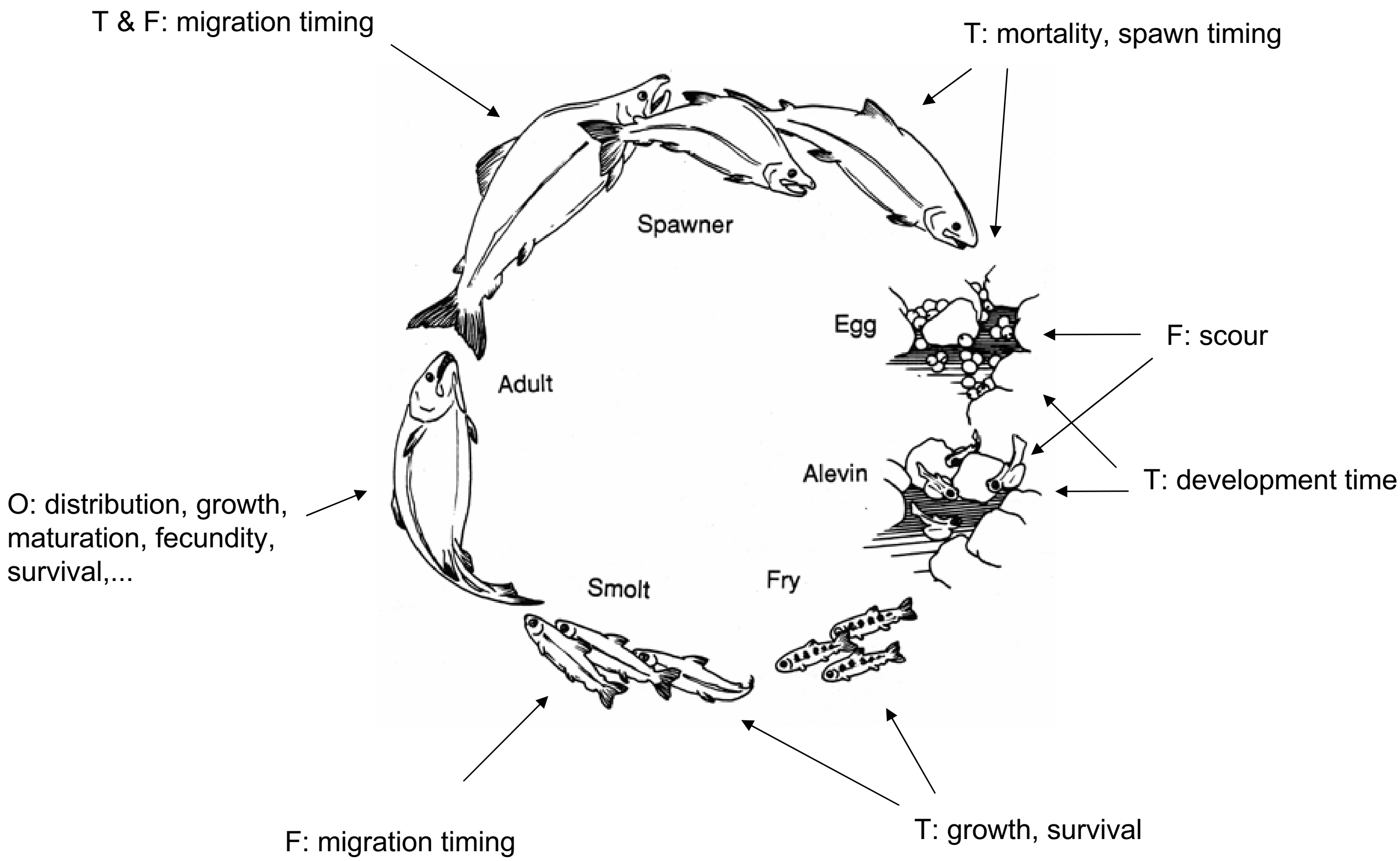


Figure 10. (a) Water-year fractions of total precipitation as rainfall; and (b) water-year centroids of snowmelt timing in the Merced River basin, in response to PCM-simulated climates; heavy curves are 9-yr moving averages.

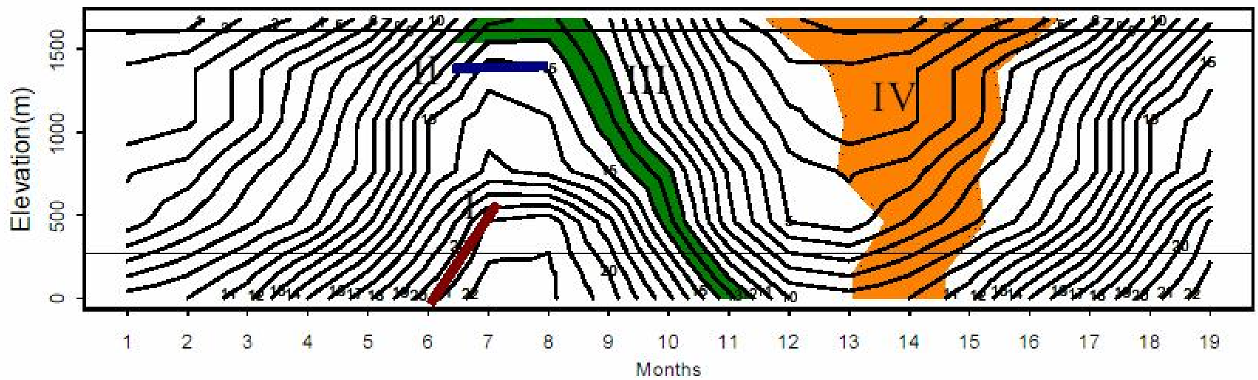
Dettinger, M. D., D. R. Cayan, M. K. Meyer, and A. E. Jeton. 2004. Simulated hydrologic responses to climate variations and change in the Merced, Carson, and American River basins, Sierra Nevada, California, 1900--2099. Climatic Change **62**:283-317.

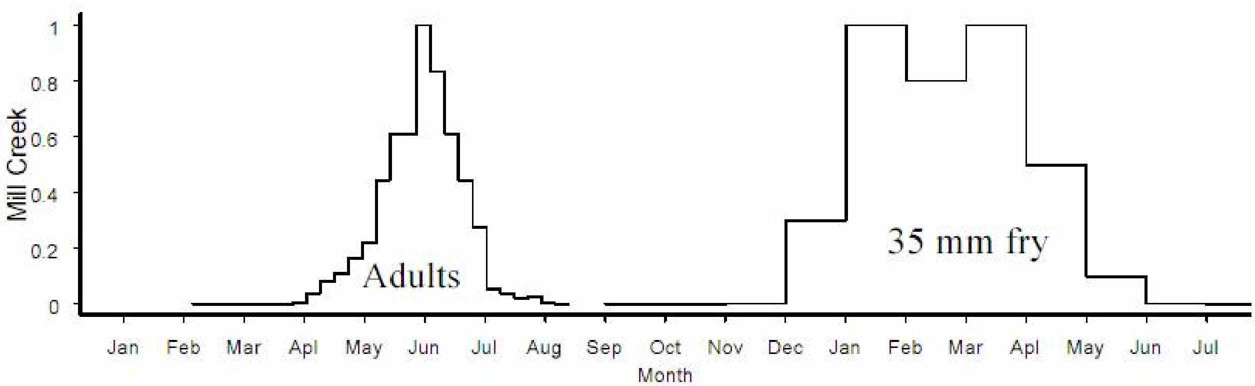


Miller et al. 2003. J Amer Wat Res Assoc 39(4): 771-784


T & F: migration timing
T: mortality, spawn timing
Spawner
Egg
F: scour
Adult
Alevin
T: development time
O: distribution, growth, maturation, fecundity, survival,...
Smolt
Fry
F: migration timing
T: growth, survival

Species	Season winter	spring	summer	fall
winter chinook	adults enter FW; fry migrate dhownstream	adults migrate to headwater springs; smolts enter ocean	adults spawn in headwater springs	fry emerge, rear in springs
spring chinook	adultsin ocean, fry in river	adults enter FR, smolts enter ocean	adults hold in high-elev. pools	adults spawn in rivers above barriers to fall chinook
fall chinook	eggs and fry in lower river	smolts enter ocean	all in ocean	adults enter FW
late-fall chinook	adults enter FW and spawn in river	fry in river, smolts (1y.o.) enter ocean	parr in FW	parr in FW
steelhead	adults enter FW	adults spawn in small tribs; smolts enter ocean	parr in FW	parr in FW





Lindley, S. T., R. S. Schick, B. May, J. J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2004. Population structure of threatened and endangered chinook salmon ESUs in California's Central Valley basin. NOAA Tech. Memo. NMFS-SWFSC-360, U.S. Dept. Commer., La Jolla, CA.

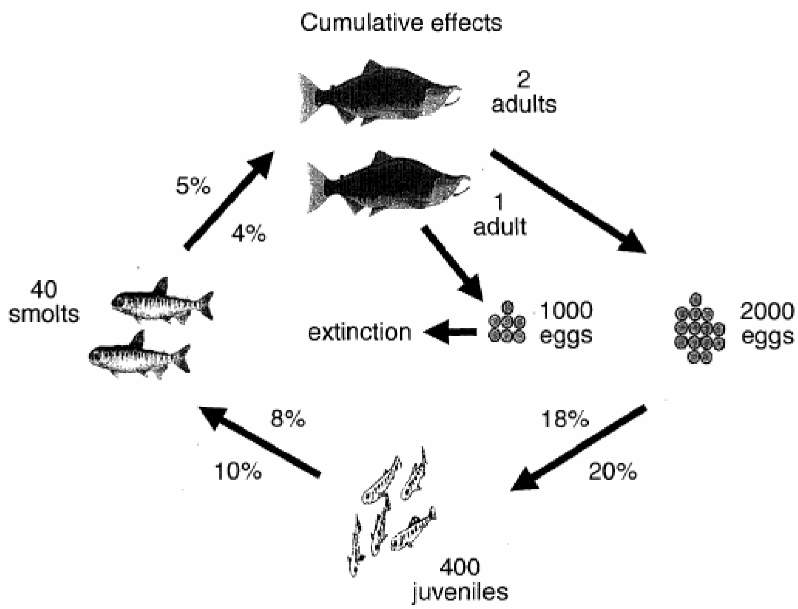
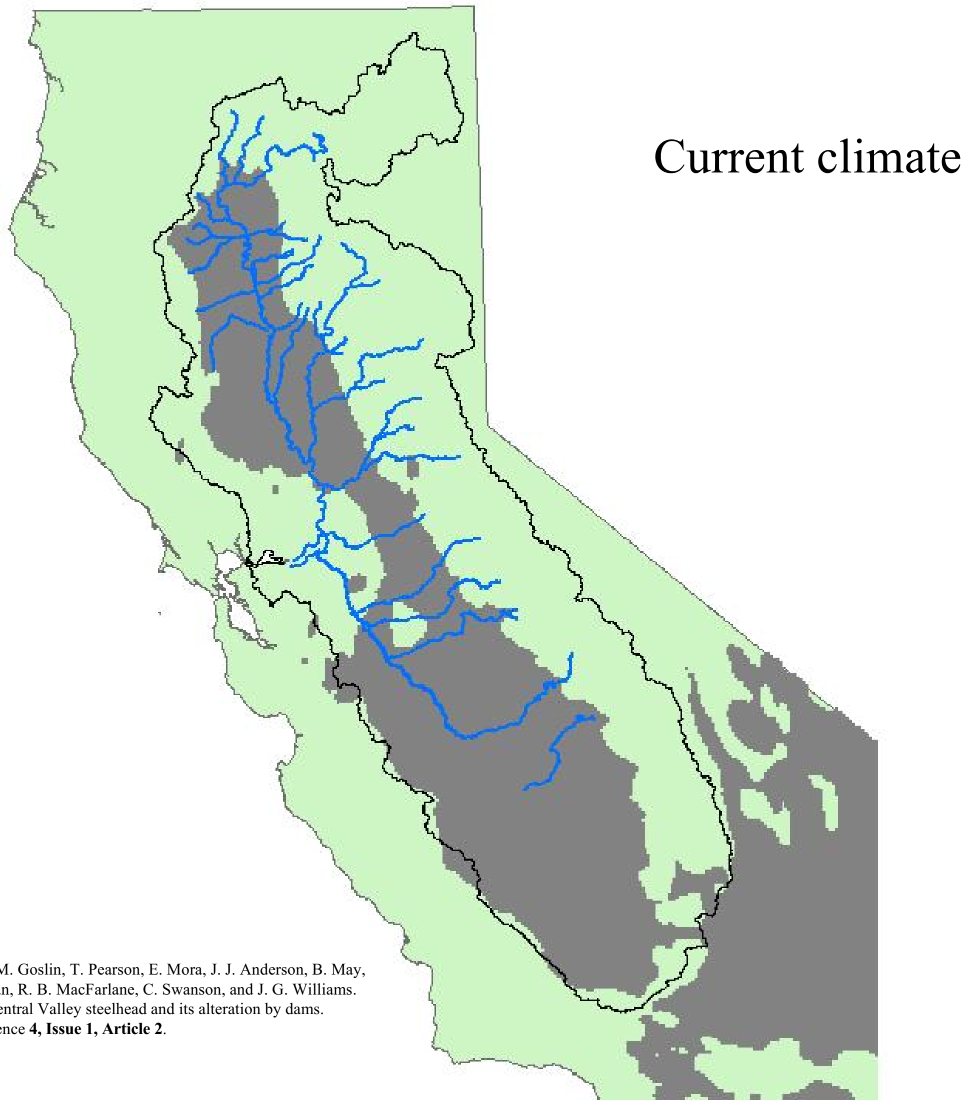
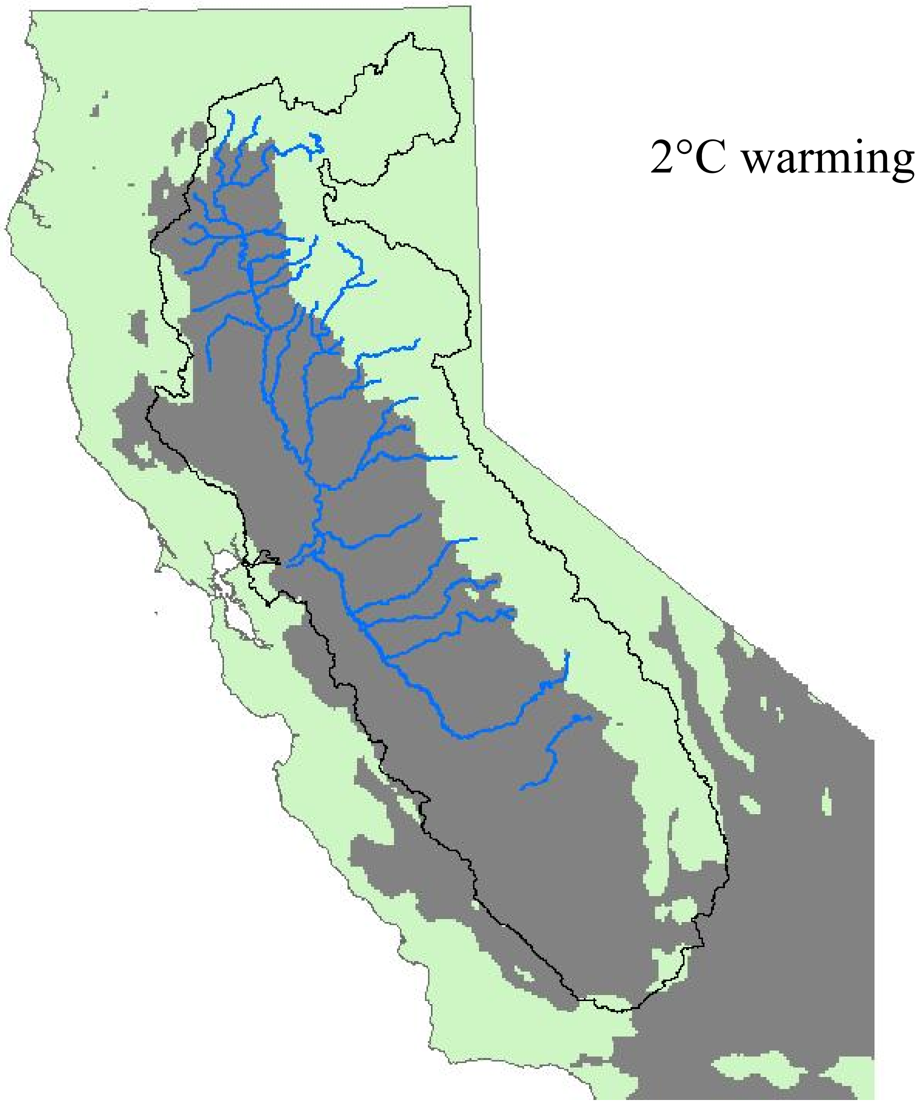


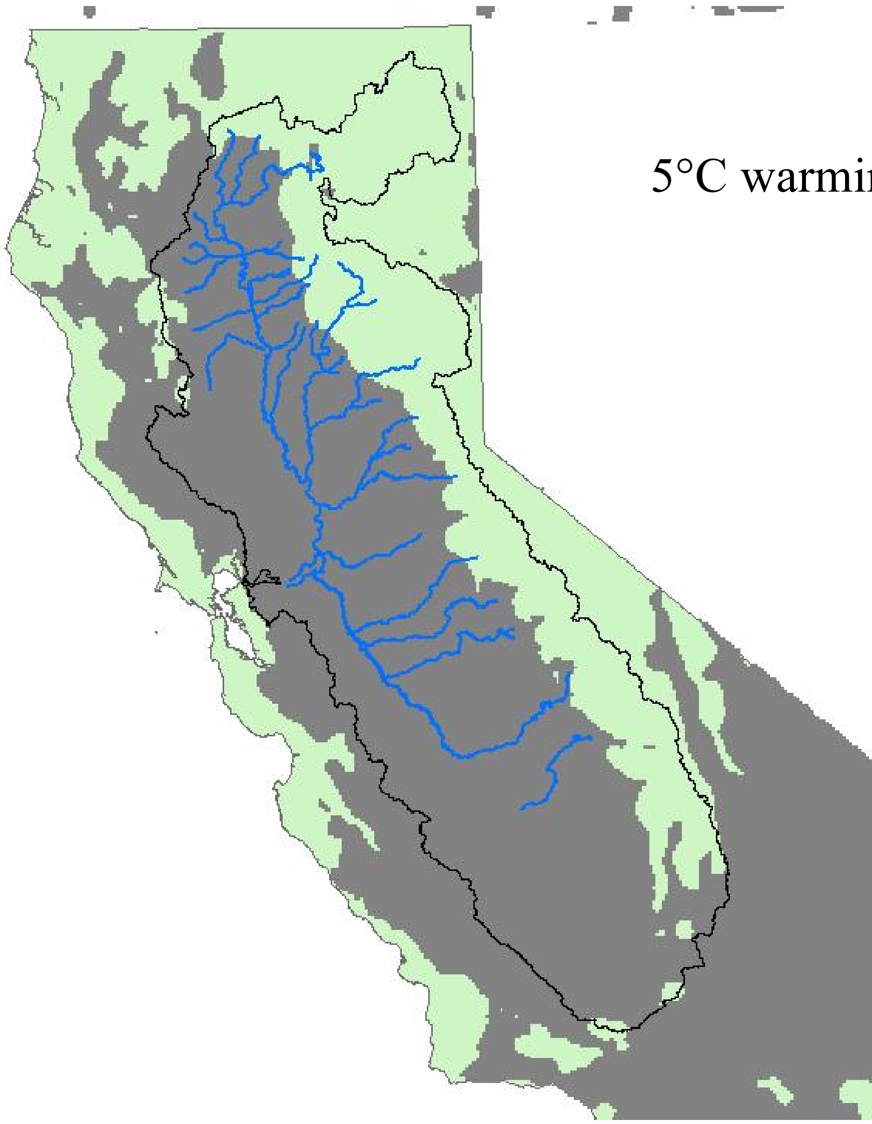
FIG. 9. Illustration of cumulative effects associated with different life stages of Pacific salmon. It is possible to increase population size, or drive the population to extinction, by only slight changes in survivorship at each life history stage. See *Consequences: Cumulative effects* for full explanation.

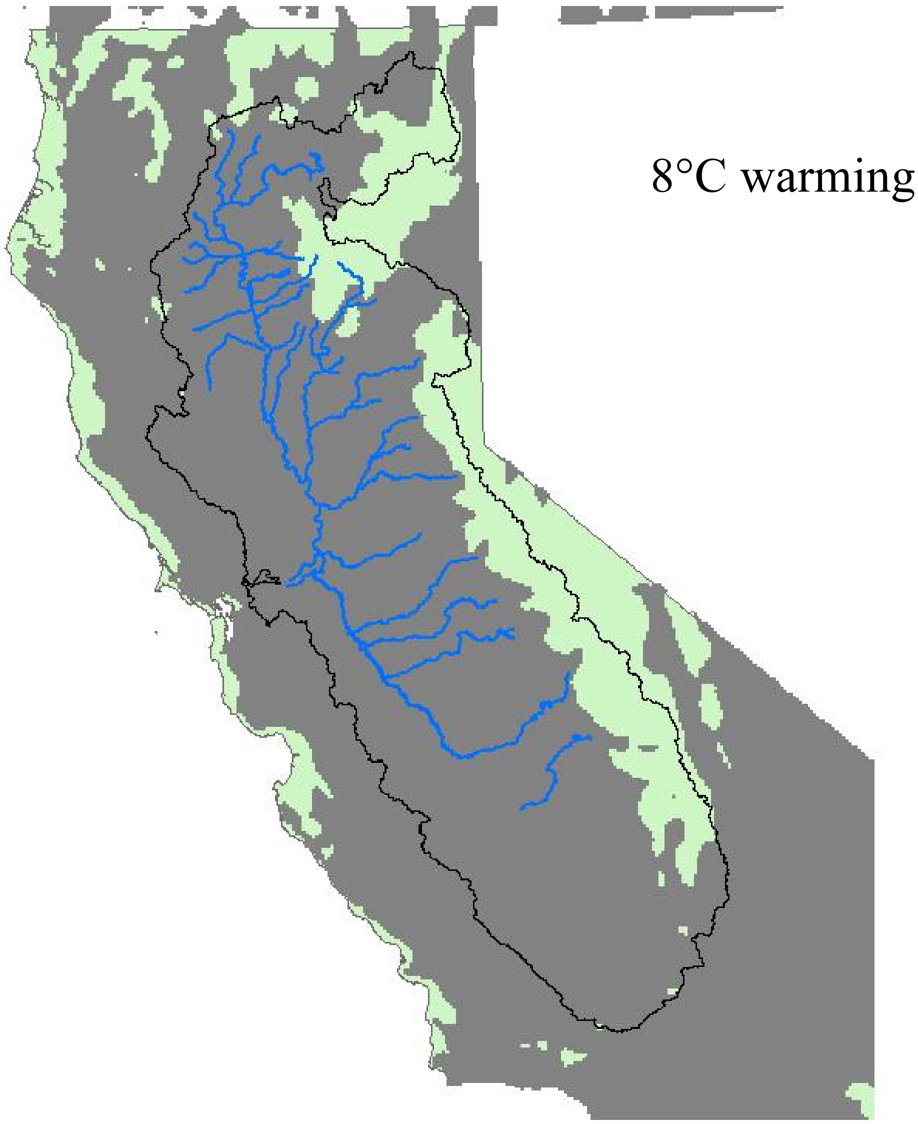
Naiman and Turner. 2000. Ecol Appl 10(4): 958-970.

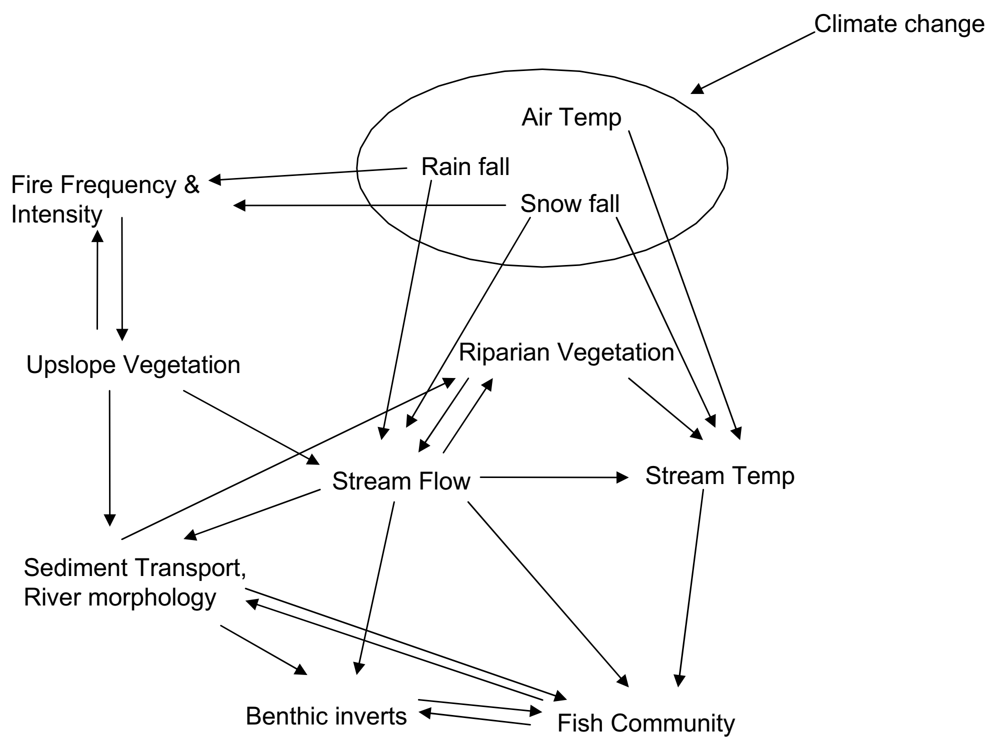


Lindley, S. T., R. S. Schick, A. Agrawal, M. Goslin, T. Pearson, E. Mora, J. J. Anderson, B. May, S. Greene, C. Hanson, A. Low, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2006. Historical population structure of Central Valley steelhead and its alteration by dams. San Francisco Estuary and Watershed Science **4, Issue 1, Article 2**.


2°C warming


5°C warming


8°C warming


Climate change
Air Temp
Rain fall
Snow fall
Fire Frequency &
Intensity
Upslope Vegetation
Riparian Vegetation
Stream Flow
Stream Temp
Sediment Transport,
River morphology
Benthic inverts
Fish Community

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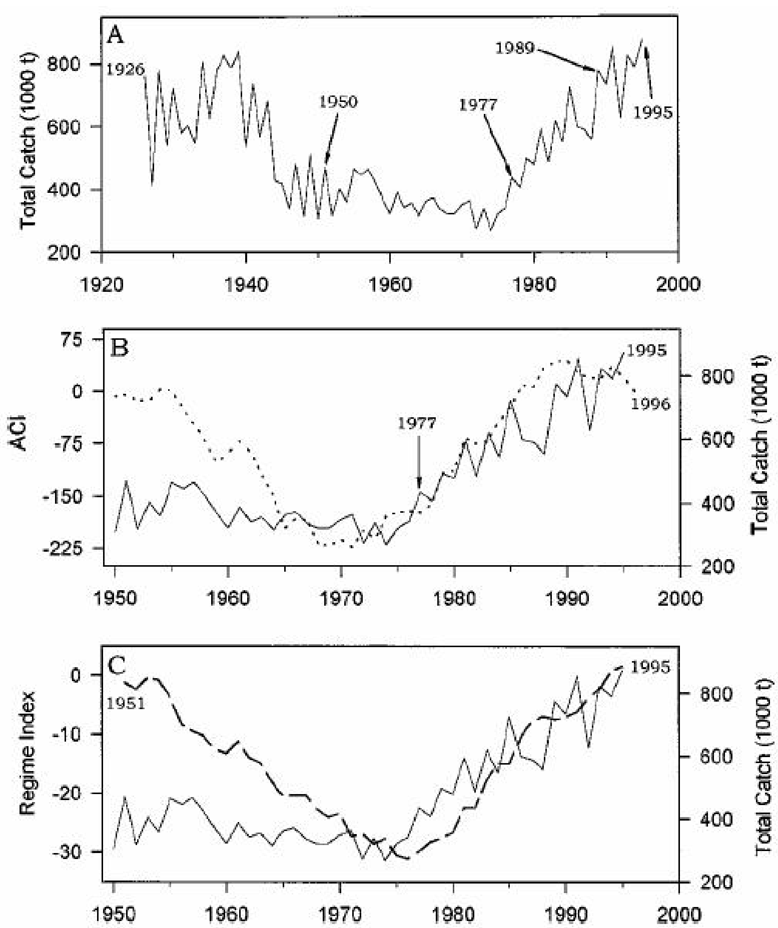
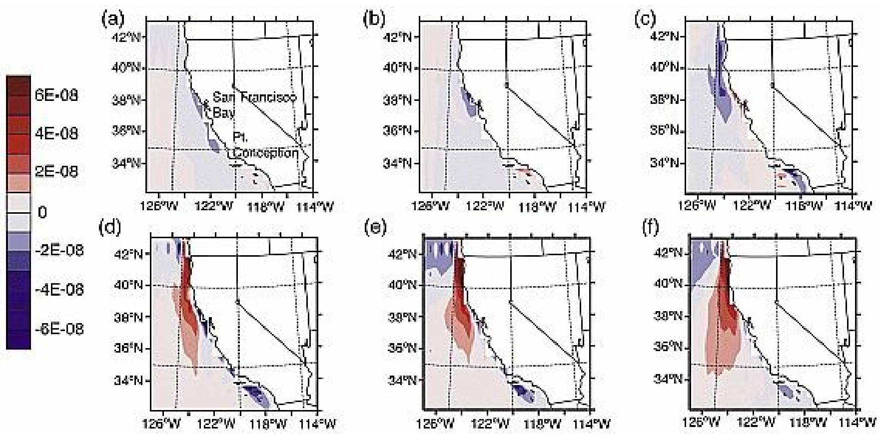
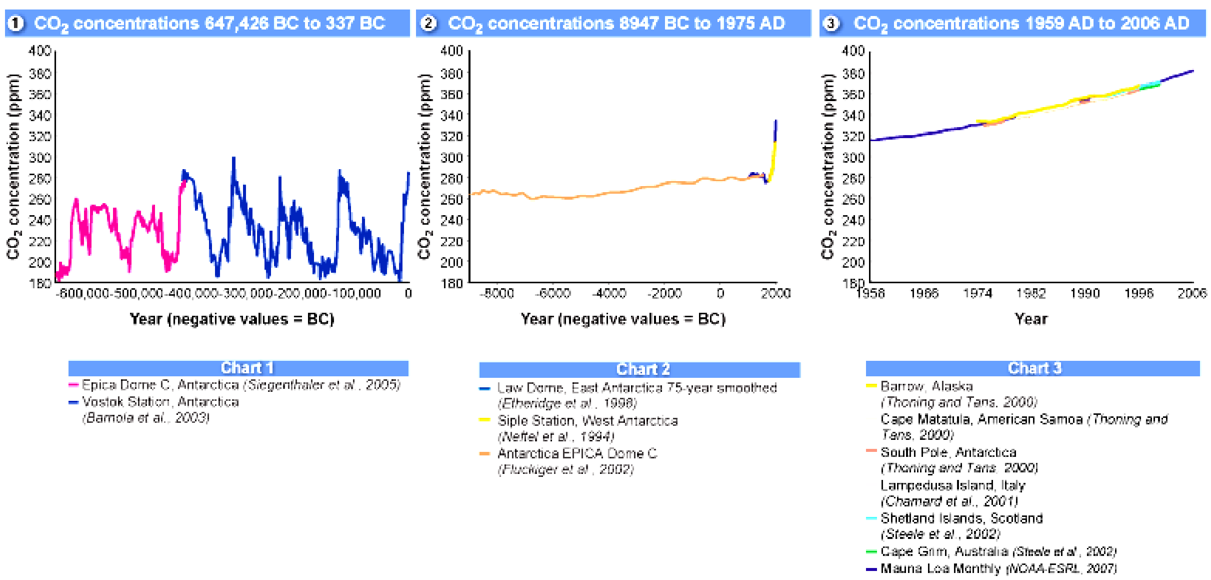


Fig. 6. (A) Total North Pacific catch of pink, chum, and sockeye salmon from 1926 to 1995. (B) Relationship between total catch (solid line) and general atmospheric circulation index (ACI) dotted line, from 1950 to 1995 (ACI is shown to 1996). (C) The relationship between total catch (solid line) and the regime index (broken line) from 1950 to 1995. Note that the CuSum form demonstrates the persistance of trends before and after the change in the late 1970's.



Difference of the monthly average wind-stress curl (N/m^2), calculated as 2X-1X, for (a) Apr, (b) May, (c) June, (d) July, (e) August, (f) September. From Snyder, 2003. Geophys Res Let 30: 1823.



http://www.epa.gov/climatechange/science/images/atmosph_conc_co2-lg.gif