What do Indicators Indicate?

Northwest Power and Conservation Council – Ocean Forum
April 4th, 2024

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NOAA Fisheries, NWFSC

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Also supported by:

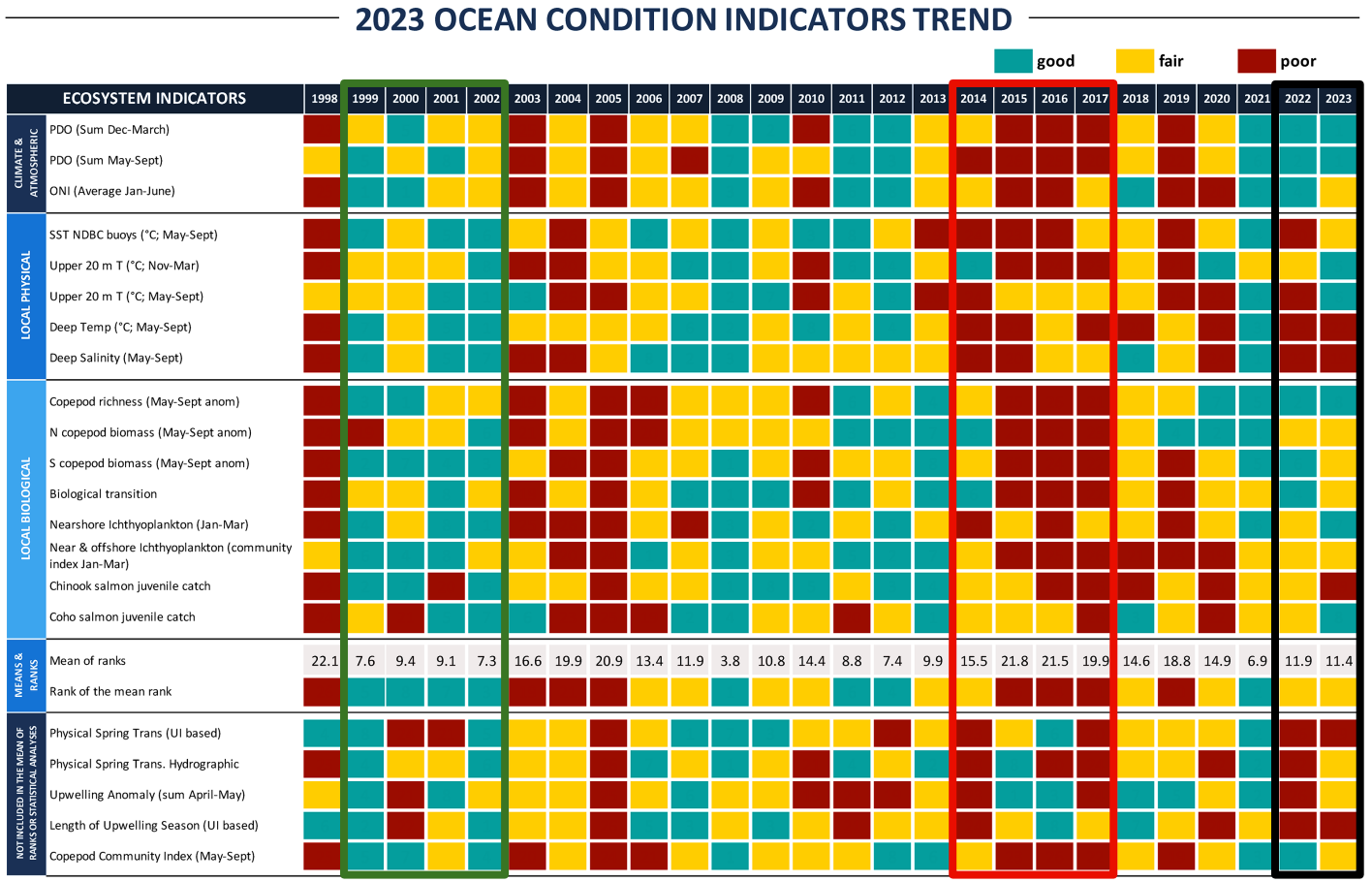
NOAA's 'Stoplight Chart'

https://www.fisheries.noaa.gov/west-coast/science-data/ocean-ecosystem-indicators-pacific-salmon-marine-survival-northern

Basin Scale

Local Physical Conditions

Local Biological Conditions



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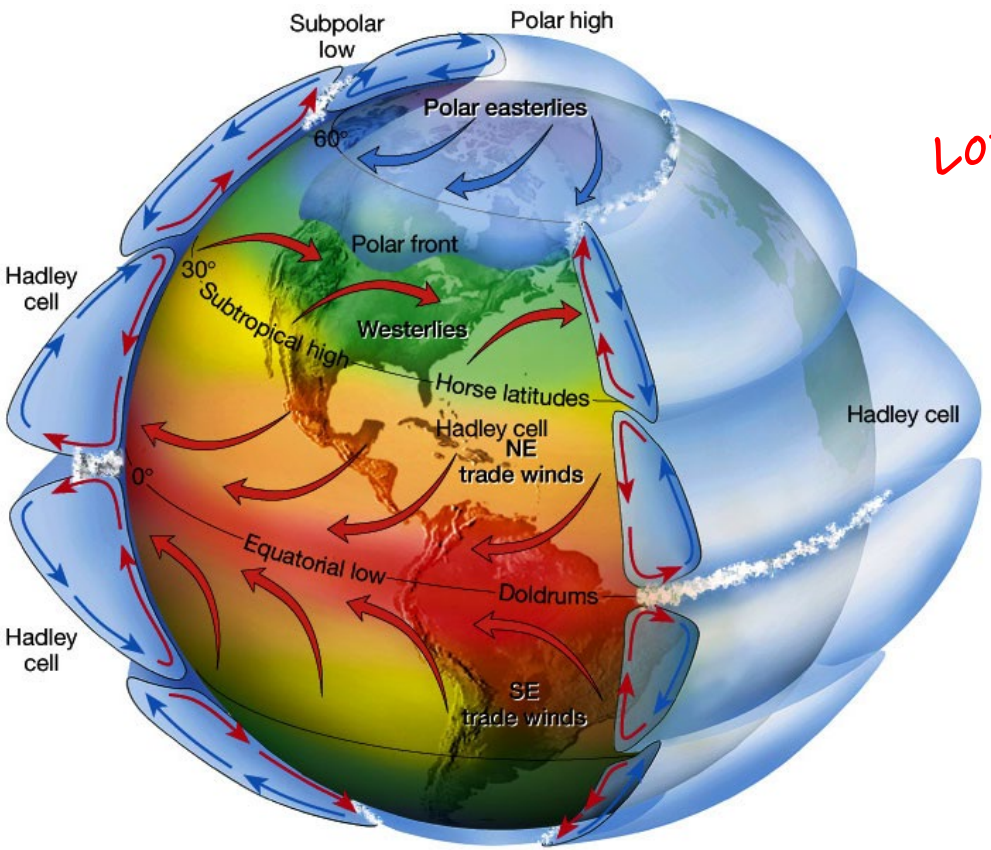
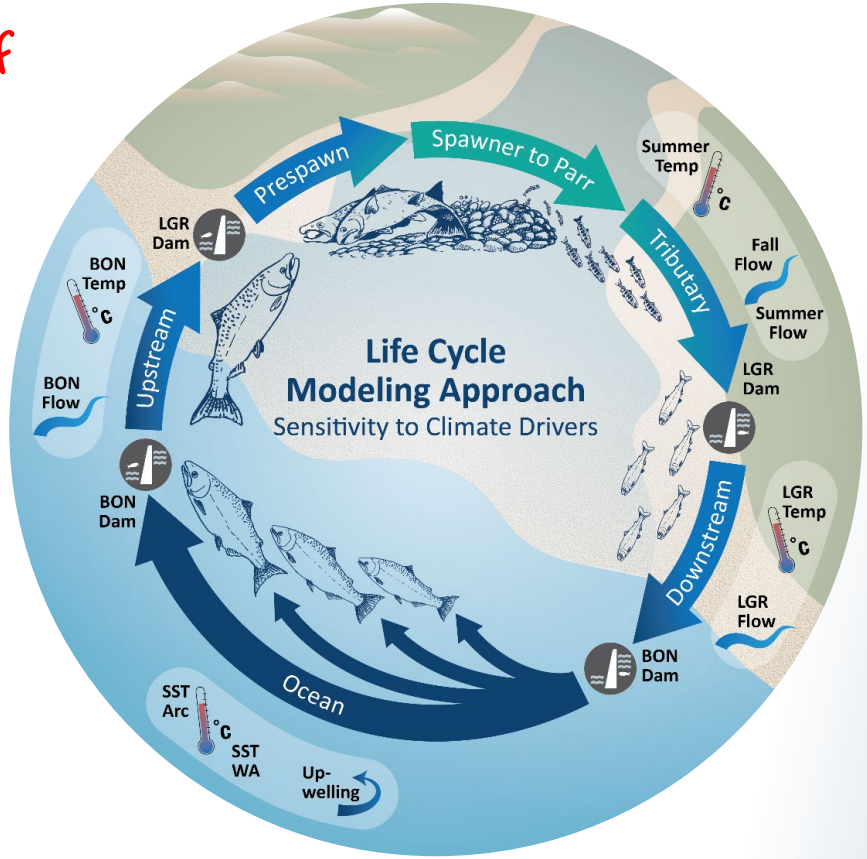
Global Dynamics Shape Local Conditions



Lots of stuff



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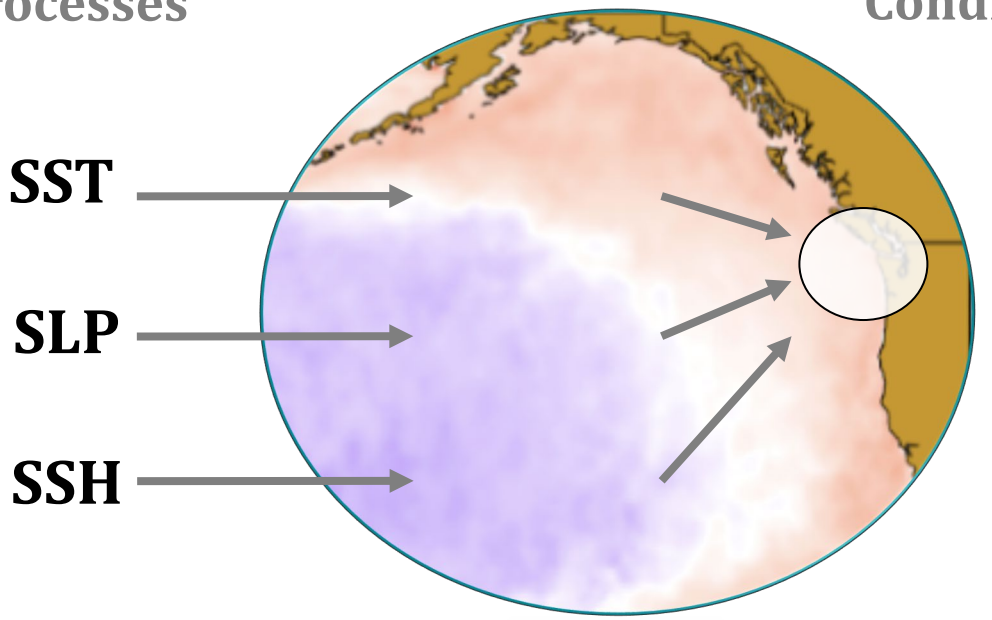
The Quick Summary

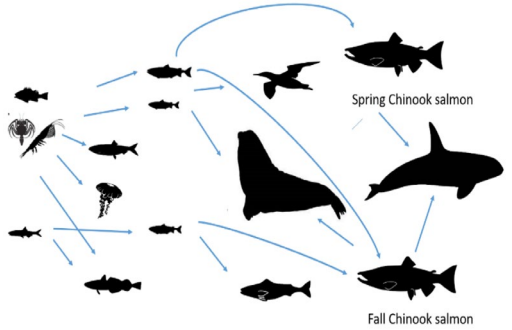
We have indicators representing many different scales

Underlying Processes

Local Physical Conditions

Local Biological Conditions





Common Indicators:	PDO, NPGO, ONI, NPH	Wind Upwelling Coastal currents	Copepods, Krill, Ichthyoplankton, Predators

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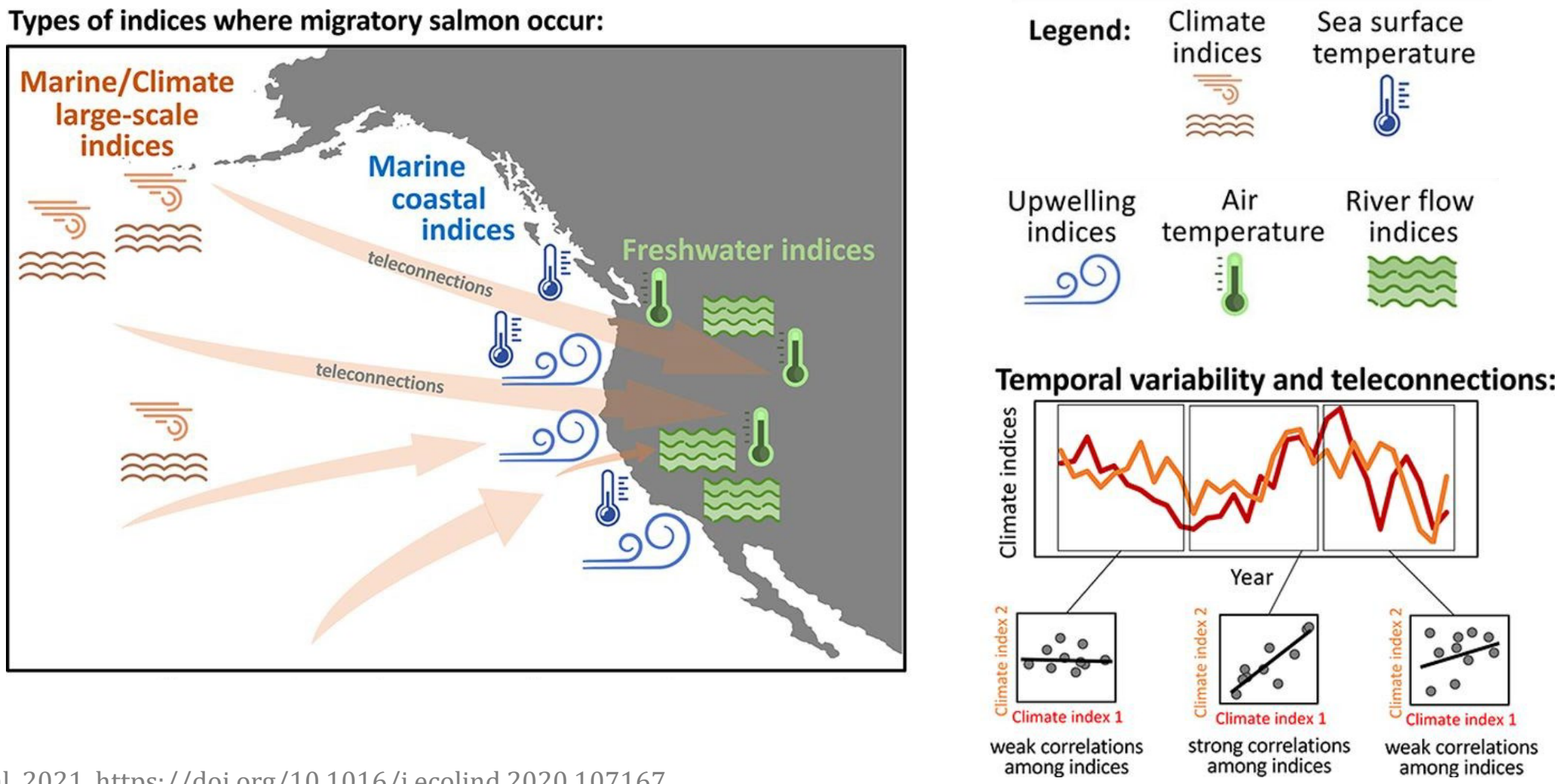
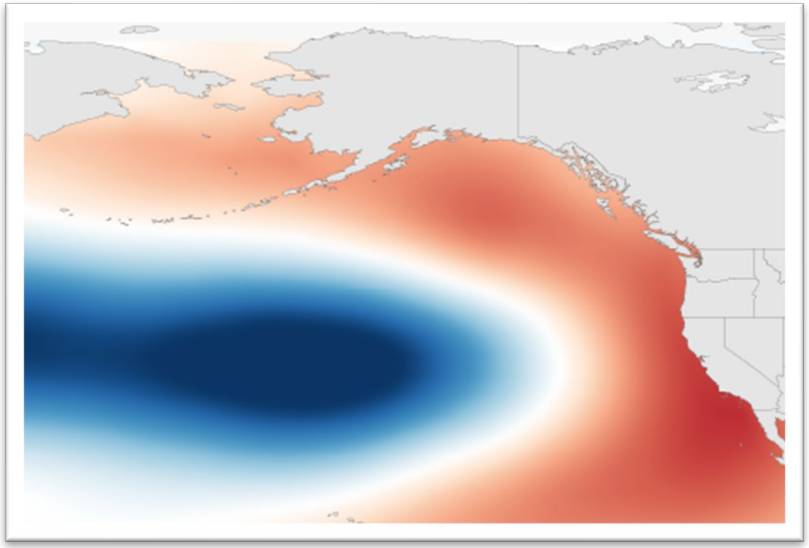
Spatial ‘teleconnections’ are broader than just marine conditions

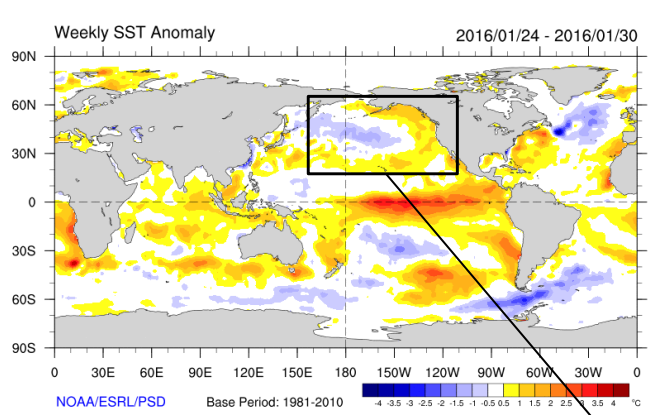


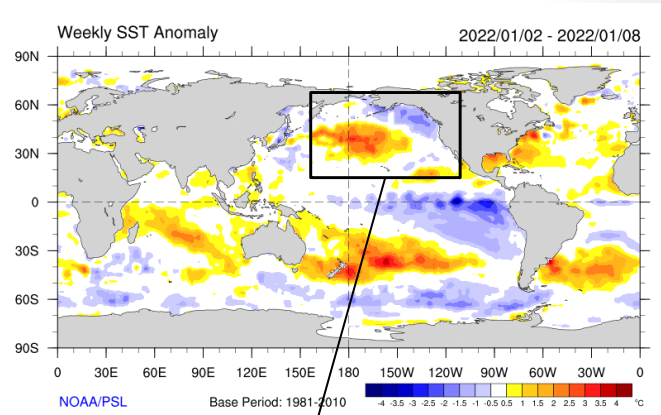
Gosselin et al. 2021. https://doi.org/10.1016/j.ecolind.2020.107167

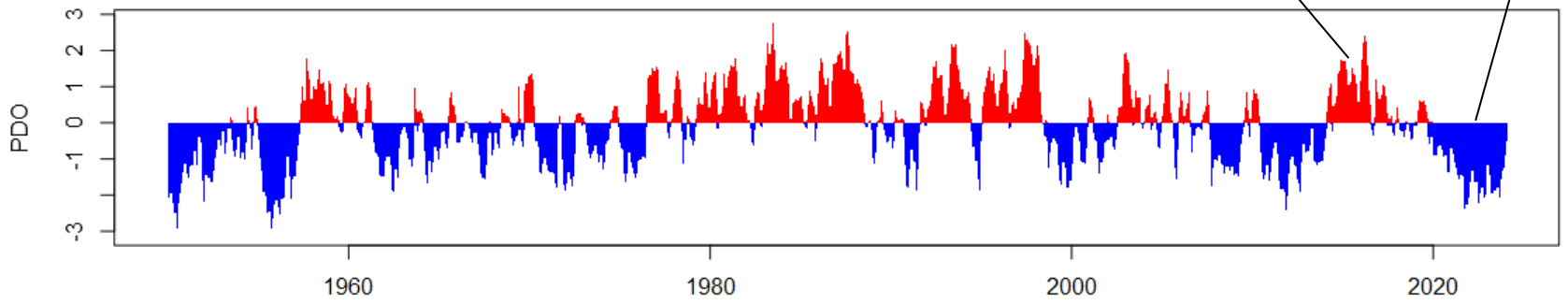
Pacific Decadal Oscillation (PDO)



https://www.fisheries.noaa.gov/insight/ocean-atmosphere-climate-indices







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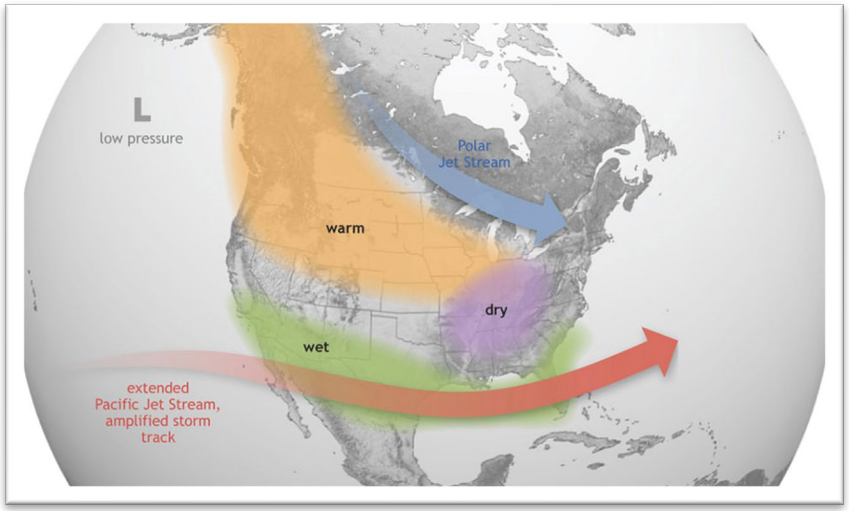
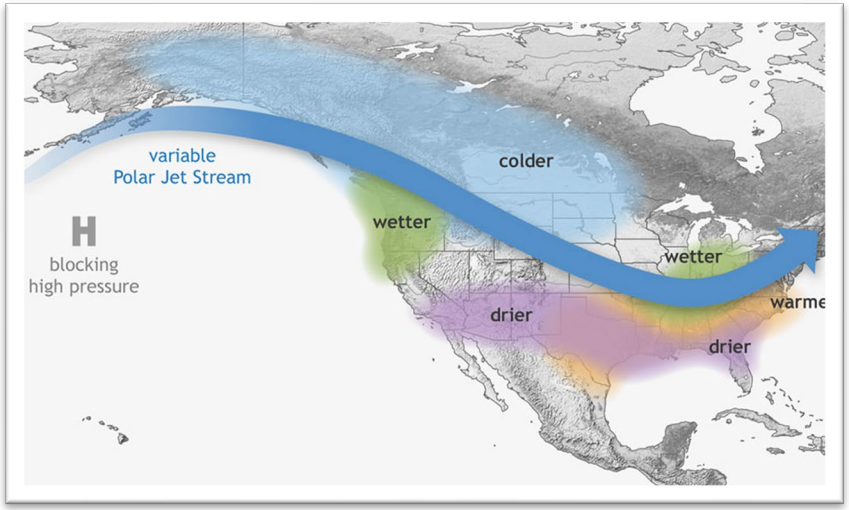
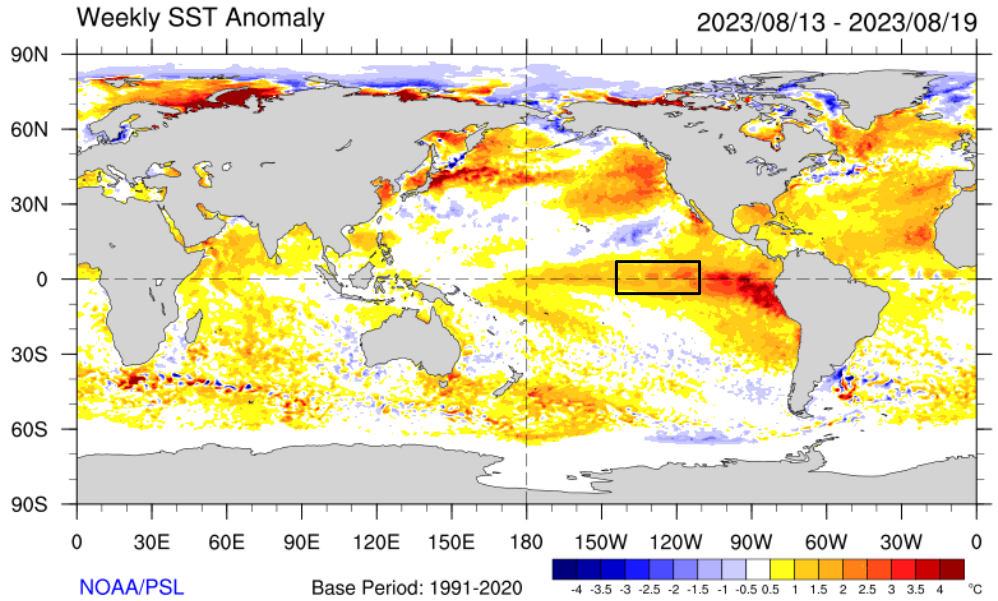
El Niño

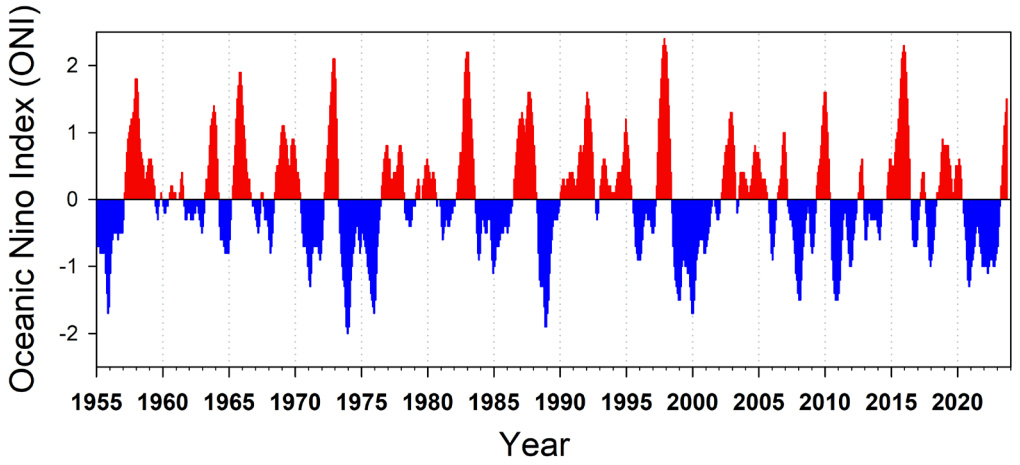
El Niño



La Niña







https://oceanservice.noaa.gov/facts/ninonina.html

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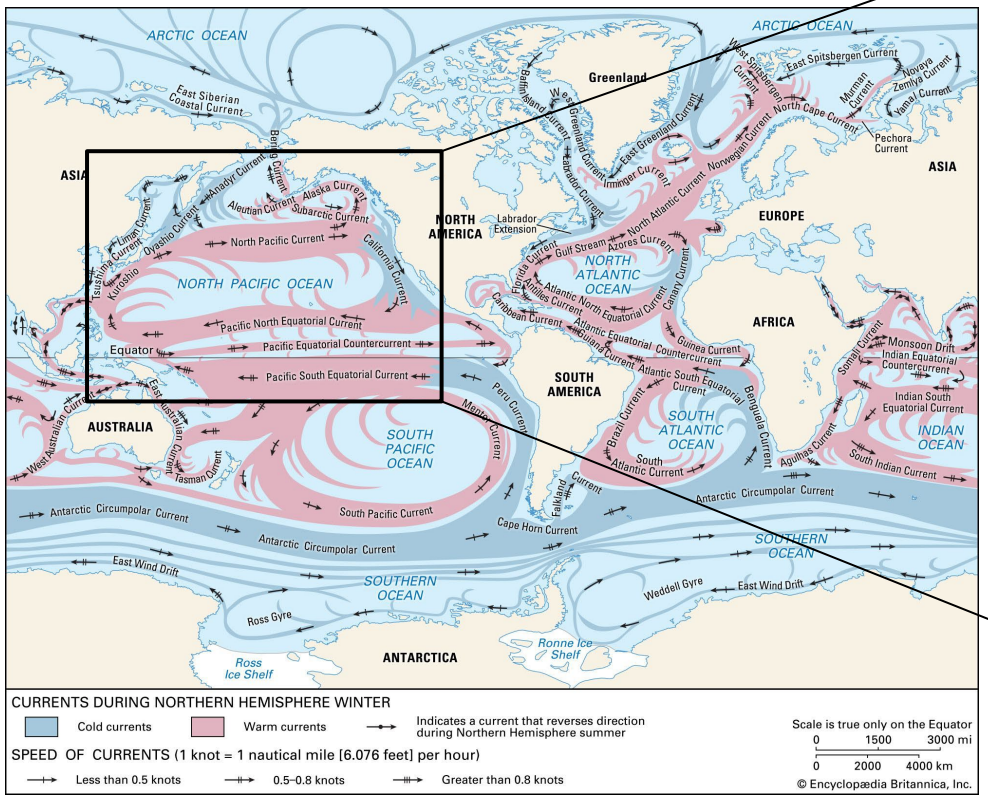
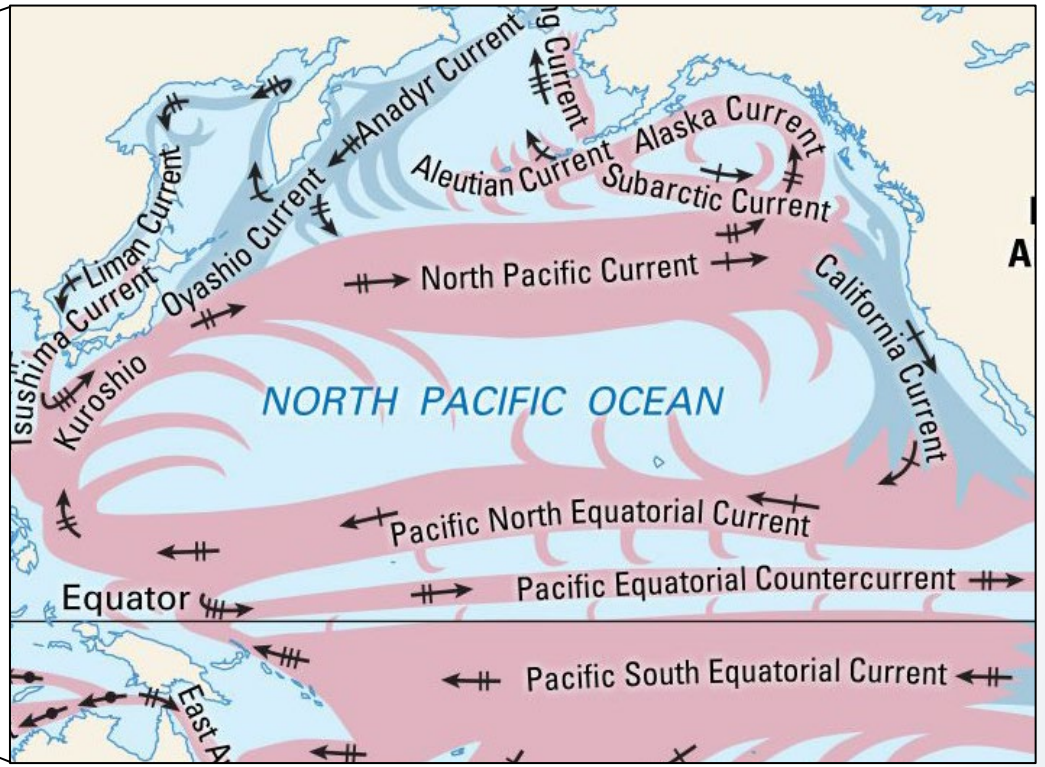
Local Conditions depend on ocean currents





Example Indicator: Bifurcation Index from Malick et al. 2016. https://doi.org/10.1111/fog.12190

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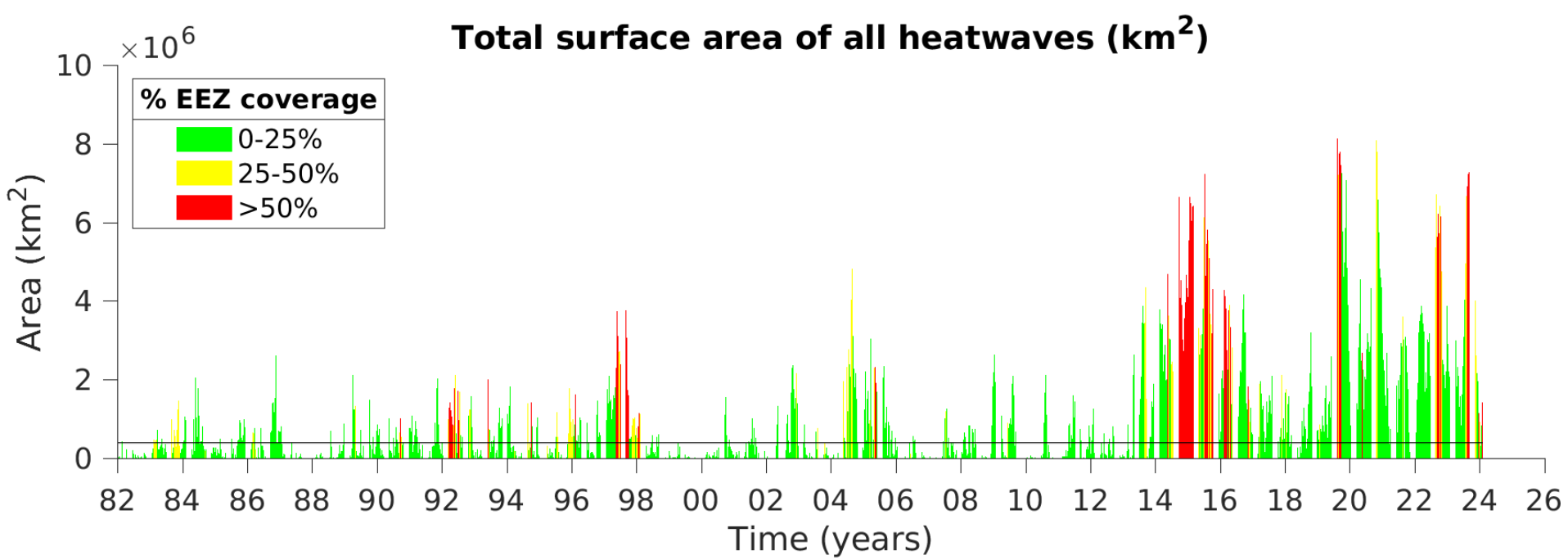
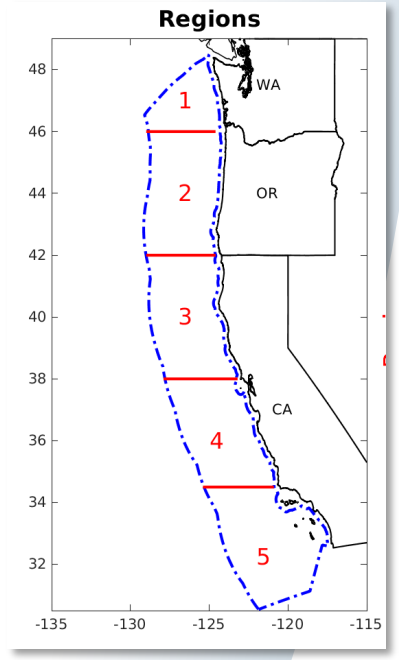
NE Pacific marine heatwaves are increasing





California Current Ecosystem Status Report NOAA
https://www.integratedecosystemassessment.noaa.gov/regions/california-current/california-current-marine-heatwave-tracker-blobtracker

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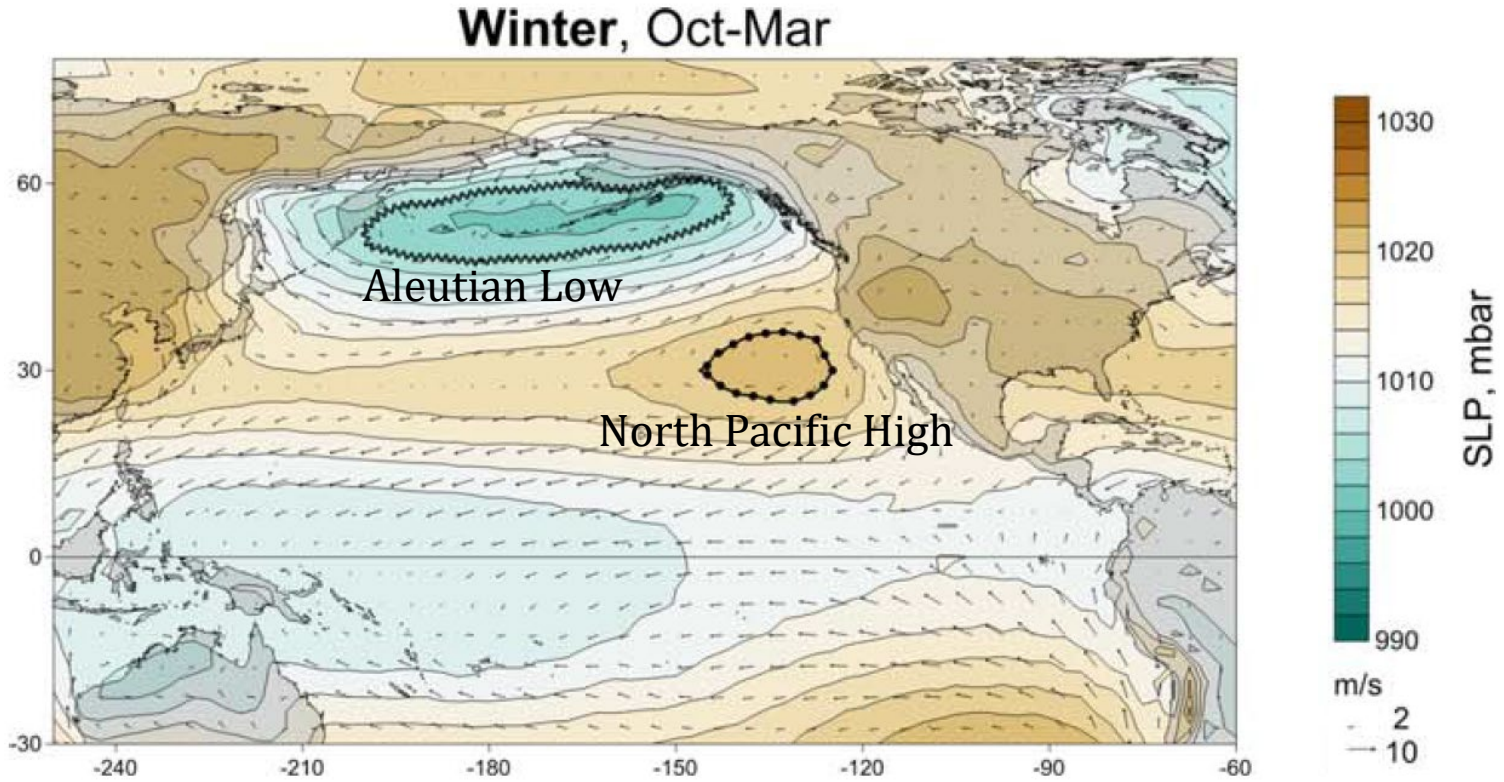
Heat waves are driven by a lack of surface mixing



Fiedler & Mantua. 2017. How are warm and cool years in the California Current related to ENSO? Journal of Geophysical Research: Oceans. 122. 10.1002/2017JC013094.

Aleutian Low - Beaufort Sea Anticyclone: https://psl.noaa.gov/data/timeseries/ALBSA/

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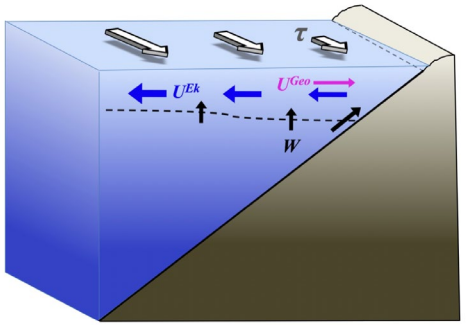
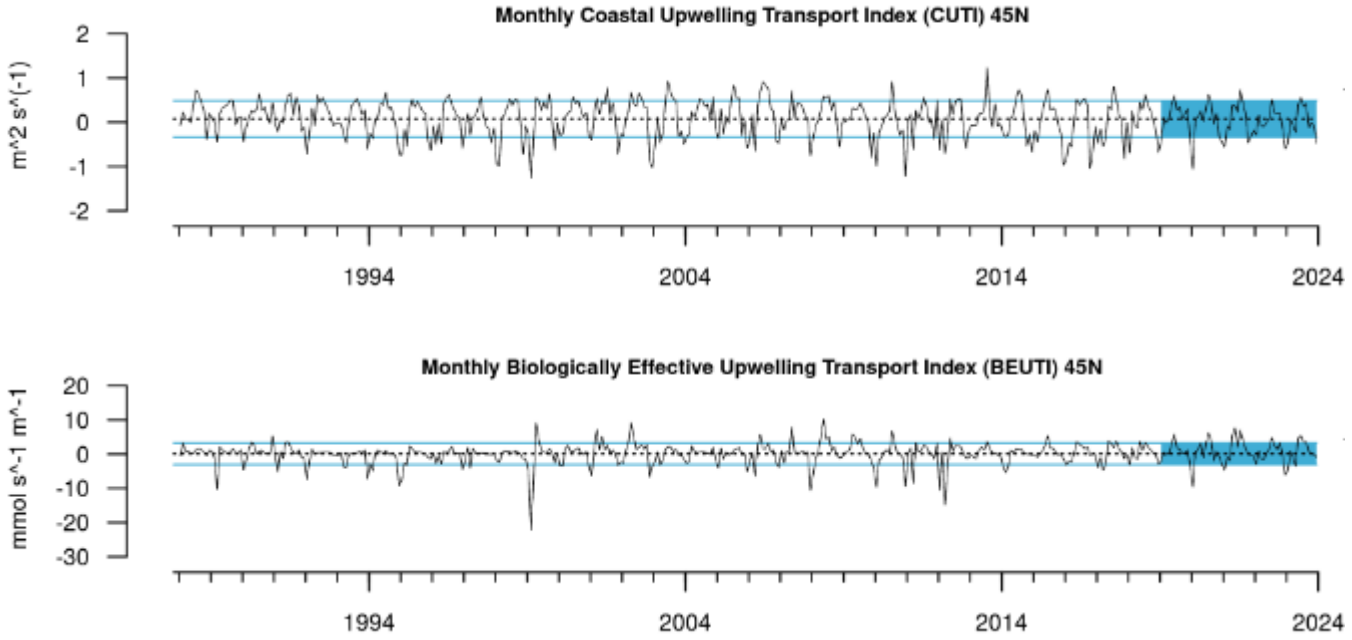
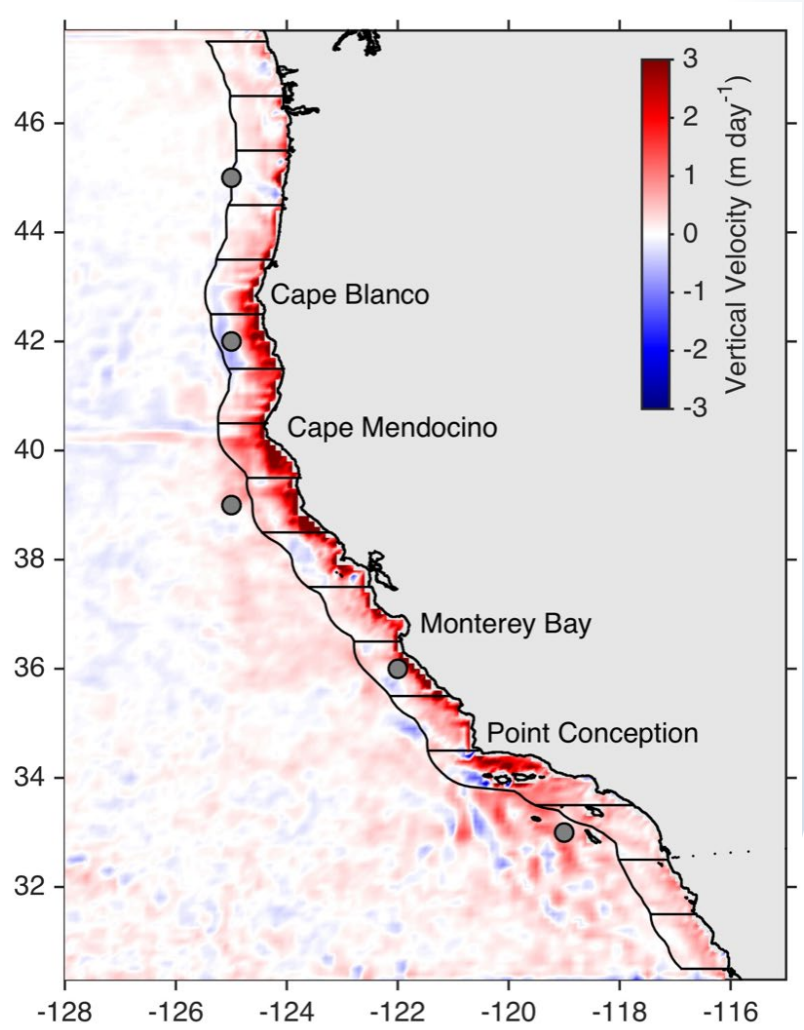
Pressure Systems also drive Upwelling



Alongshore wind stress (τ) and positive wind stress curl drive Ekman transport (U^{Ek}). Coastal sea surface height slopes downward toward the north, driving onshore geostrophic flow (U^{Geo}). Net upwelling (W) through the base of the mixed layer (dashed line) equals the sum of U^{Ek} and U^{Geo}. Not shown are alongshore changes in τ, which also contribute to U^{Ek}.





Mean spring/summer vertical velocity (upwelling in red, downwelling in blue). CUTI and BEUTI are calculated for 1° latitude bins, outlined in black. Gray dots are Bakun Index locations.

https://mjacox.com/upwelling-indices/

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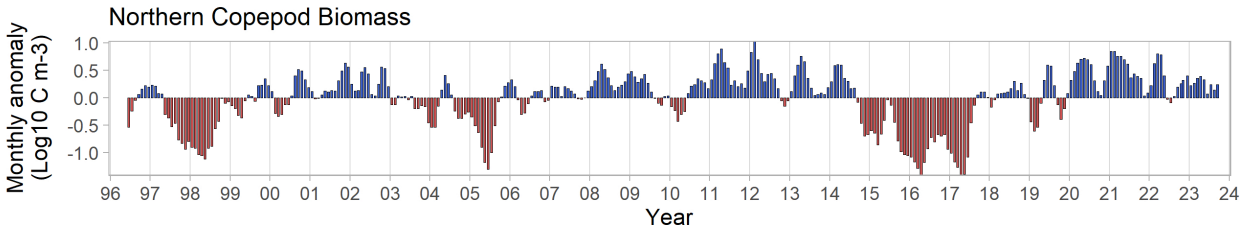
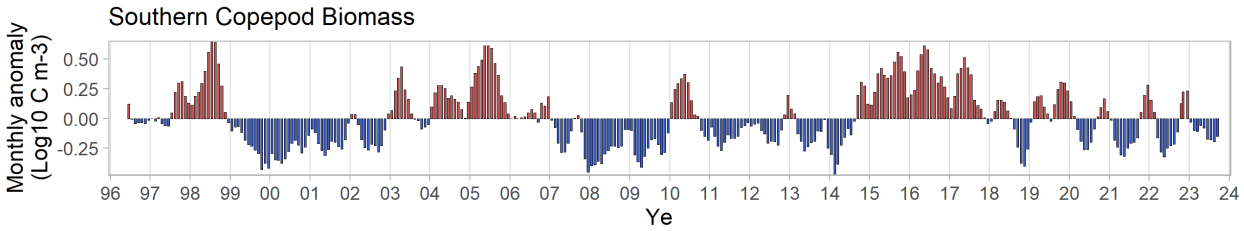
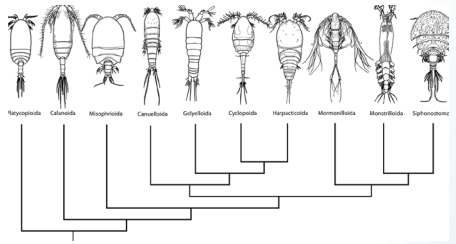
Currents, temperature, upwelling all drive the local food web



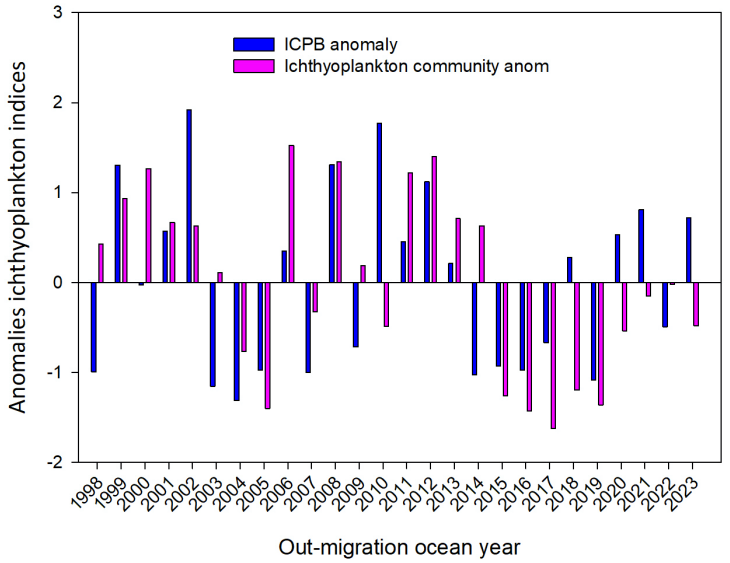




Khodami et al., (2017)

Ammodytes hexapterus
Author Fisheries and Oceans Canada, Moira Galbraith - CaRMS@dfo-mpo.gc.ca

Sebastes sp. - larva
Author Fisheries and Oceans Canada, Jean-François St-Pierre - roberta.miller@dfo-mpo.gc.ca



https://www.fisheries.noaa.gov/west-coast/science-data/ocean-ecosystem-indicators-pacific-salmon-marine-survival-northern

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Non-stationarity

(you know, cause it wasn't complicated enough already)

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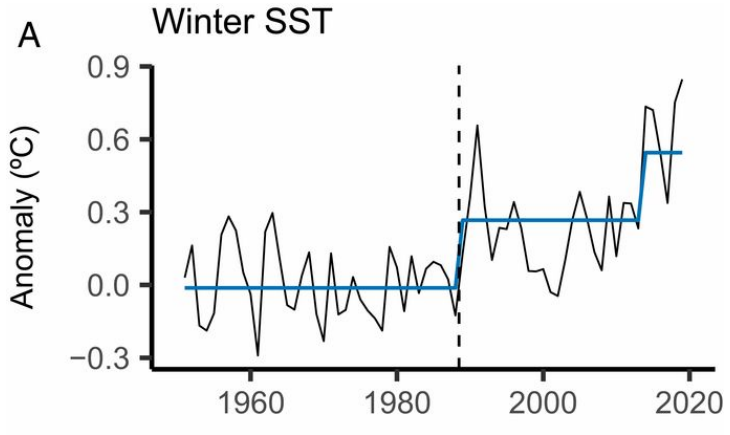
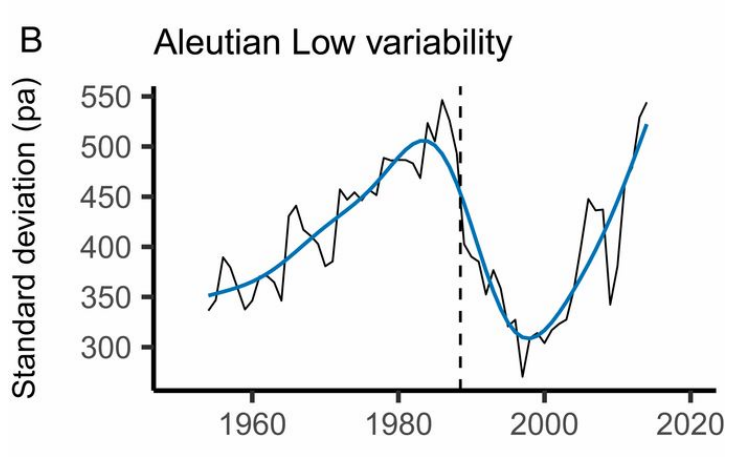
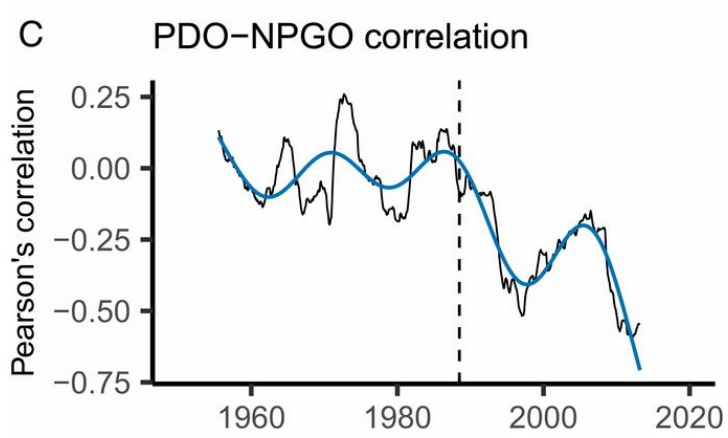
Changes in individual time series or in the relationship among time series

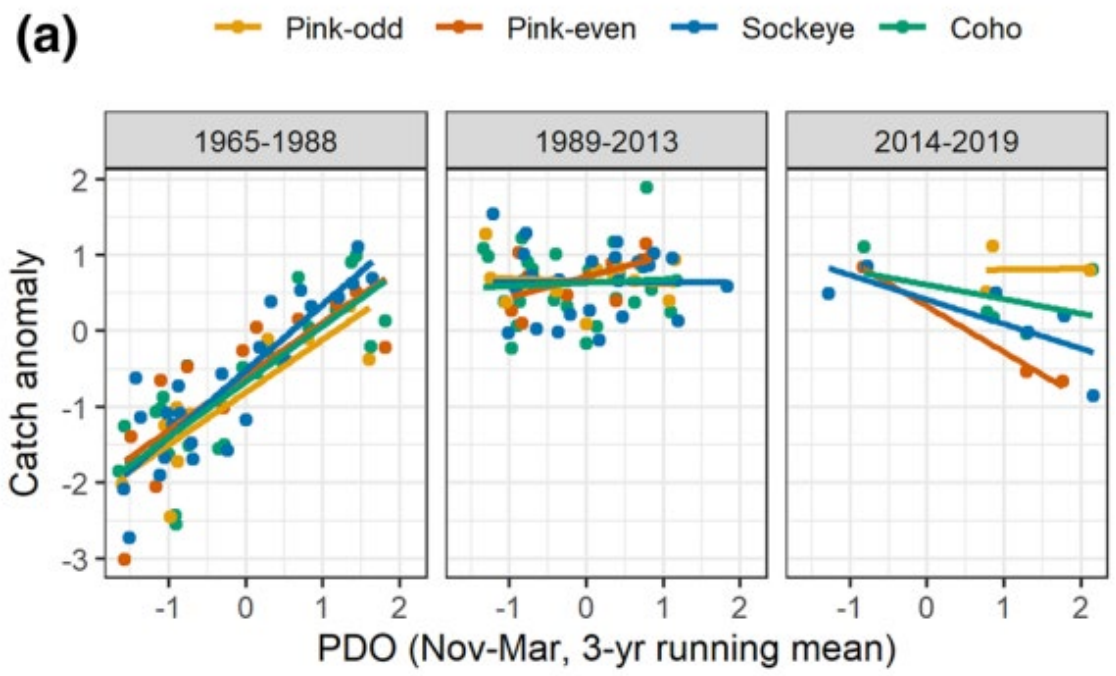


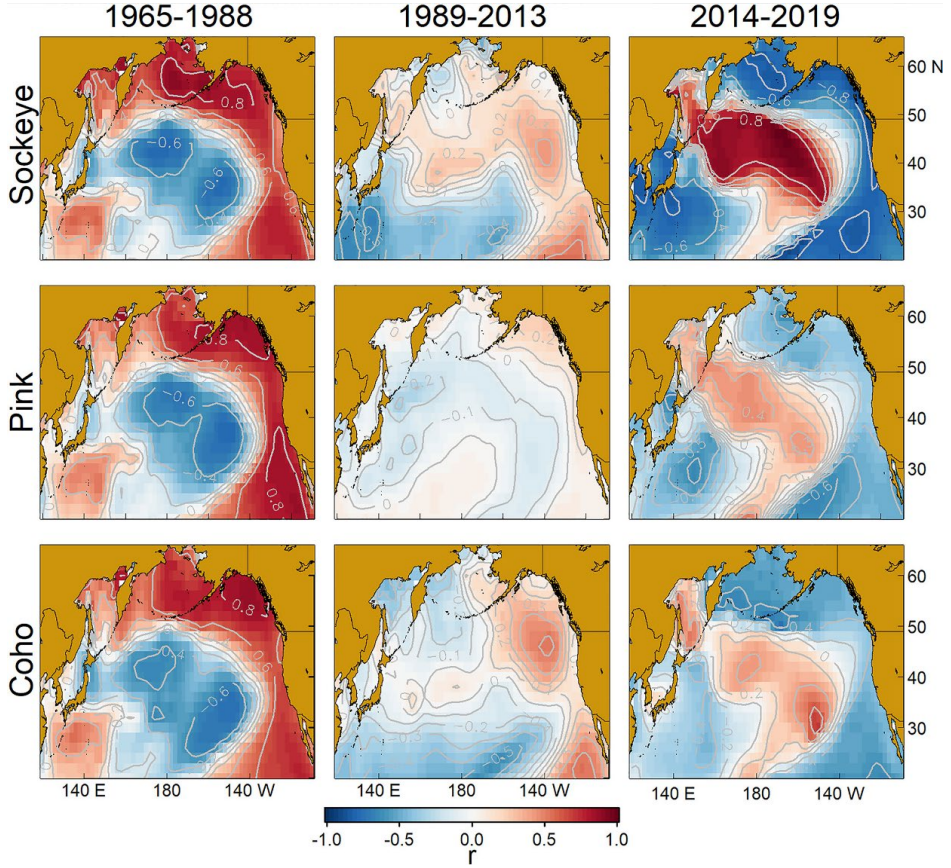




Litzow et al. 2020. https://doi.org/10.1073/pnas.1921266117

Changing PDO-Salmon Relationships

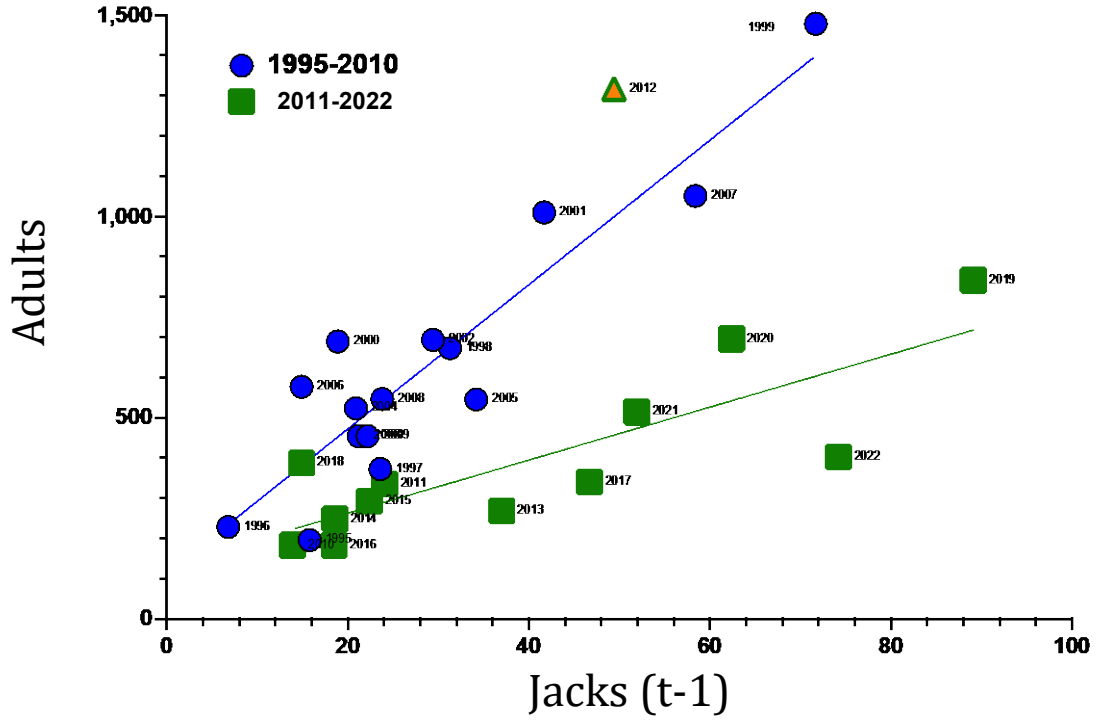




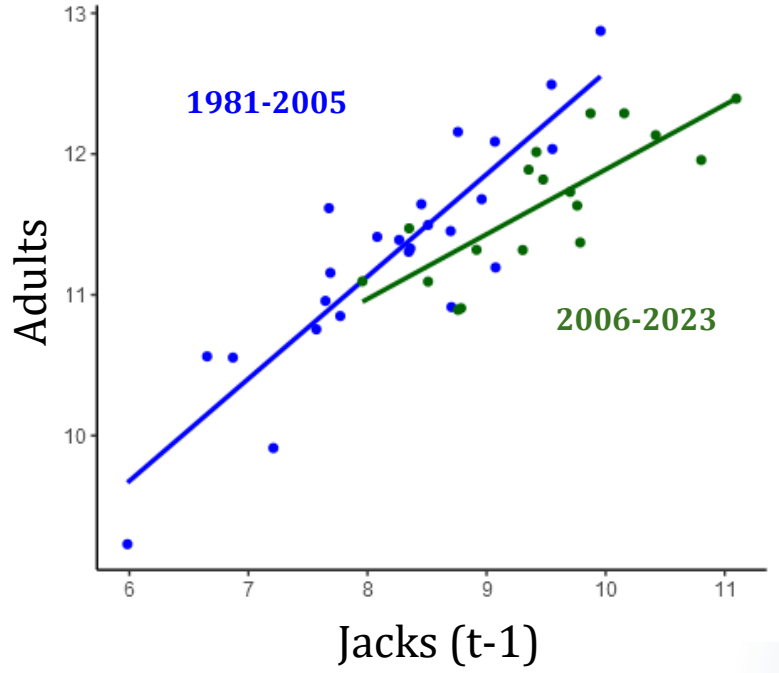
Litzow, M. A., et al. (2020). Quantifying a novel climate through changes in PDO-climate and PDO-salmon relationships. Geophysical Research Letters, 47, e2020GL087972. https://doi. org/10.1029/2020GL087972

Sibling Regressions are not immune

Coho Oregon Production Index - Hatchery



Counts of spring Chinook at Bonneville Dam (in log space)



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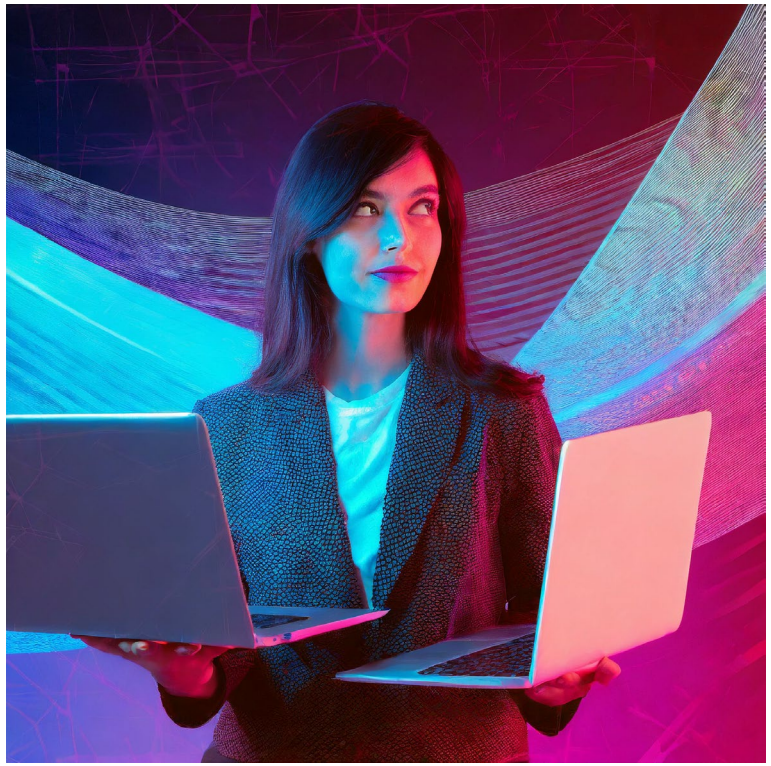
What's a forecaster to do?

Better understand salmon marine ecology?

Try every possible covariate?

Take advantage of patterns in physical-biological relationships?



Find a simple indicator that works okay?

Build a full ecosystem model to represent every potential process?

Random number generator?

Use the recent 5-year mean?

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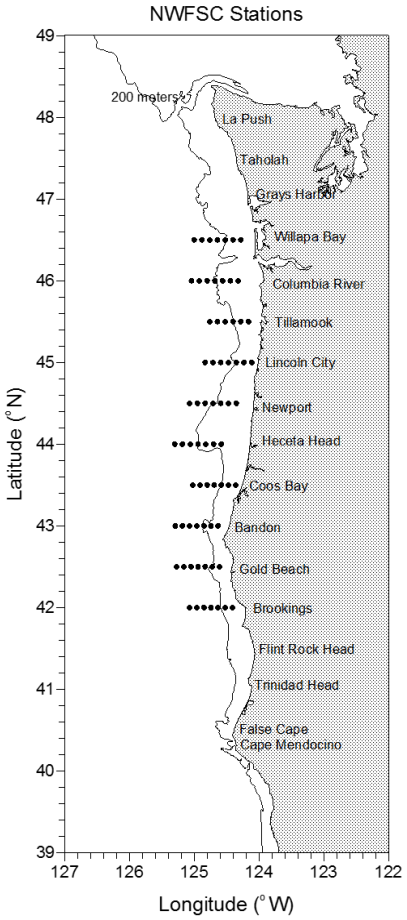
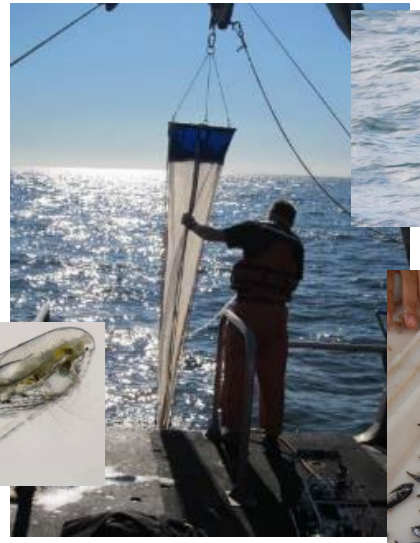
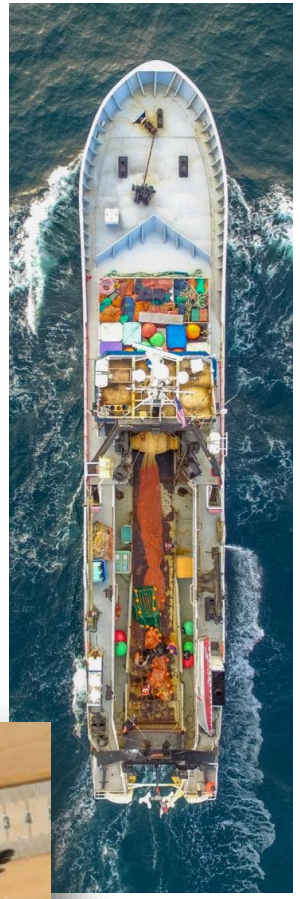
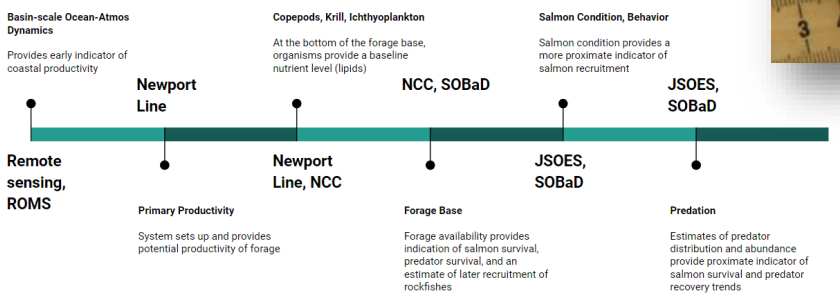
Our projects cover all ecosystem components









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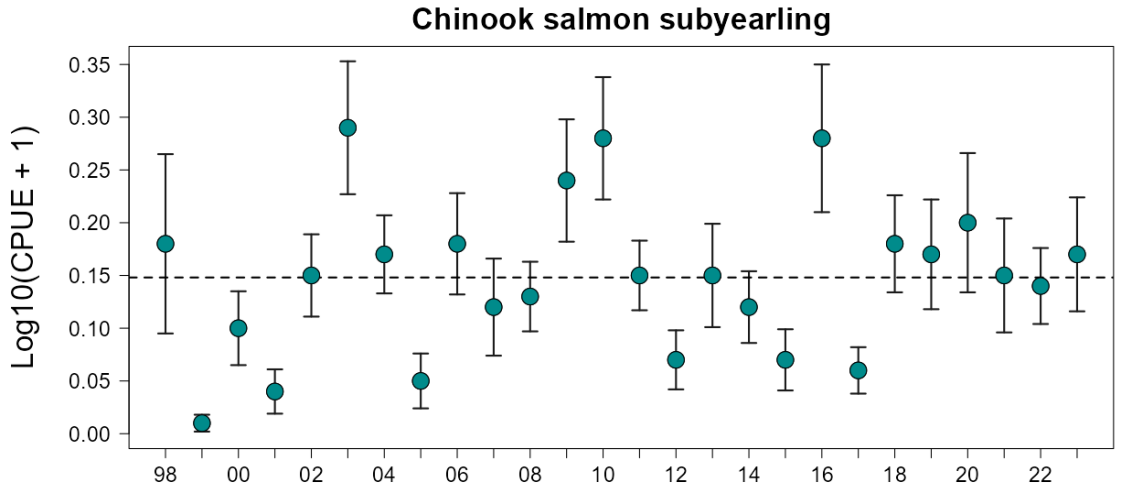
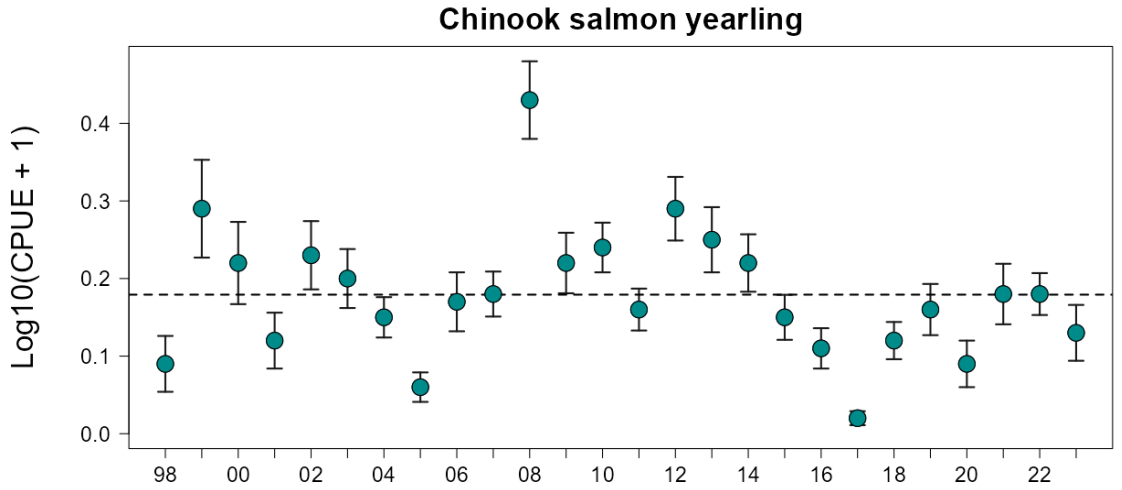
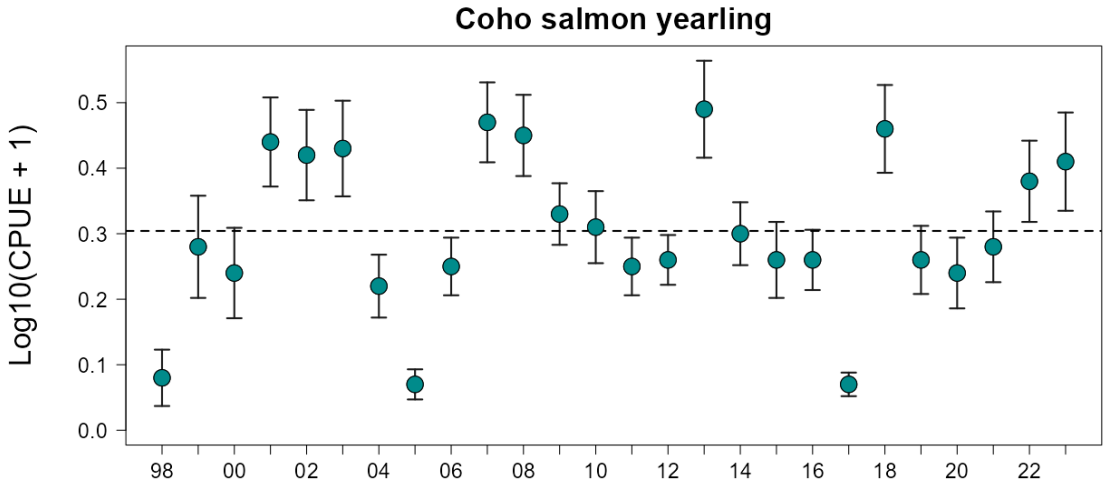
JSOES Catches - June, 1998-2023







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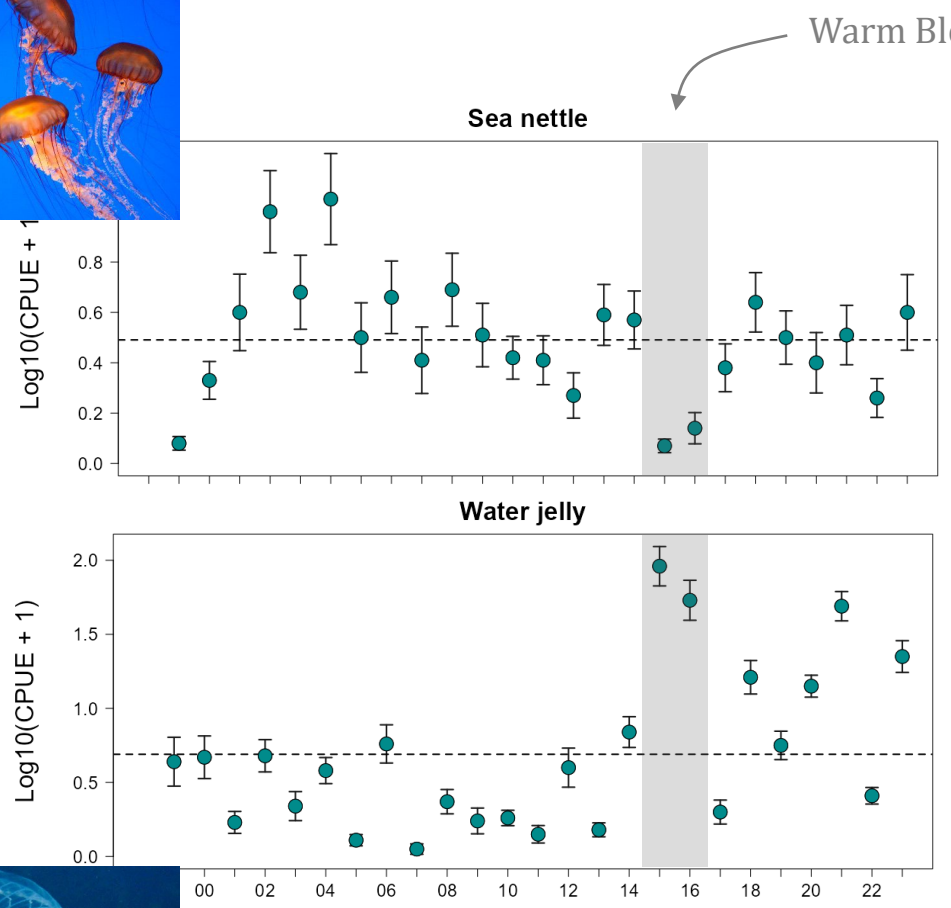
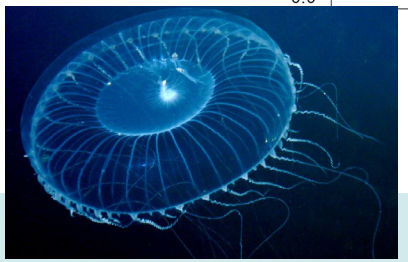
Recent trends among biological data streams





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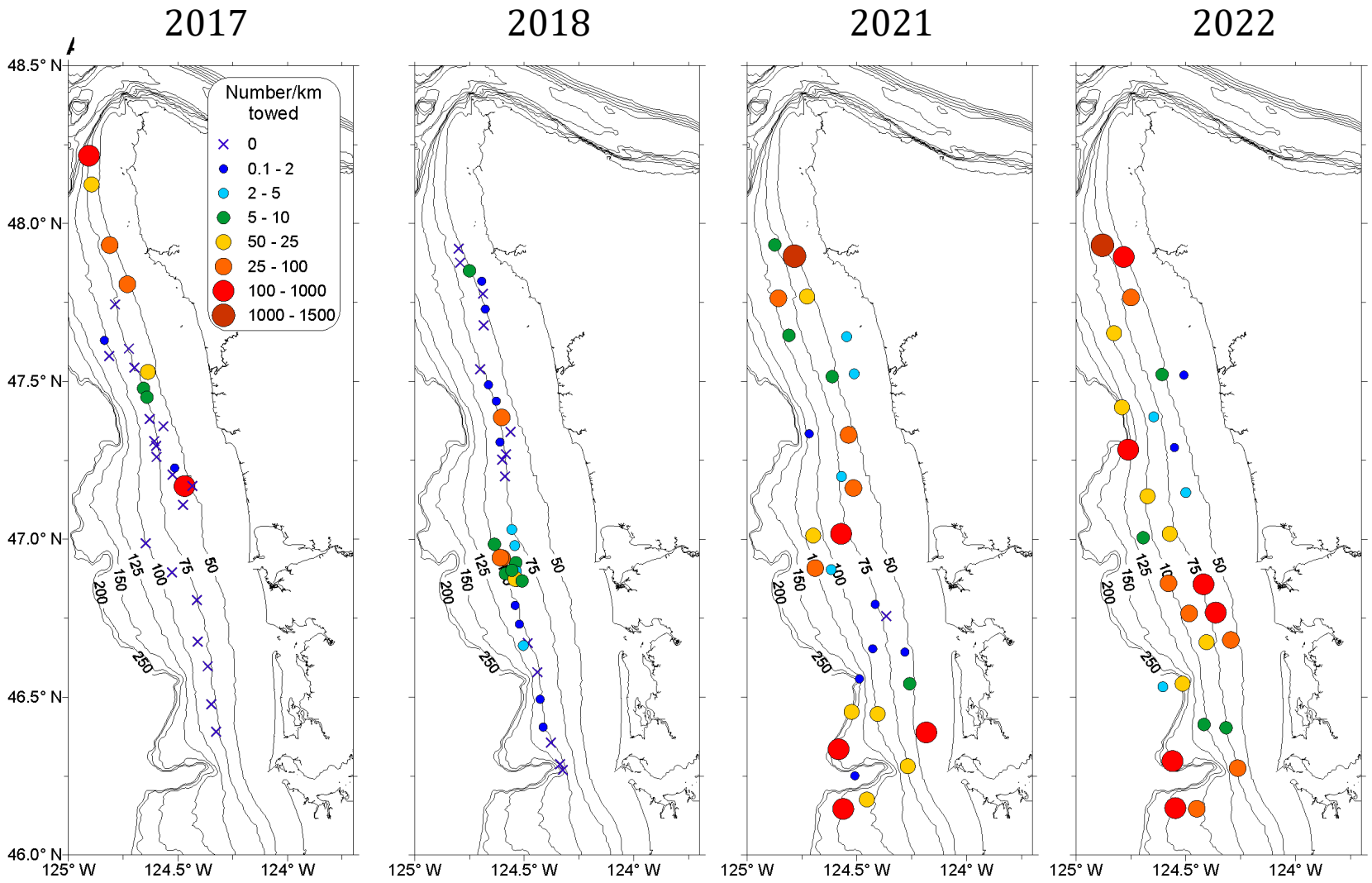
Pacific Sardine (larval)



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Part II - CMISST

Summary:

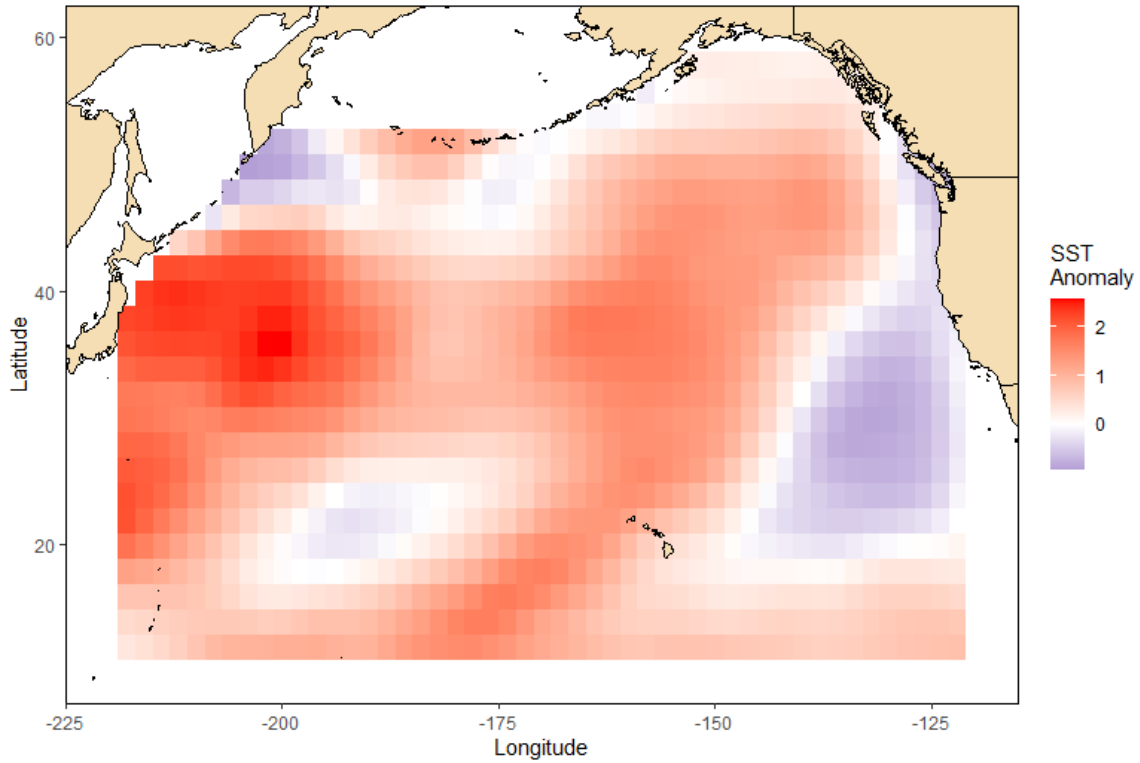
- No single metric can represent our diverse uses for ocean indicators
- Current management needs can't wait for fully developed mechanistic ecosystem models
- We can quickly and easily generate a stock-specific indicator for a variety of species / management applications

Wealth of existing data sources

Satellite data (SST, SSH):

- Publicly-available
- Spatially-explicit
- Regularly updated

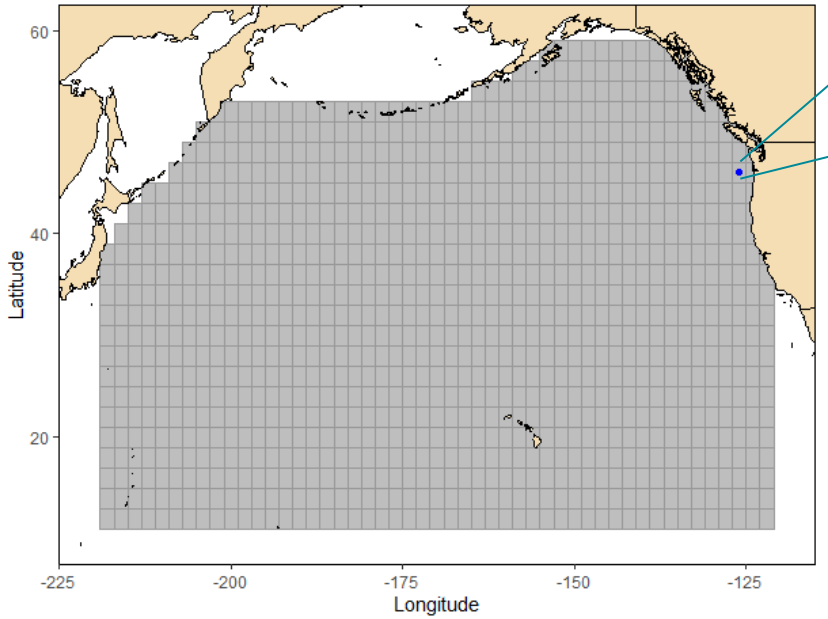
Jan-Mar 2020, Sea Surface Temperature Anomaly



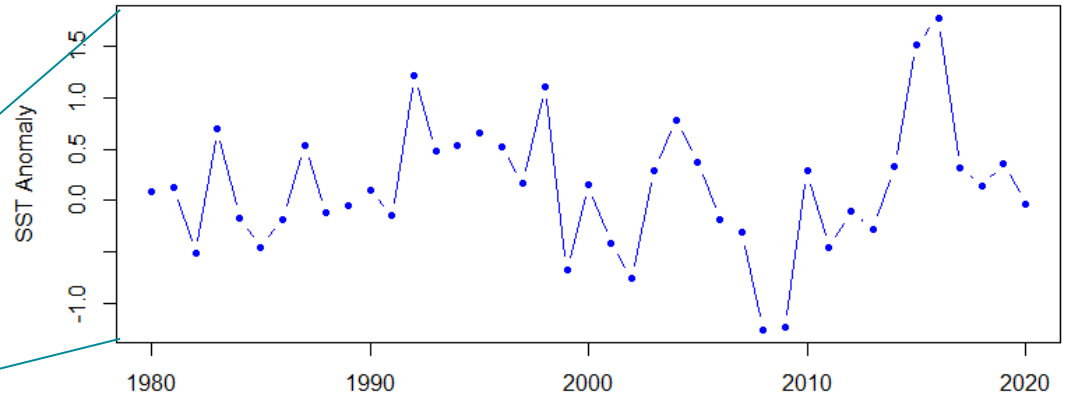
SST data are from ERSST
(https://www.ncei.noaa.gov/pub/data/cmb/ersst/v5/netcdf/)
See: Huang et al, 2017

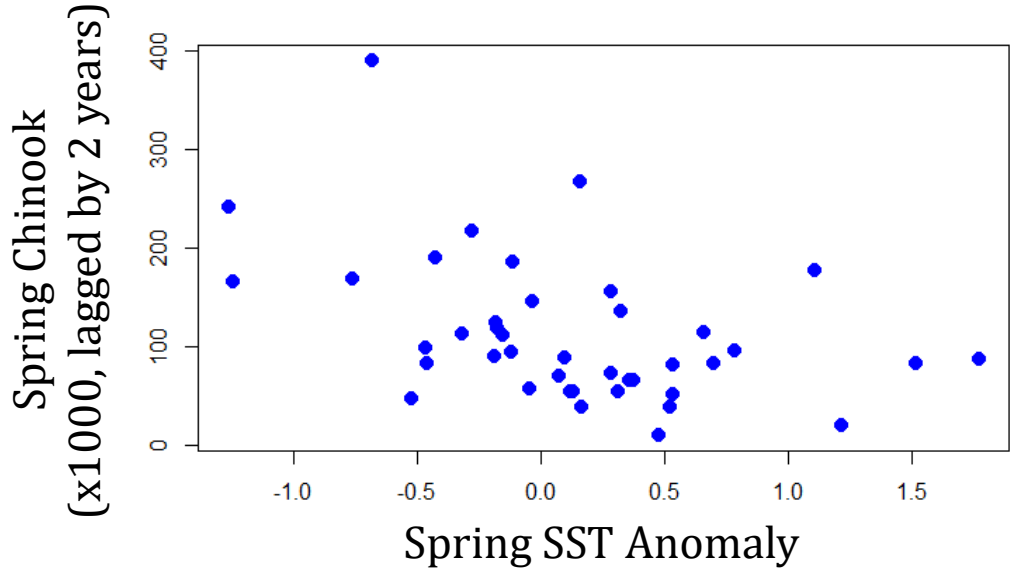
Methods

We can quantify the covariance between SST at any single location and the response variable we're interested in



Spring SST Anomaly





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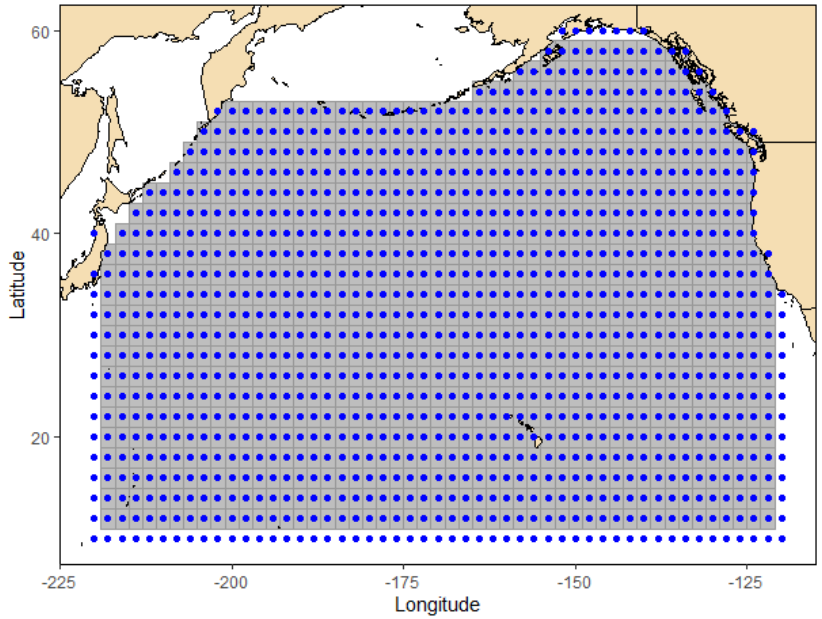
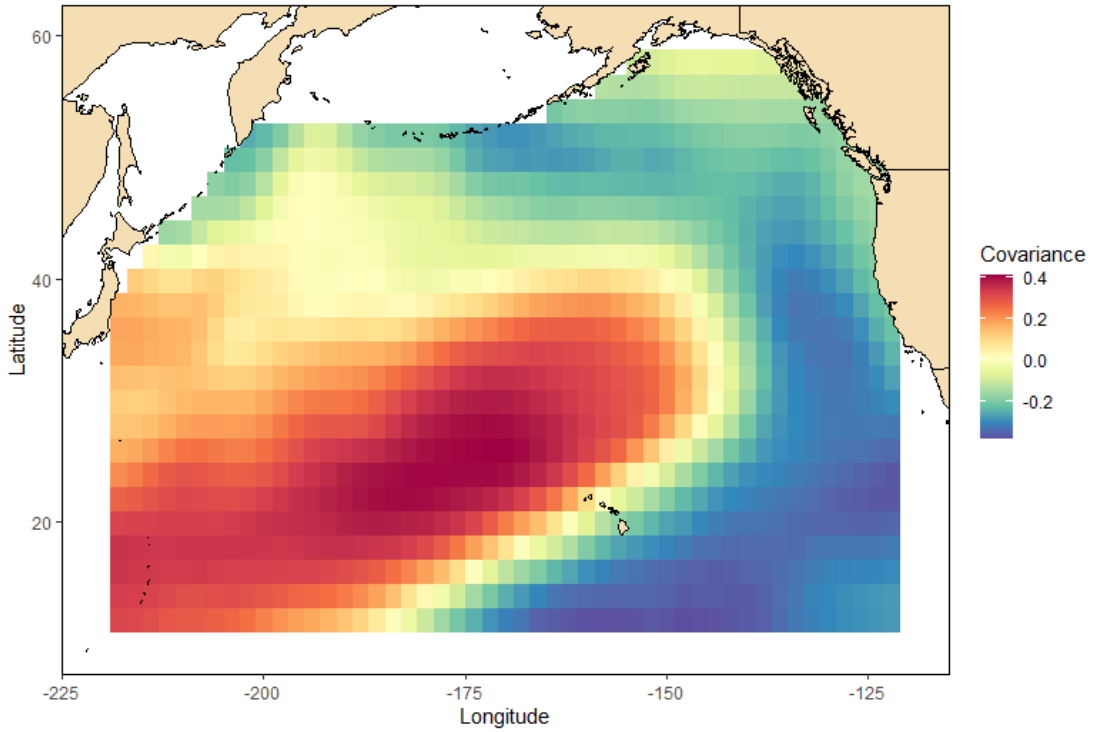
Methods

We can do the same thing for every grid cell in the North Pacific



This "Covariance Map" represents the <u>Optimal Spatial Distribution</u> of SST anomalies for a given salmon population

Covariance between winter SST anomalies and counts of adult spring Chinook in the Columbia River 1980 - 2020



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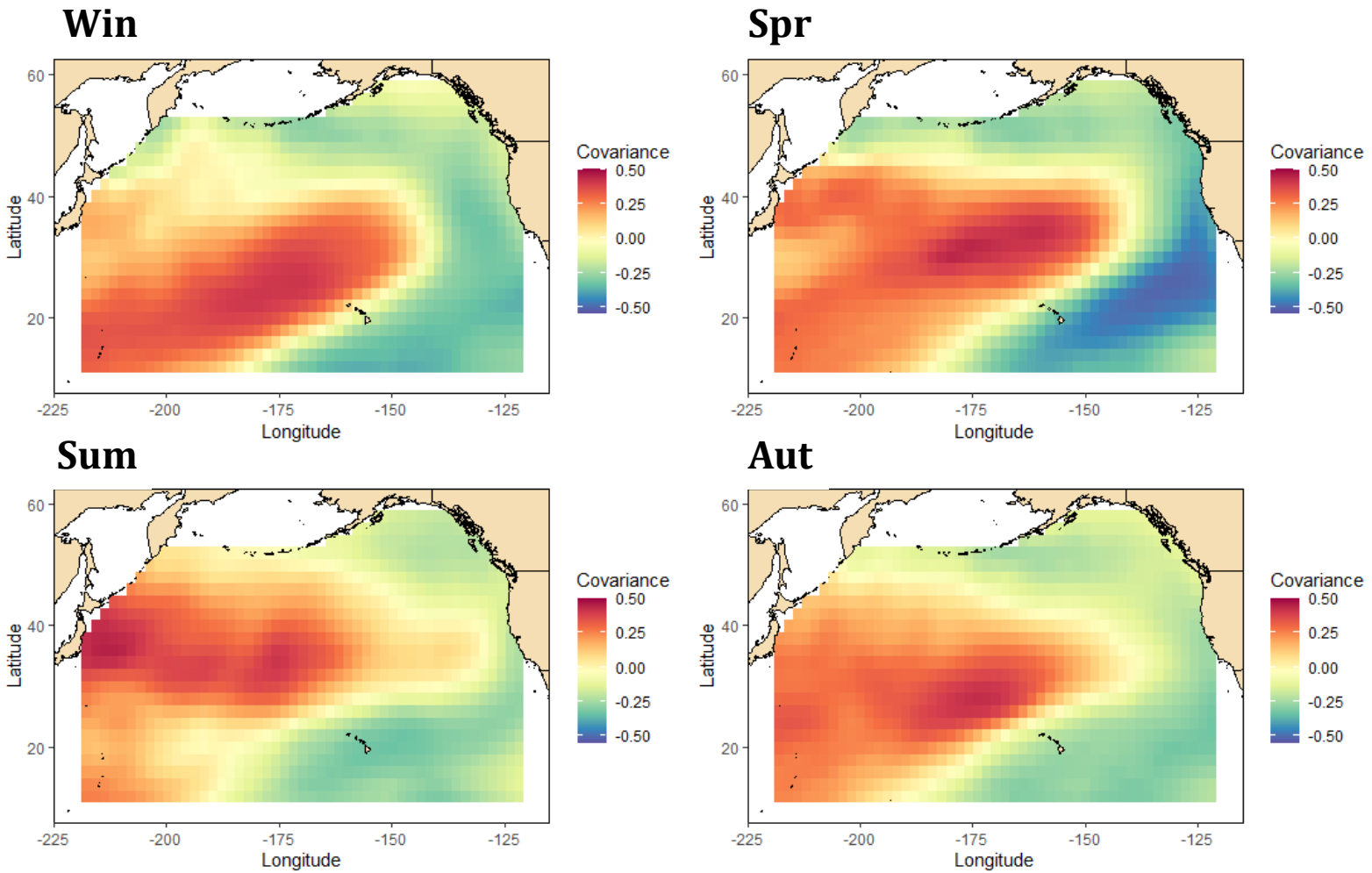
Basic Comparisons:

Spring Chinook Covariance Patterns by Season



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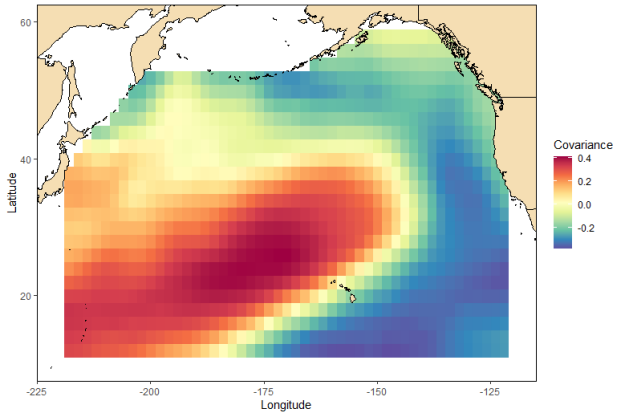
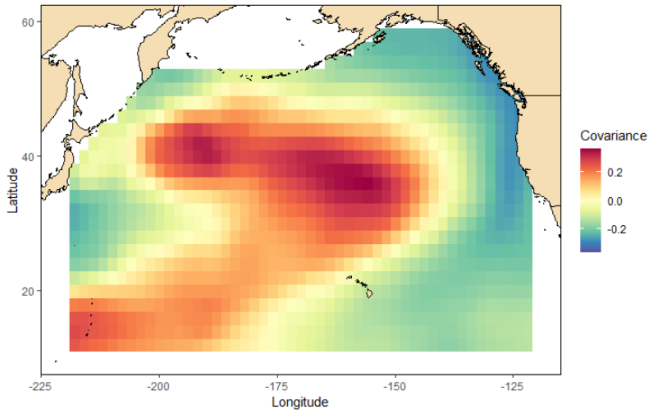
Basic Comparisons: Covariance Patterns by Species

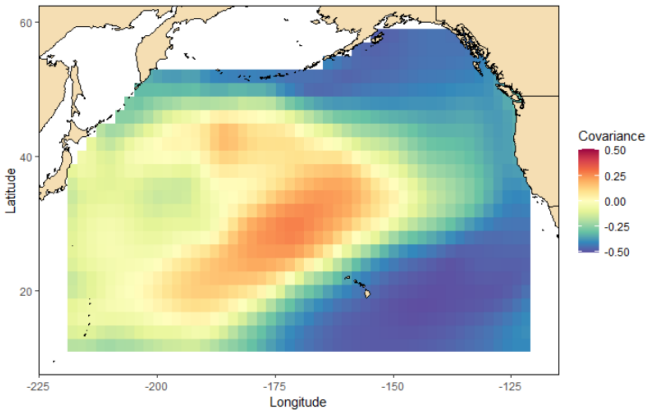
Spring Chinook



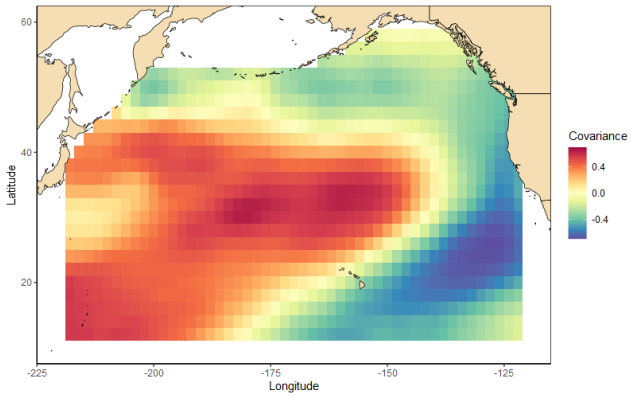
Fall Chinook



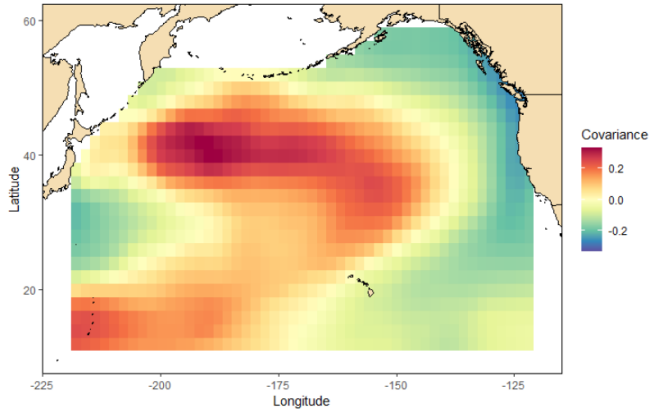
Steelhead



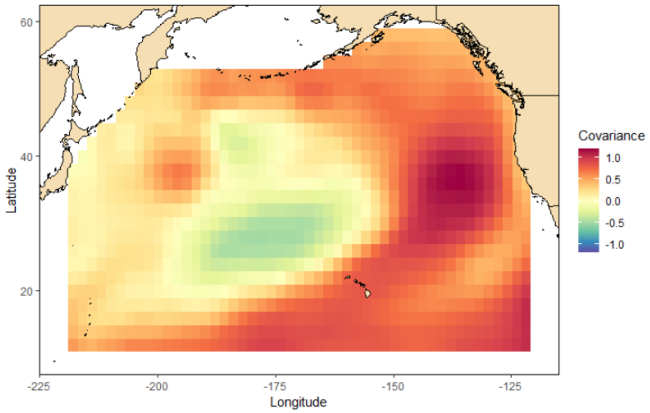
Spring Chinook jacks



Northern Copepods



Juvenile Rockfish



Note: Different scales

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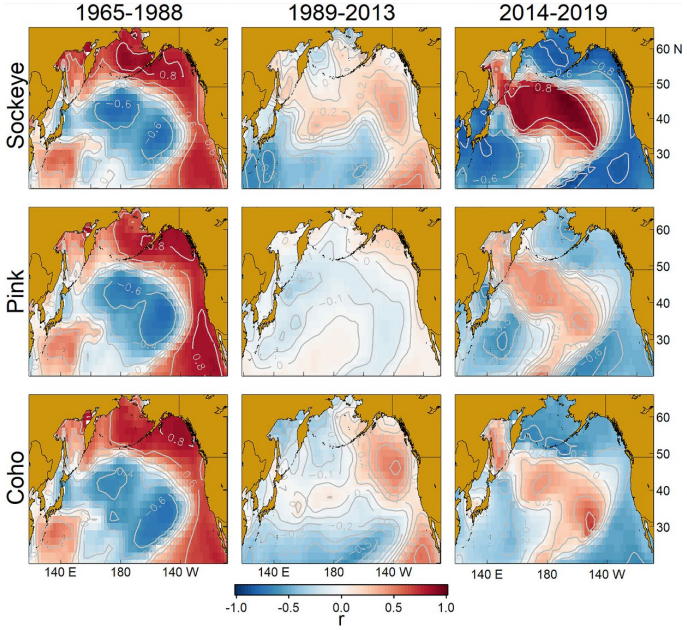
This isn't new - spatial correlations have been created for many reasons

Correlation between SST and salmon catch rates

Litzow, M. A., et al. (2020). https://doi. org/10.1029/2020GL087972



Correlation between predator abundance and salmon survival

Friedland et al. 2012. Fisheries Management and Ecology, 19, 22–35

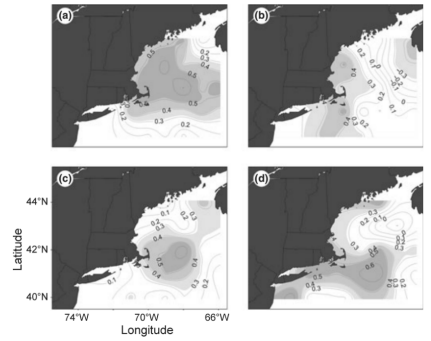


Figure 6. Correlation between 2SW return rates and the abundance of *Amblyraja radiata* (a), *Urophycis tenuis* (b), *Pollachius virens* (c), and *Gadus morhua* (d). Shading denotes correlation probabilities: light grey, $P < 0.05$; medium grey, $P < 0.01$; and dark grey, $P < 0.001$.

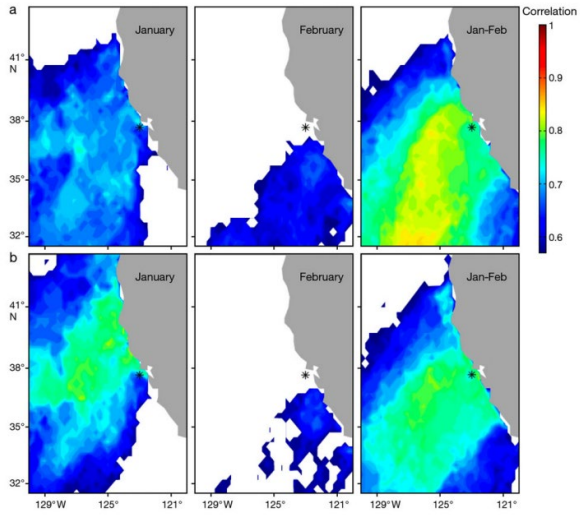


Fig. 3. *Ptychoramphus aleuticus* and *Uria aalge*. Correlations between meridional wind and mean egg-laying dates for (a) auklets and (b) murres. The spatial meridional wind data are the monthly means for January, February, and the average of January and February. For this and all subsequent correlation maps, a black asterisk marks the location of southeast Farallon Islands (SEFI). Only correlations with $p < 0.01$ are shown; areas in white are for non-significant correlations ($p > 0.01$)

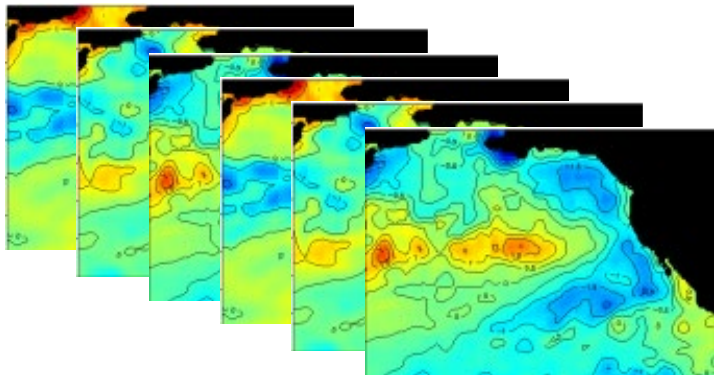
Correlation between wind and seabird egg-laying dates

Schroeder et al. 2009. Marine Ecology Progress Series 393:211-223
DOI:10.3354/meps08103

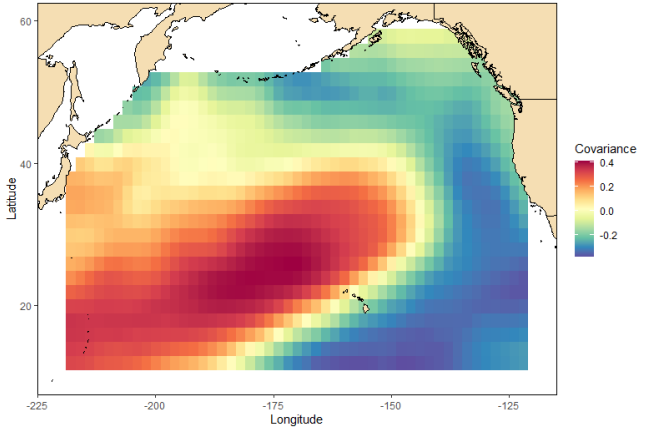
Taking the Next Step

Regress annual SST patterns onto the Optimal Pattern to obtain an index of similarity, here called the Covariance Map Index of Sea Surface Temperature

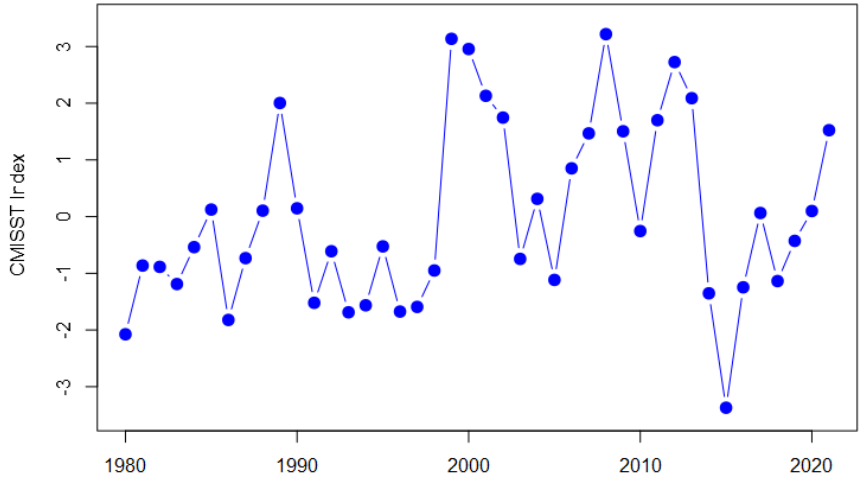
Winter SST data



Optimal Pattern



Winter Index (CMISST) for spring Chinook



Y ~ X

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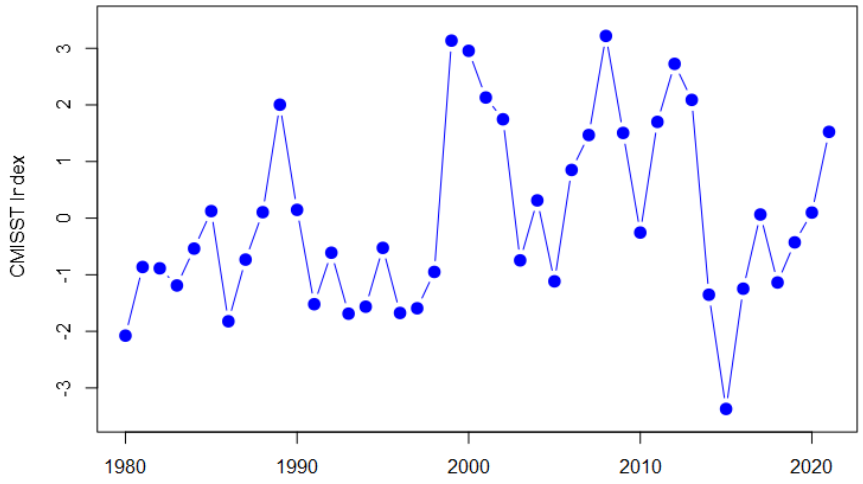
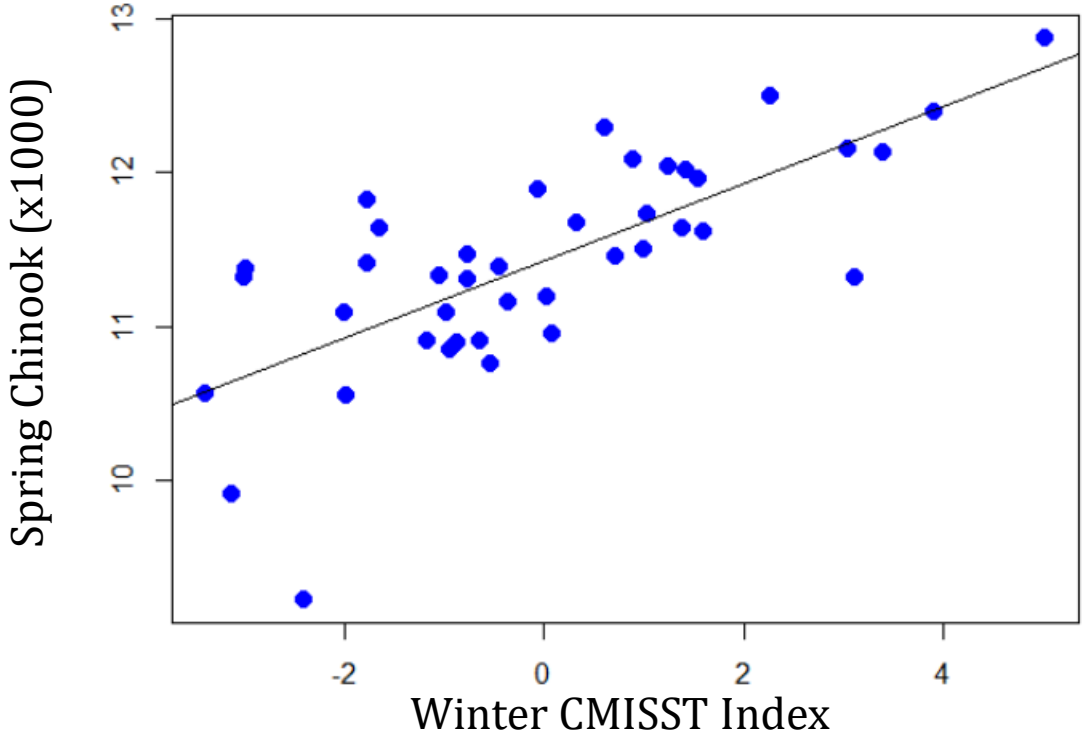
Methods

Once we have the index, we can model the response variable with a regression model





Years when SST is opposite of Optimal Pattern

Years when SST is similar to Optimal Pattern

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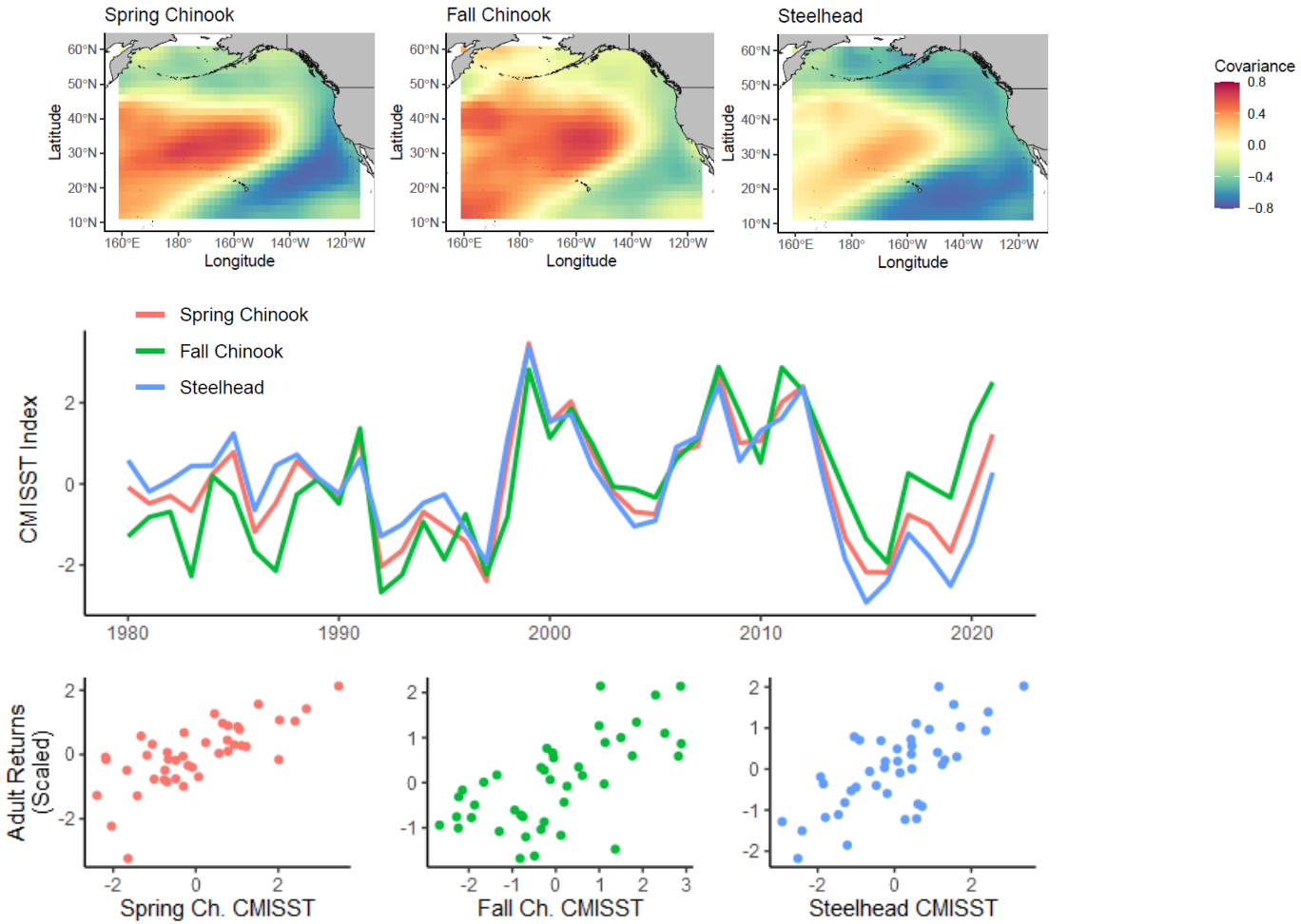
A Stock-Specific Index can be created from each Map



CMISST = Covariance Map Index of Sea Surface Temperature

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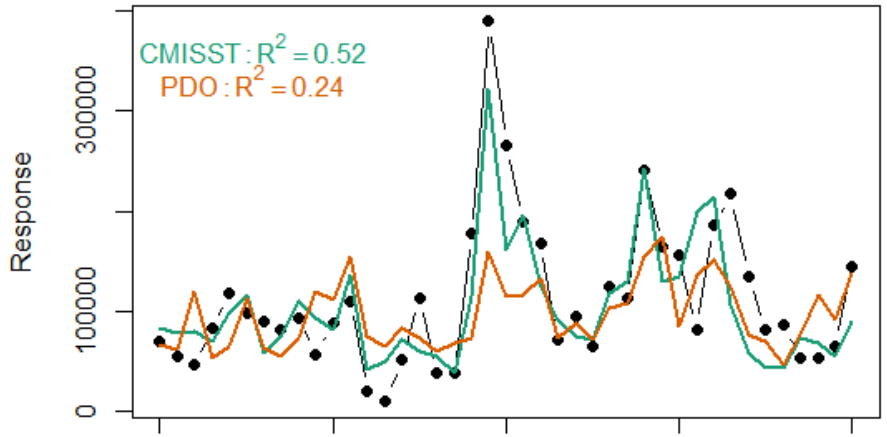
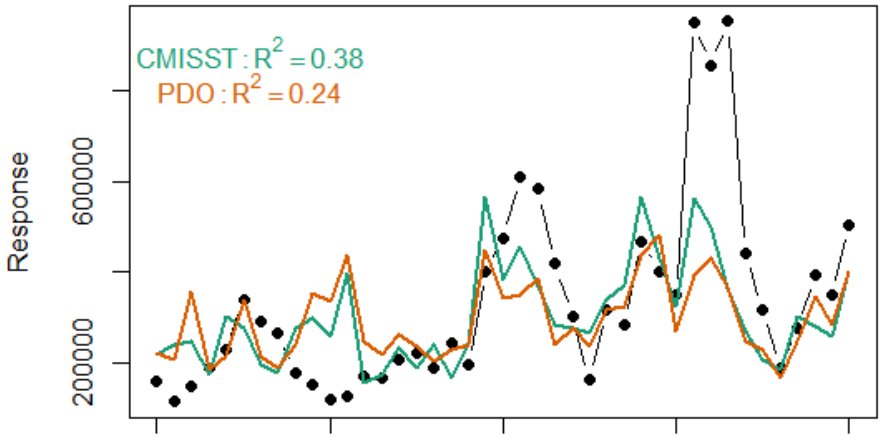
Methods

And compare performance to other indicators

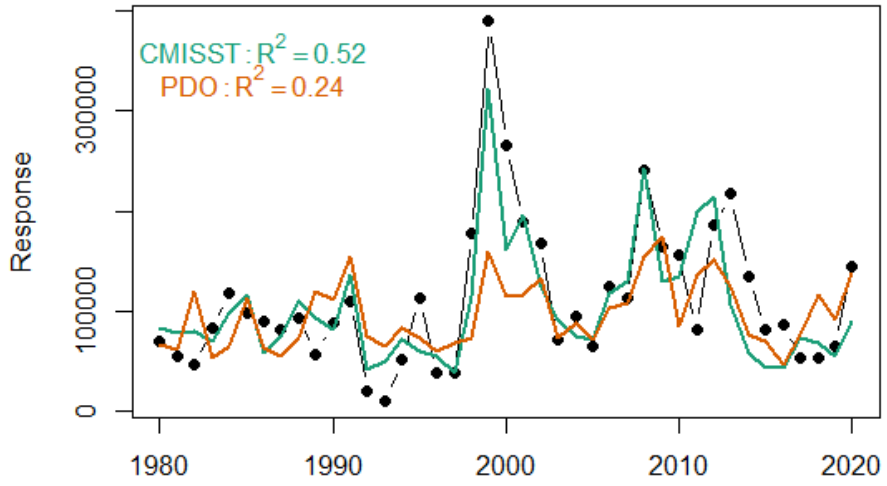
Spring Chinook



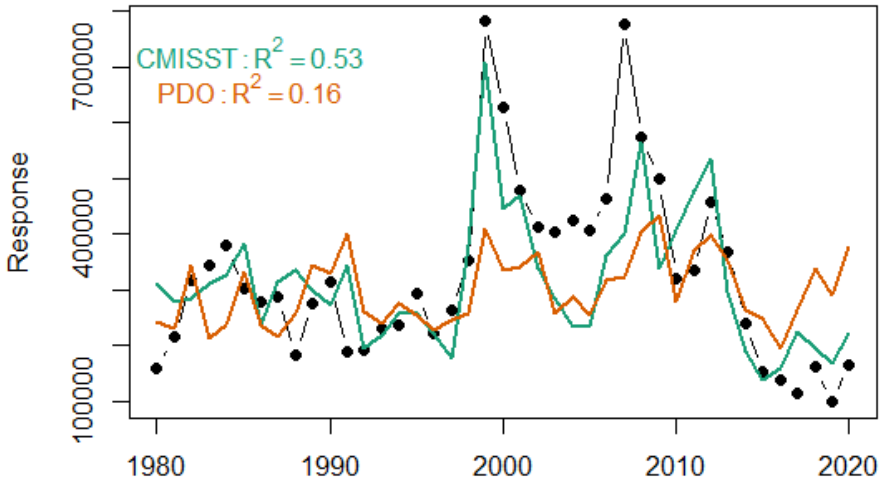
Fall Chinook



Spring Chinook jacks



Steelhead



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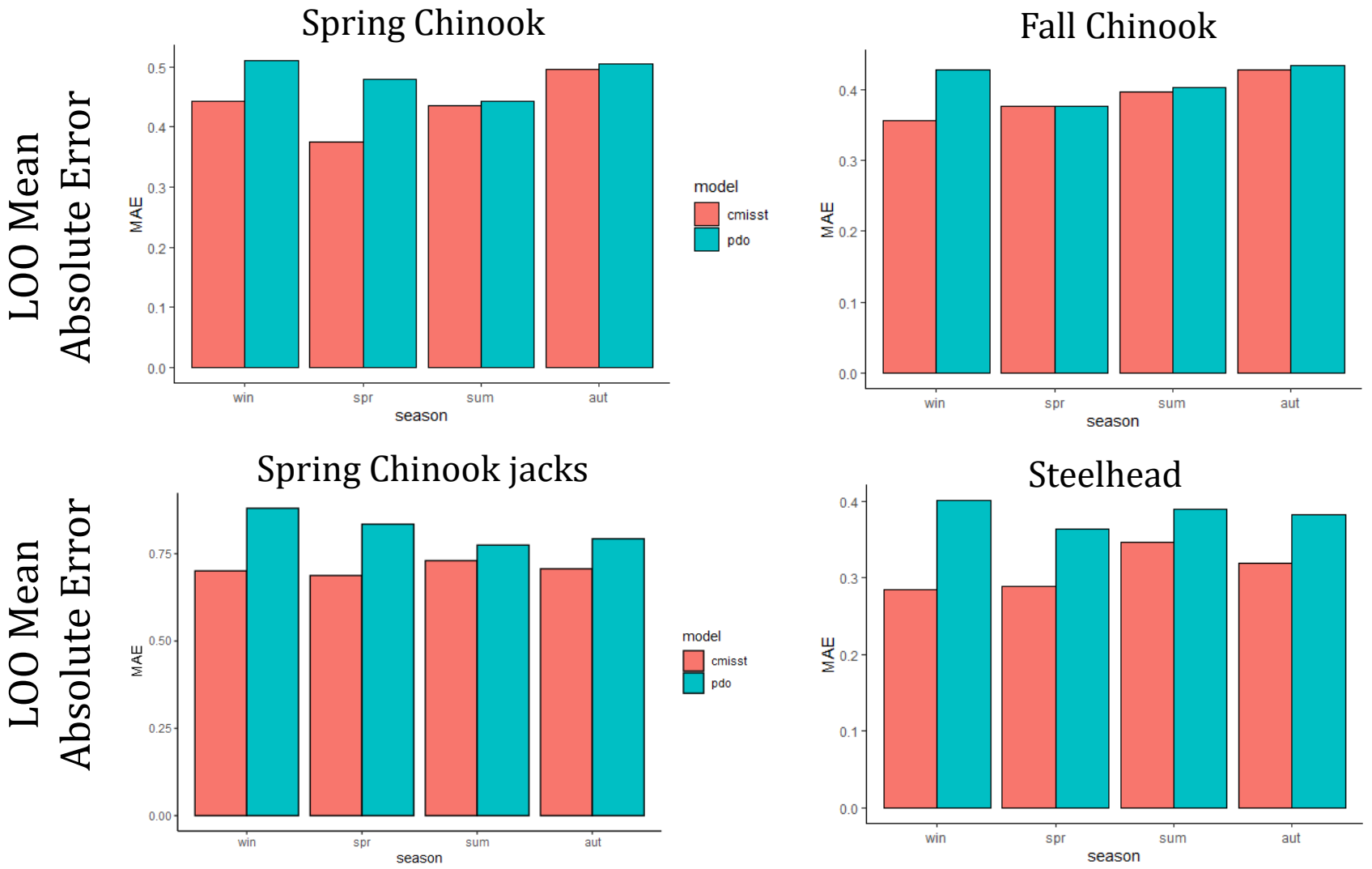
Methods

If you're thinking "but you used the response variable to create the Index, creating a circular relationship"…



Shiny App

CMISST

Controls

Spatial Data

- (•) SST
- ( ) SSH (higher res, will take longer)

Select Response

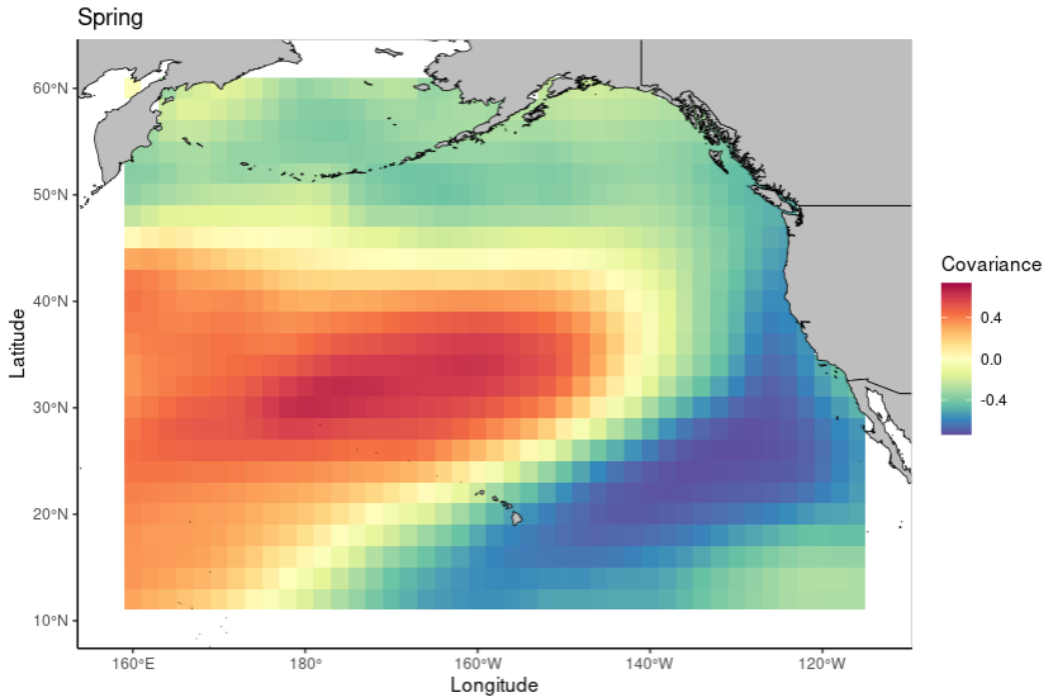
Spring Chinook

Or choose your own CSV file

Browse... No file selected

CSV file should have 2-columns (year and response) with headers. Year should be adult return year (specify lags below). To reset the file to null, refresh the webpage

Covariance Map of Sea Surface Temperature



Log response?

Years:

1970 1980 2021

1970 1976 1982 1988 1994 2000 2006 2012 2018 2023

Years refer to the SST or SSH data. If your response variable is different, use the lag option below to align the data.

Lag Response:

2 years

Index Prediction Year:

Enter a single year to predict. The response for this year will be left out of the calculations and the seasonal indices will be calculated for that year (to reset this to null, reload the webpage)

Latitude Range:

-88 10 62 88

-88 -70 -52 -34 -16 2 20 38 56 74 88

Longitude Range (0 and 360 are the Prime Meridian):

0 158 246 358

0 36 72 108 144 180 216 252 288 324 358

https://connect.fisheries.noaa.gov/content/9df237ec-ec94-4c71-8782-8f1c7332fd77

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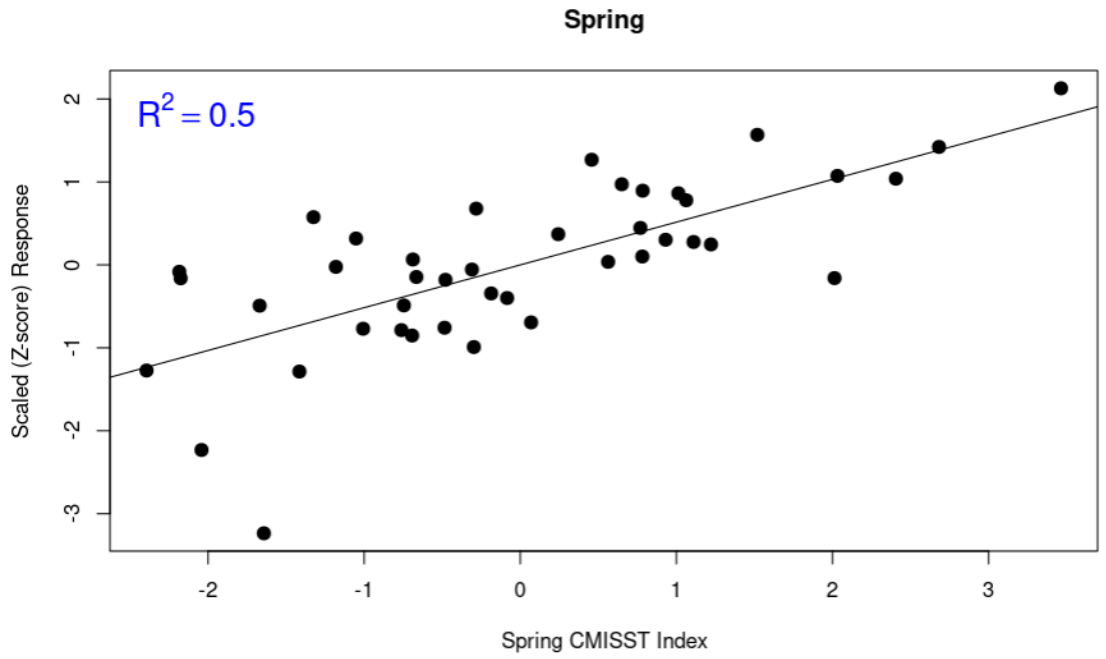
Shiny App (cont.)

Which season to plot:

- ○ Winter (Jan-Mar)
- ◉ Spring (Apr-Jun)
- ○ Summer (Jul-Sep)
- ○ Autumn (Oct-Dec)



year	win.cov	spr.cov	sum.cov	aut.cov	response
1980	-2.08	-0.08	0.21	0.60	-0.40
1981	-0.86	-0.49	-0.37	-0.54	-0.76
1982	-0.89	-0.30	-0.73	-0.46	-0.99
1983	-1.19	-0.67	-0.12	0.15	-0.15
1984	-0.54	0.24	-0.13	0.30	0.37
1985	0.12	0.78	-0.55	-0.46	0.10
1986	-1.82	-1.18	-1.49	-2.29	-0.02
1987	-0.73	-0.48	-1.50	-1.70	-0.18
1988	0.10	0.56	0.67	1.24	0.04
1989	2.00	0.07	0.11	-0.33	-0.69
1990	0.15	-0.31	-0.38	-0.39	-0.06
1991	-1.52	1.11	0.72	-1.36	0.28
1992	-0.61	-2.04	-2.20	-2.54	-2.23
1993	-1.69	-1.64	-1.90	-2.21	-3.24
1994	-1.56	-0.69	-0.40	-0.13	-0.85
1995	-0.53	-1.05	-1.14	-0.12	0.32
1996	-1.68	-1.41	-0.55	-1.31	-1.29
1997	-1.59	-2.39	-2.27	-1.80	-1.27
1998	-0.95	0.65	1.32	1.89	0.97
1999	3.14	3.46	3.06	3.30	2.13
2000	2.96	1.52	1.36	1.99	1.57
2001	2.13	2.03	1.71	1.33	1.07
2002	1.75	0.78	0.85	-0.08	0.89
2003	-0.75	-0.19	-0.50	-0.59	-0.34
2004	0.31	-0.69	-0.60	-0.26	0.06
2005	-1.12	-0.75	0.20	1.72	-0.49
2006	0.85	0.77	0.35	-0.50	0.45
2007	1.47	0.93	0.73	2.76	0.30
2008	3.22	2.68	2.72	2.42	1.42
2009	1.50	1.01	-0.31	0.20	0.86

https://connect.fisheries.noaa.gov/content/9df237ec-ec94-4c71-8782-8f1c7332fd77

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Next Steps

- Apply to more situations (more species, more independent data)
- Interpret Covariance Maps?
- Investigate non-stationarity and non-linearity
- Management applications (please provide feedback!)

Questions?

brian.burke@noaa.gov

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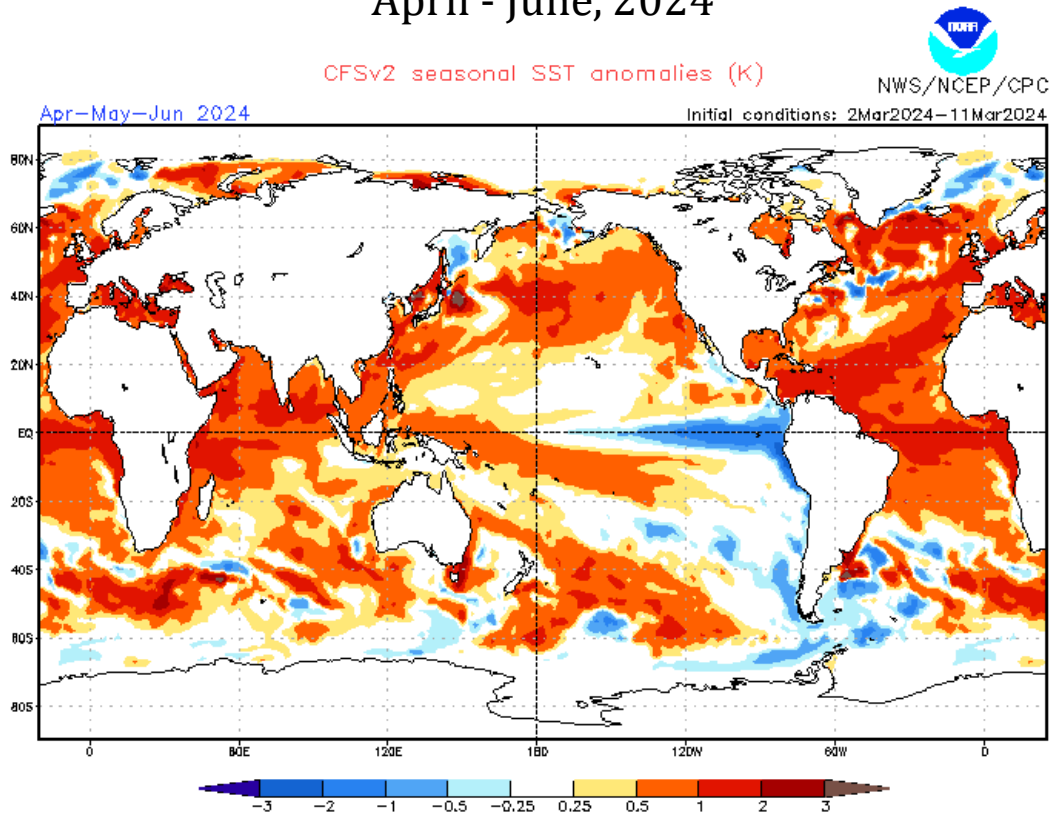
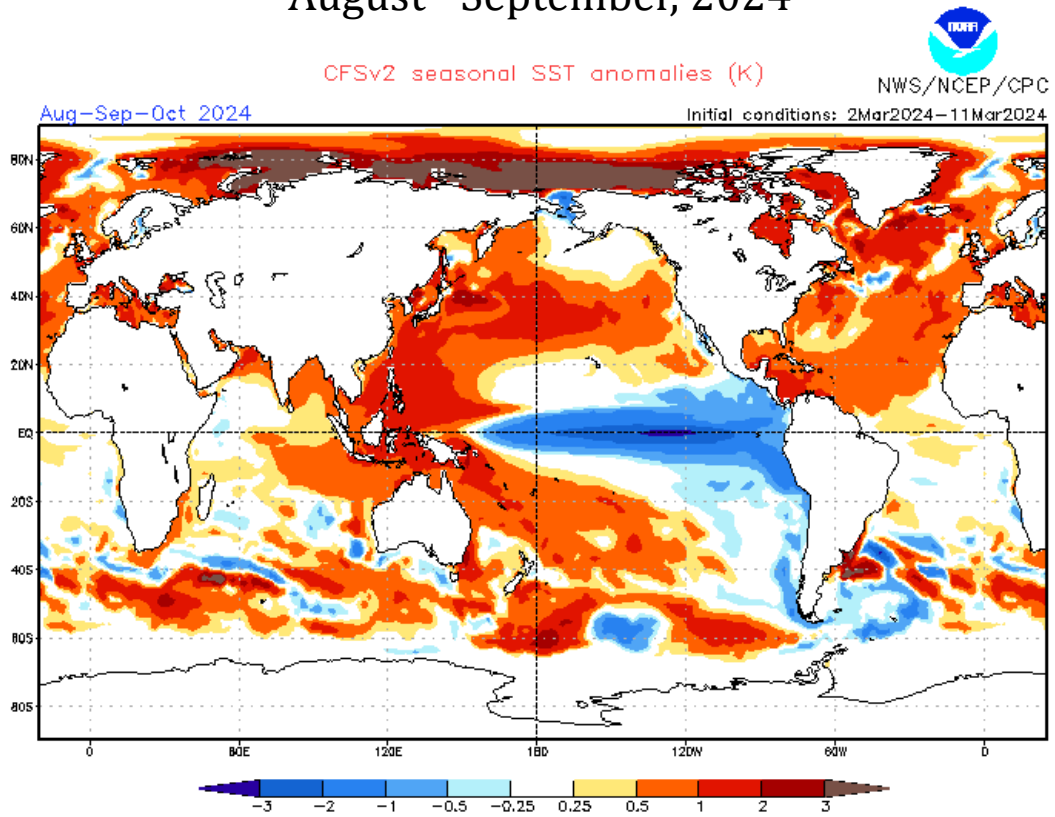
Heading towards a La Niña?

April - June, 2024



August - September, 2024



https://www.cpc.ncep.noaa.gov/products/CFSv2/CFSv2seasonal.shtml

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