Changing central Pacific El Niños affect survival rates of North American salmon

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Our Story

- The **North Pacific Gyre Oscillation** explains factors related to **ecosystem productivity**
- **NPGO** is linked to **central Pacific warming-type ENSO**, which is more frequent in recent decades
- **NPGO** linked to **coho** and **Chinook** salmon **survival** rates, which are becoming increasingly **coherent**
- Concern that coherence in survival causes **increased overall variability**

Approach

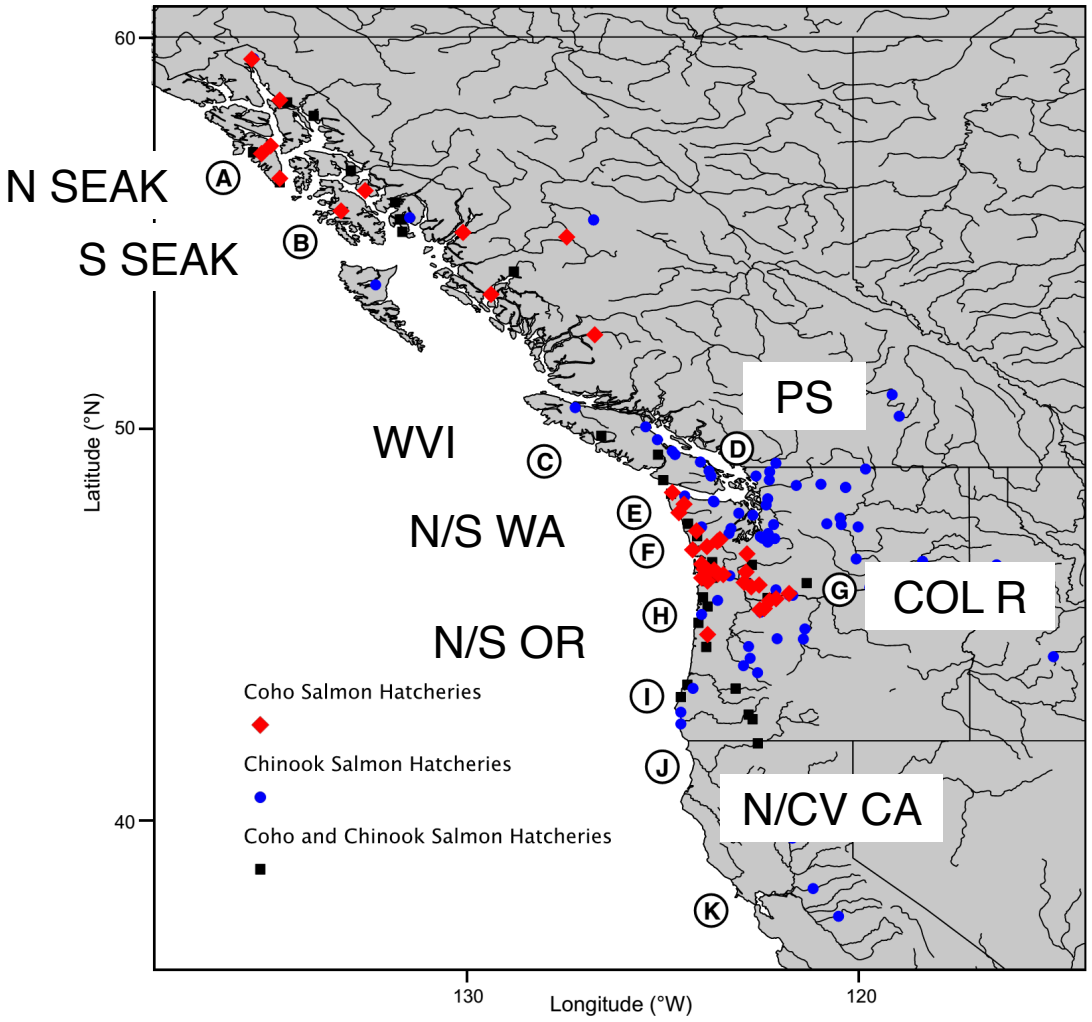
- Early ocean survival a critical period for salmon
- Used CWT-based estimates of coho and Chinook salmon survival to investigate:
  - Spatial and temporal coherence of survival rates from AK to CA, 1980-2006
  - Relationships between survival rates and low-frequency, broad spatial scale environmental variability (NPGO, PDO)
  - Consequences of coherent responses to environmental variability on harvest (simulations)

Background

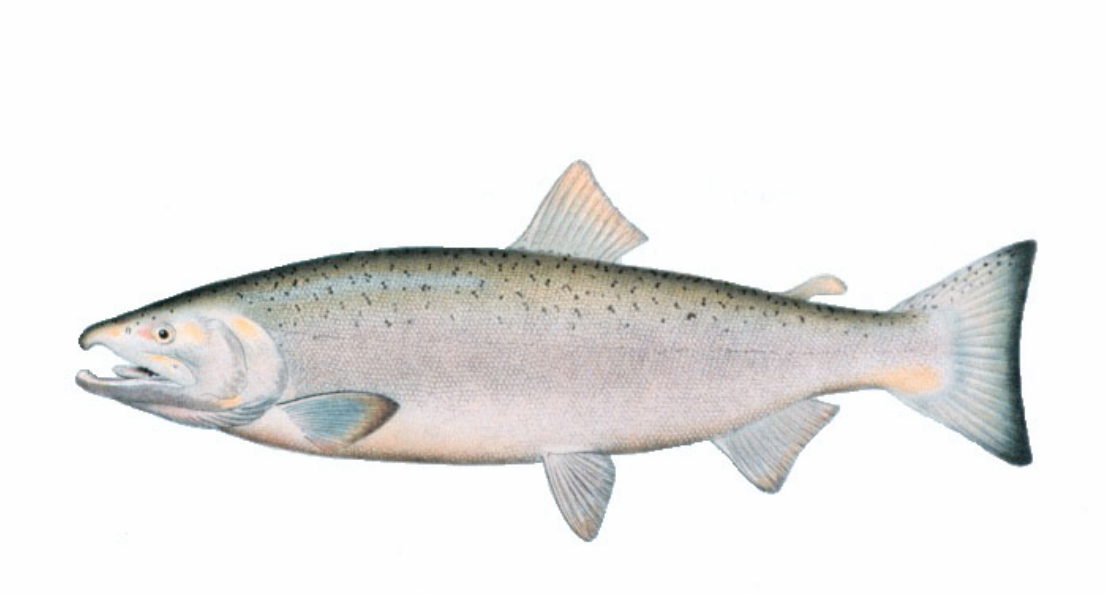
- Pacific Decadal Oscillation (PDO) linked to important changes in salmon productivity:
  - Most salmon species had long-term, synchronous changes in mid-1920s, mid-1940s and mid-1970s
- California Current salmon productivity:
  - Coho: spatially coherent fluctuations
  - Chinook: varied at smaller spatial scales
  - Different spawning-age distributions

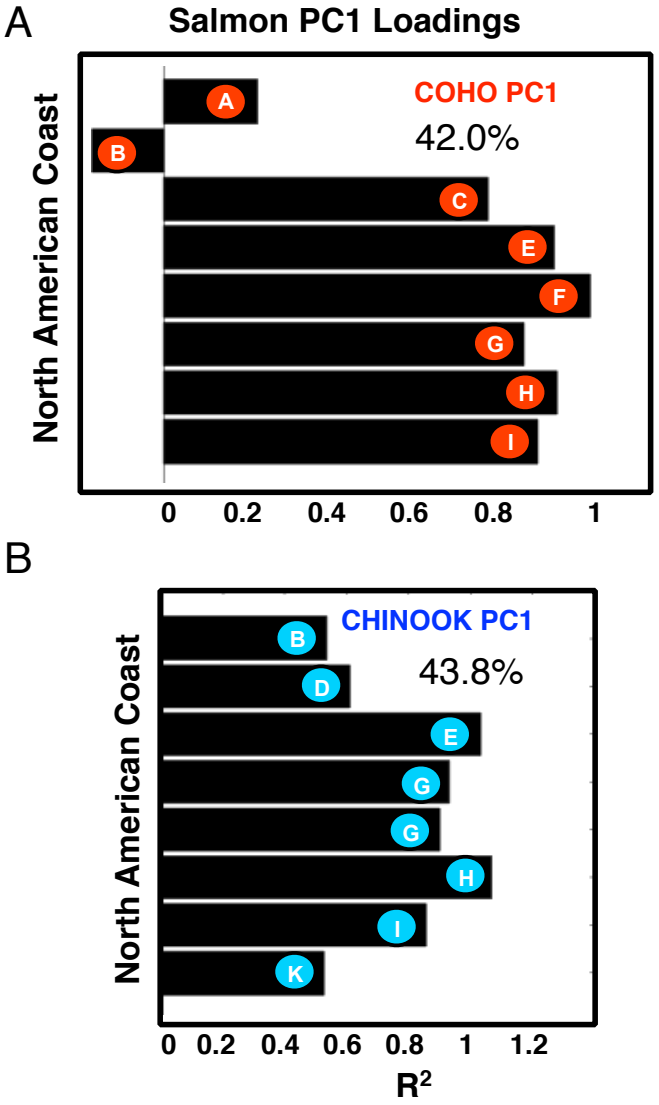
Mantual et al. 1997, Mantua and Hare 2002, Botsford and Lawrence 2002

Getting oriented



How do coho and Chinook survival rates vary over space?





Chinook PC 1: 1986-2006

- Principal components of survival time series
- Contribution of each region to 1st principal component
- Coho: high loadings in CCS; lowest in AK
- Chinook: high loadings OR to WA; lower in S and N
- **Spatial coherence within species**

Regional covariability: coho

- Coherence from Vancouver Is. to Oregon

(A)

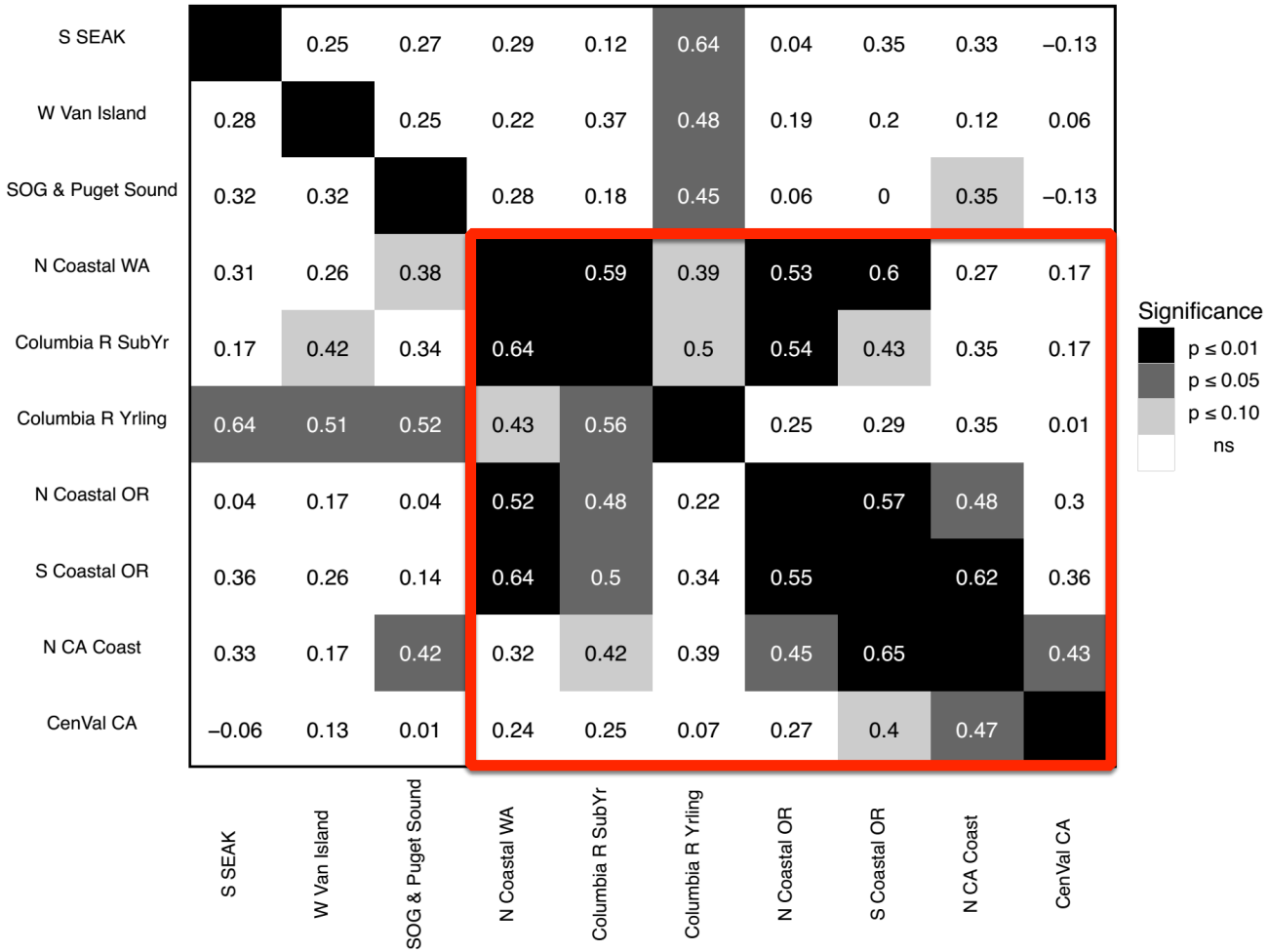
	North SEAK	South SEAK	North BC	Vancouver I.	North WA	South WA	Columbia R.	North OR	South OR	North CA
North SEAK		0.445	0.165	-0.081	0.154	0.153	0.017	-0.047	0.149	-0.526
South SEAK	0.425		0.602	-0.205	-0.024	-0.293	-0.076	-0.092	-0.128	-0.219
North BC	0.233	0.572		0.021	0.306	0.246	0.310	0.376	0.401	-0.998
Vancouver I.	0.192	-0.117	0.149		0.477	0.671	0.346	0.429	0.266	-0.299
North WA	0.144	-0.021	0.262	0.319		0.684	0.347	0.445	0.337	-0.572
South WA	0.175	-0.284	0.290	0.584	0.669		0.580	0.614	0.591	-0.097
Columbia R.	0.064	-0.094	0.347	0.424	0.318	0.581		0.787	0.572	0.486
North OR	-0.051	-0.090	0.338	0.309	0.446	0.606	0.755		0.552	-0.179
South OR	0.191	-0.145	0.447	0.430	0.306	0.577	0.610	0.502		0.283
North CA	-0.663	-0.262	0.686	-0.218	-0.441	-0.133	0.630	0.064	0.256	

$p \leq 0.10$ $p \leq 0.05$ $p \leq 0.01$

Teo et al. 2009

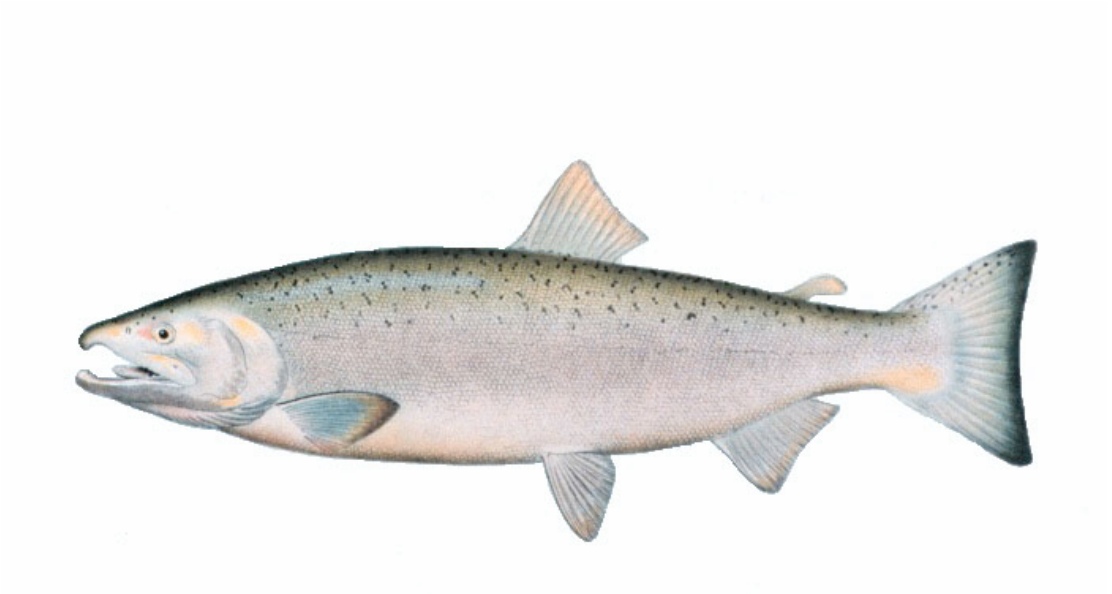
Regional covariability: Chinook

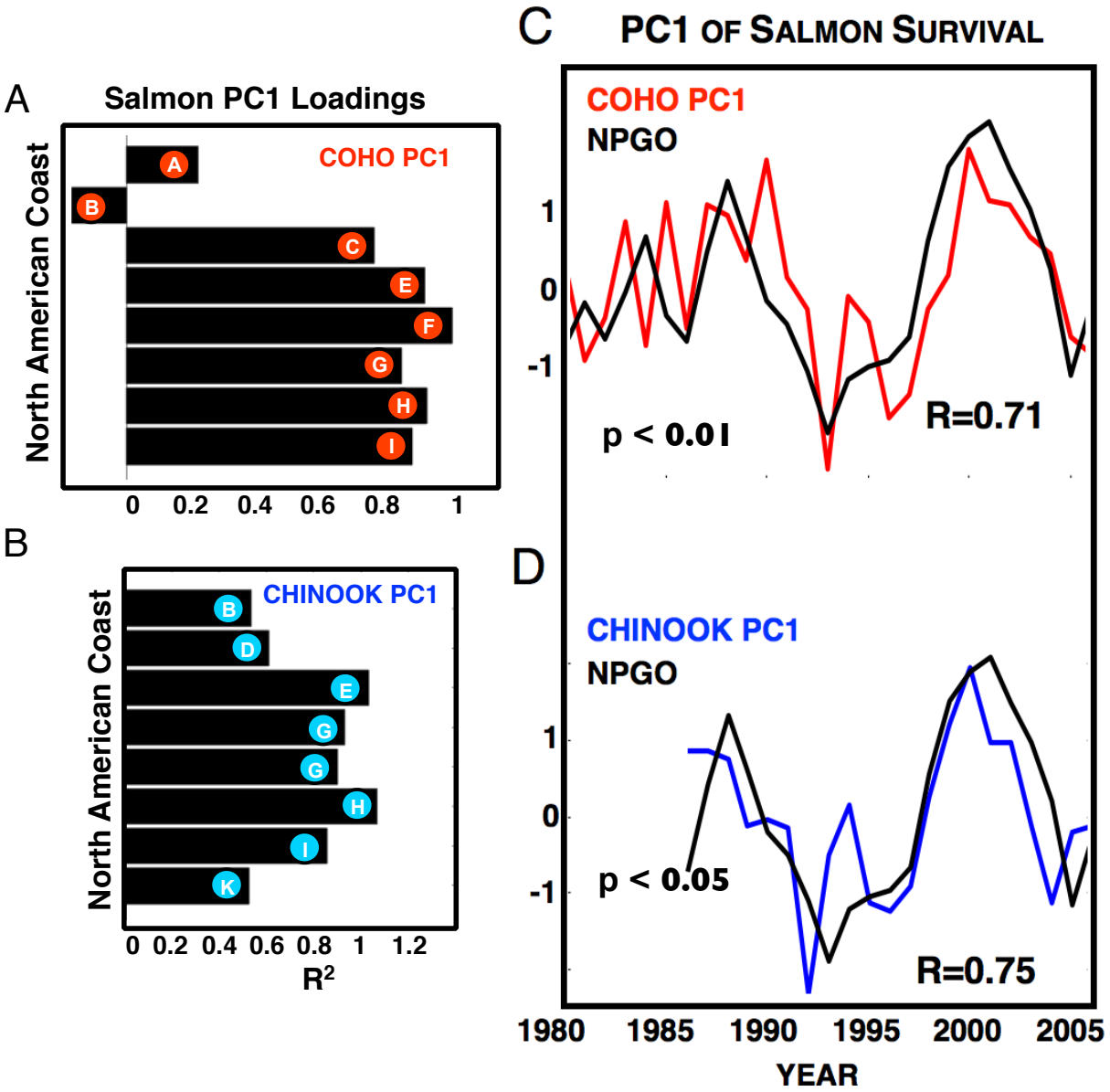
- Coherence WA to CA



Kilduff et al. in press

How does survival relate to large-scale ocean conditions?



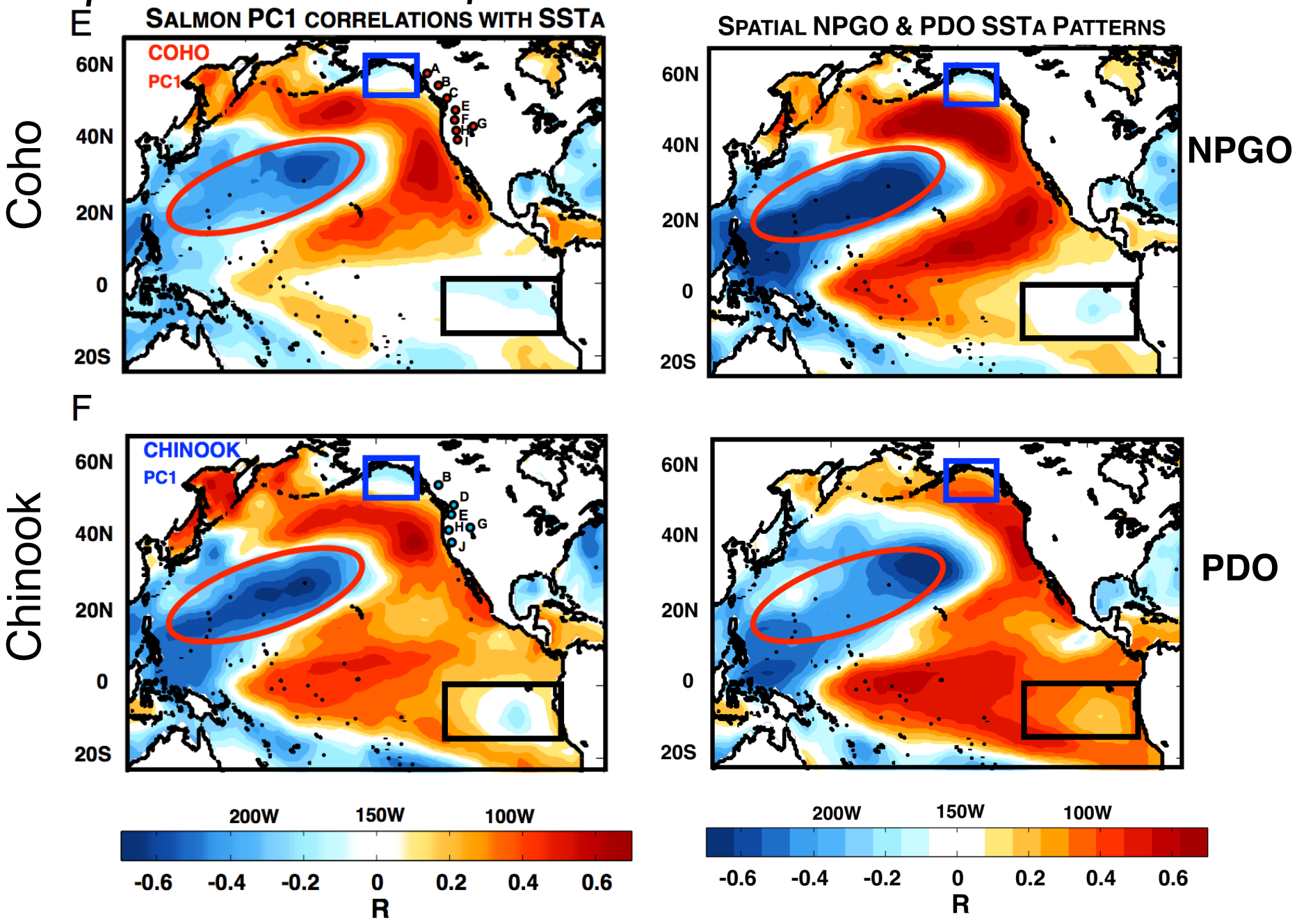


Chinook PC 1: 1986-2006

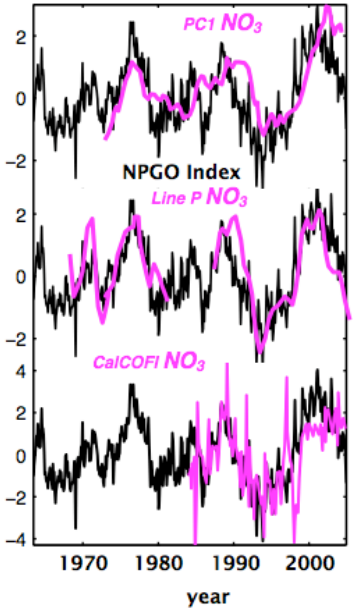
Each PC1 is highly correlated with NPGO

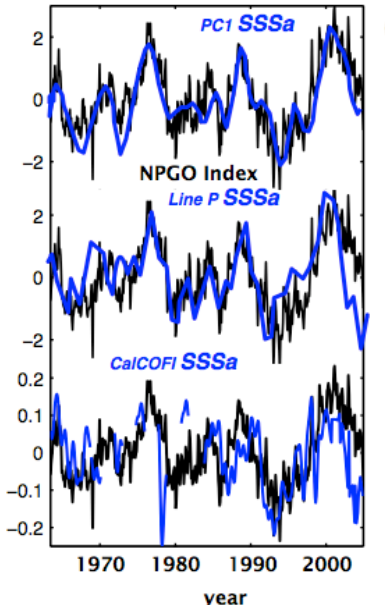
Correlation with PDO not significant

Spatial correlation of PC1s with SST like NPGO

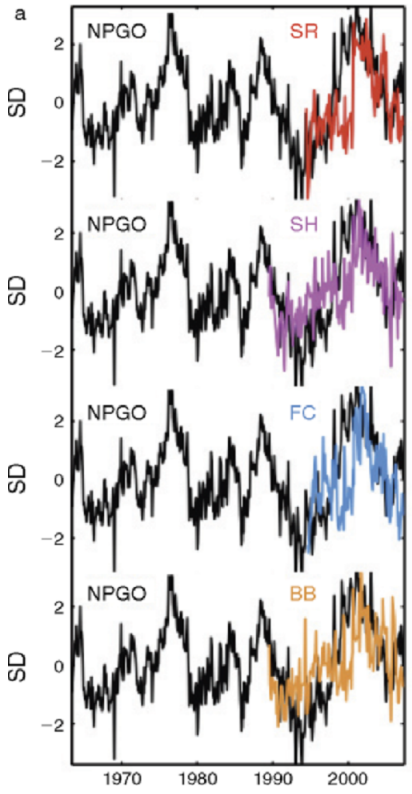


NPGO → ecosystem



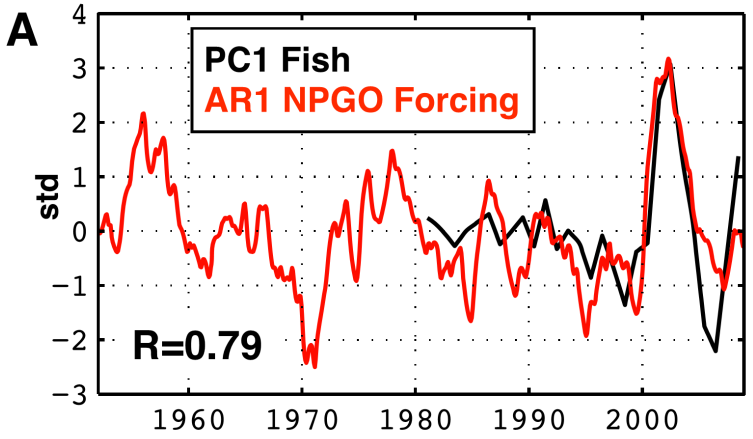


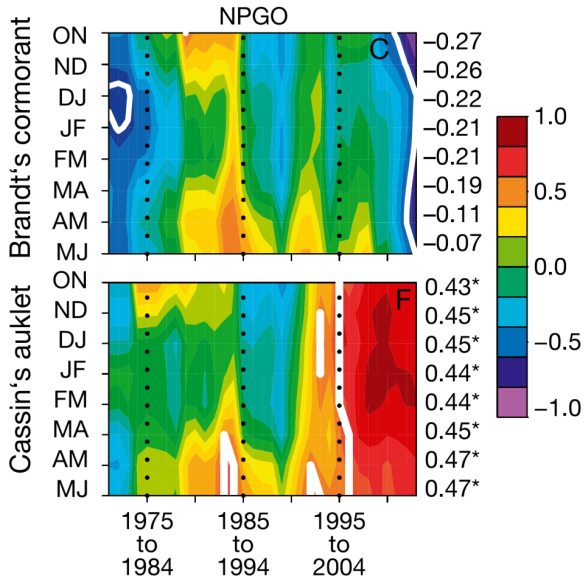
Di Lorenzo et al. 2008
(http://www.o3d.org/npgo/)



Menge et al. 2009

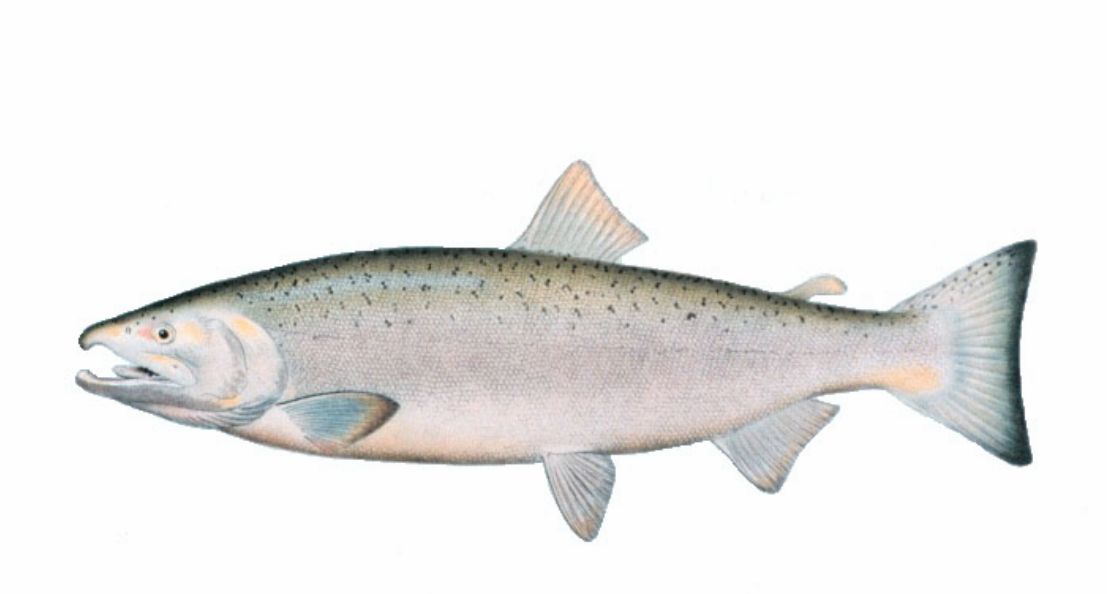
Cloern et al. 2010



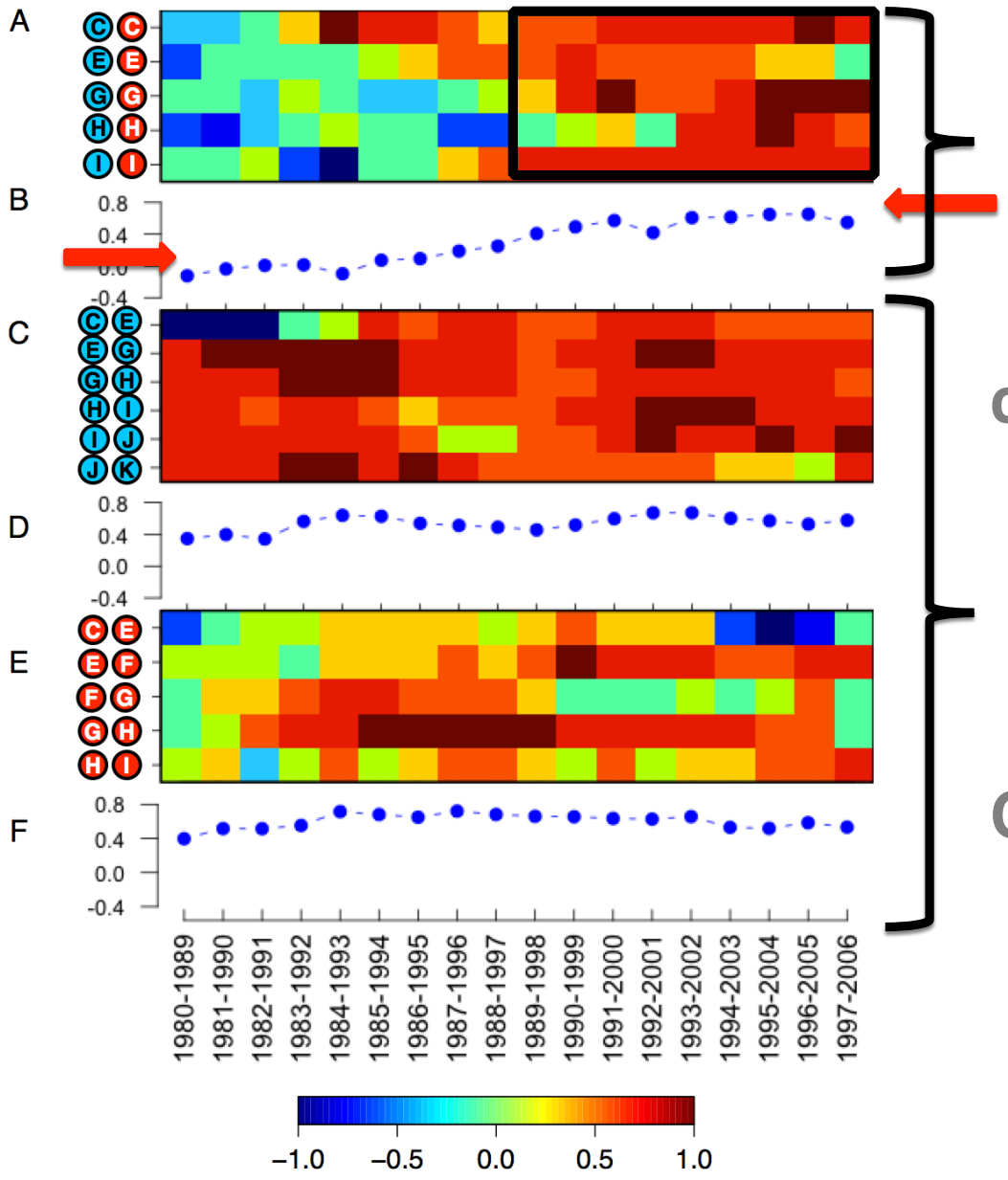


Schmidt et al. 2014

How did these species become “similar”?



Increased between species correlation



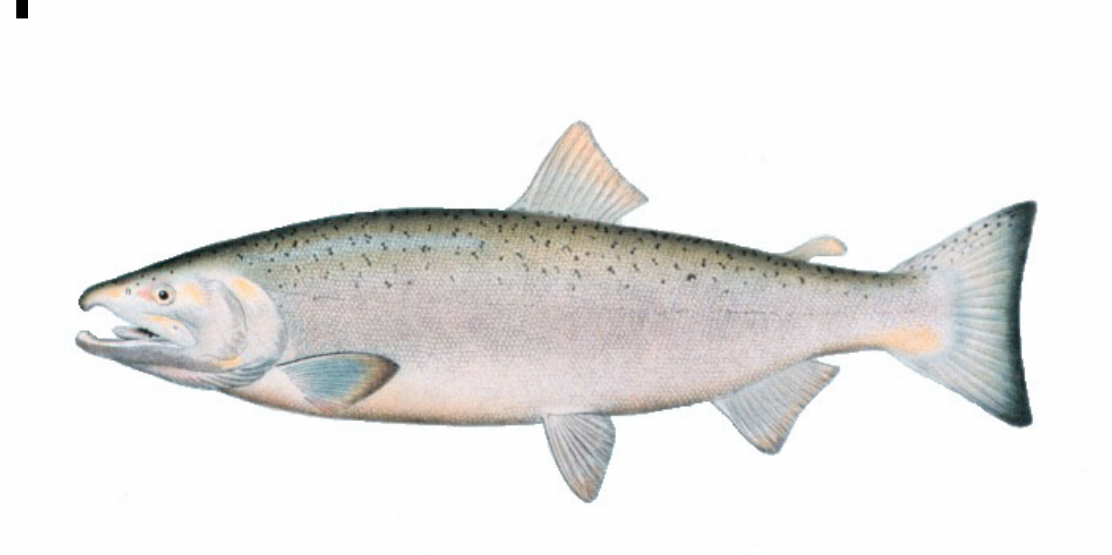
between species, same region

coho

within species, neighboring regions

Chinook

What are the consequences of increased between species coherence?

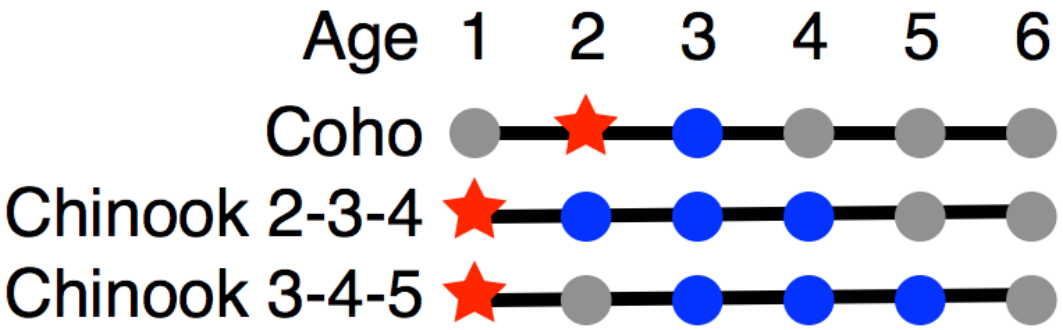


Population diversity and stability

- Independent sub-populations buffer aggregate response to environmental variability:
  - Decreased overall population risk
  - Reduced risk of overharvest
- Species diversity important for community stability
- Increased covariability in two components of ecosystem

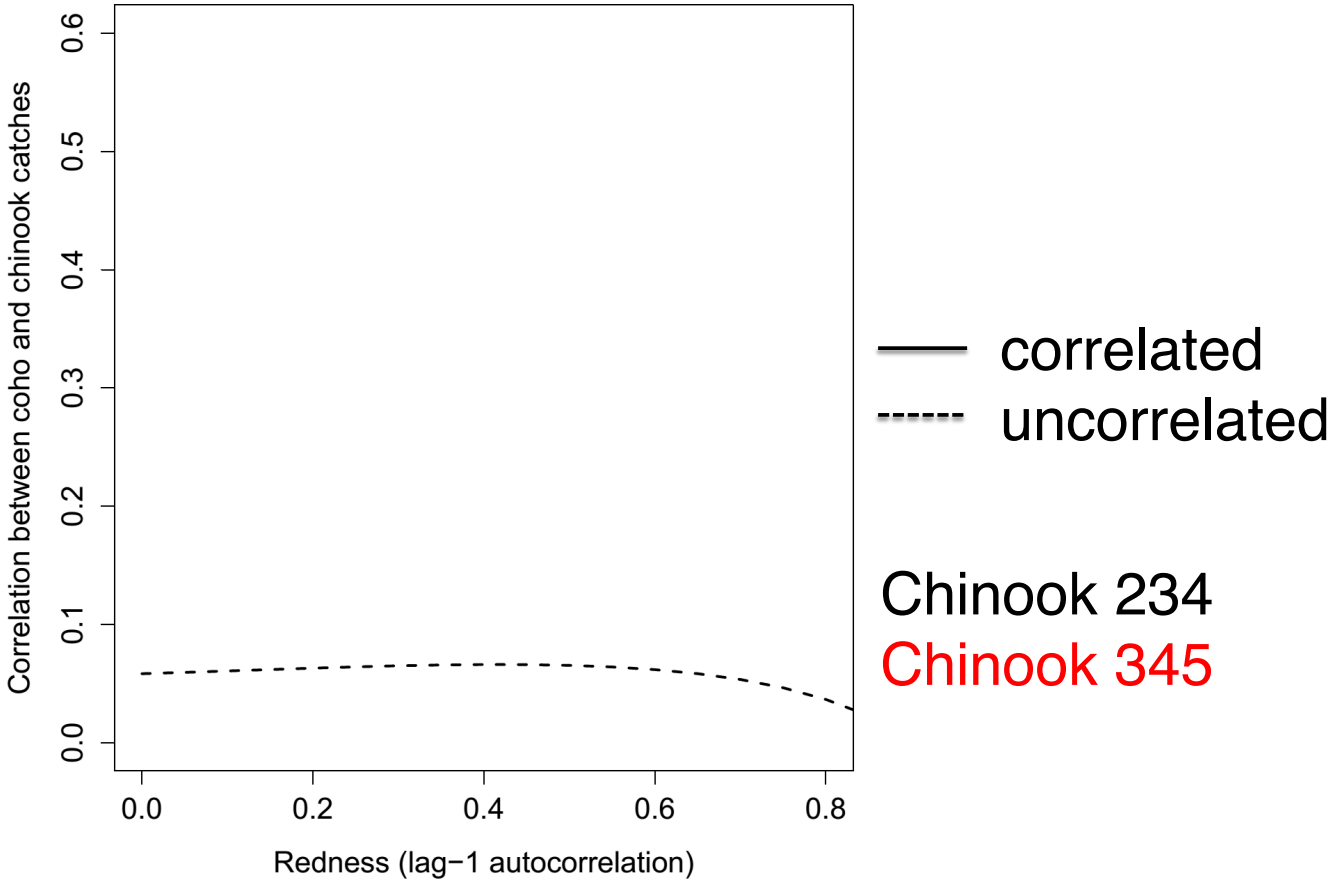
(Tilman 1996; Doak et al. 1998; Schindler 2010)

Effects of coherence over different life histories?



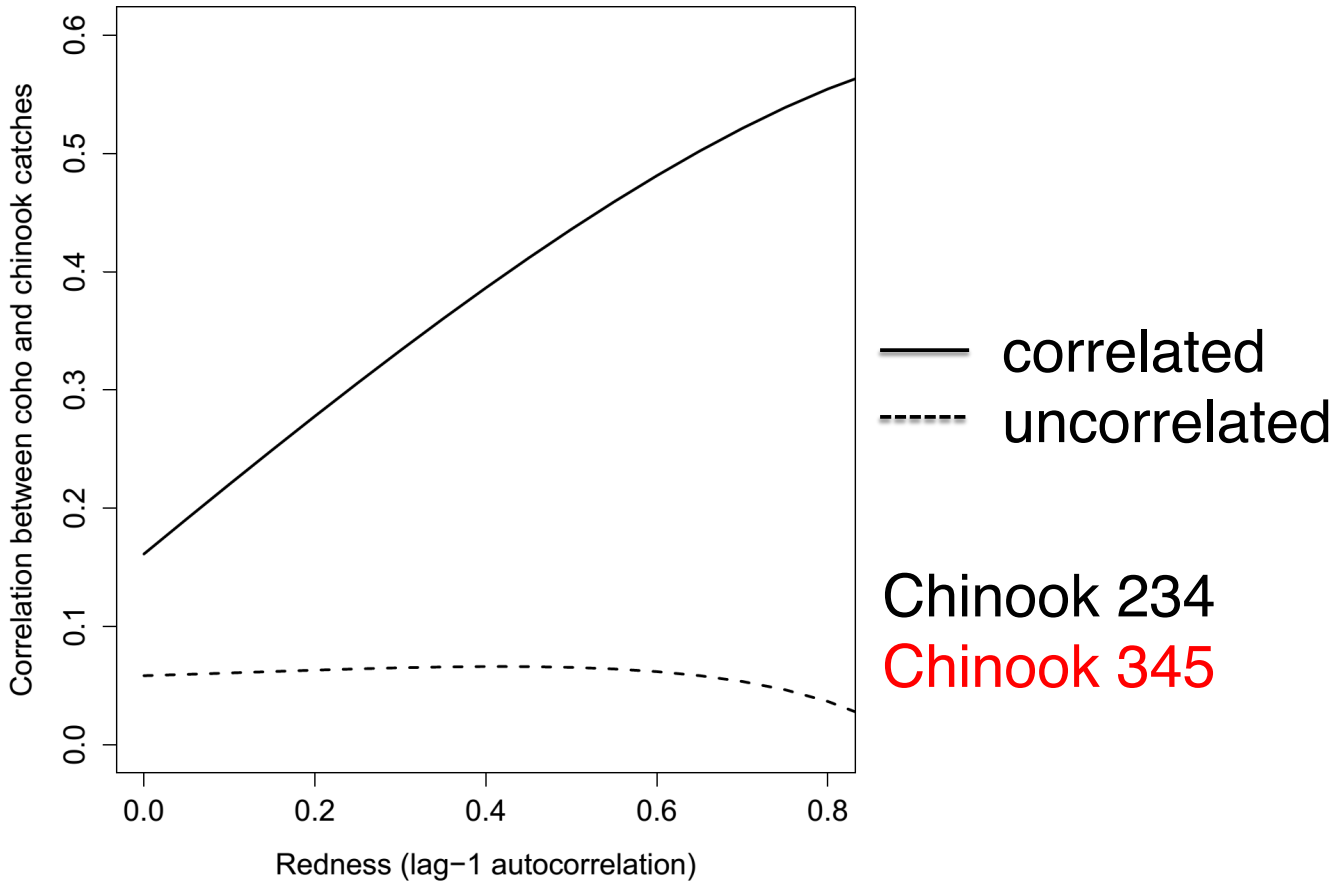
- Environmental variability → ocean survival at ocean entry ★
- Coho have a 1-year time lag from to harvest ●
- Chinook salmon broader age distributions
  - Different lags and longer lags than coho
- Impact on catch?
  - Function of survival correlation between species and intra-series correlation

Consequence of coherence?



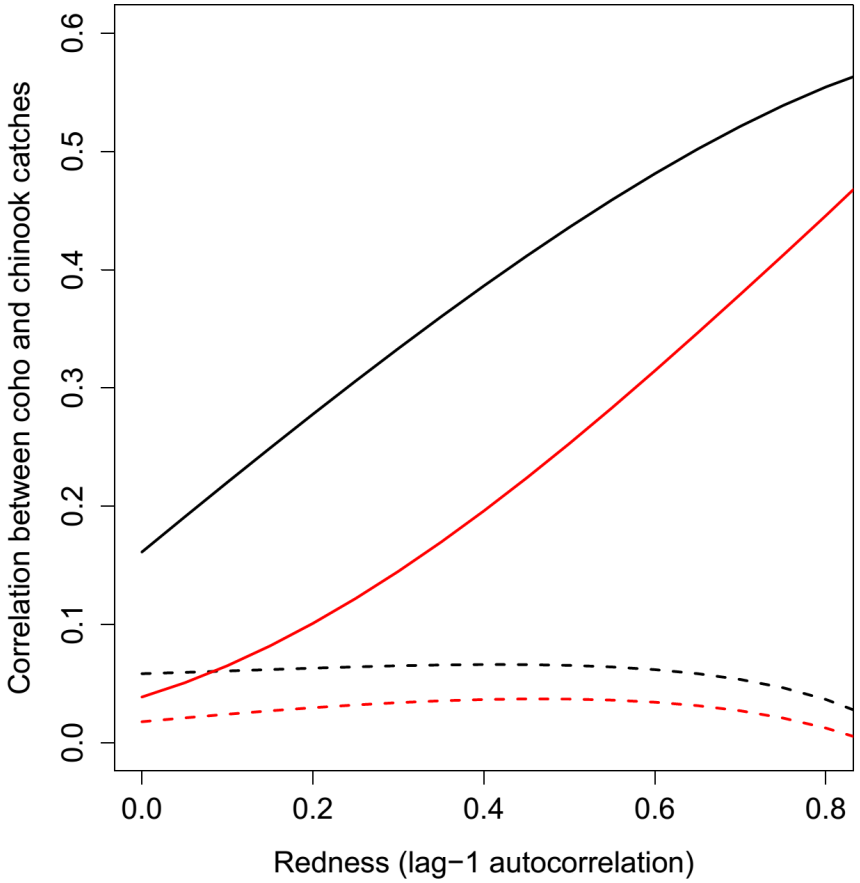
No matter how “red” the noise, if coho and Chinook (2,3,4) survival does not have a similar response to environment, catches will not be correlated

Consequence of coherence?



What coho and Chinook salmon have correlated survival rates, catch correlation increases with increasing redness

Consequence of coherence?



Chinook 345 have longer lags from ★ to ●, which decreases correlation of catches

Take home message

- Both species have **spatial coherence**
- Dominant mode of variability in survival of **both species covaries** with the **NPGO**, which is linked to **central Pacific warming**
- Increased covariability between species implies **greater aggregate variability** in catch and abundance

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