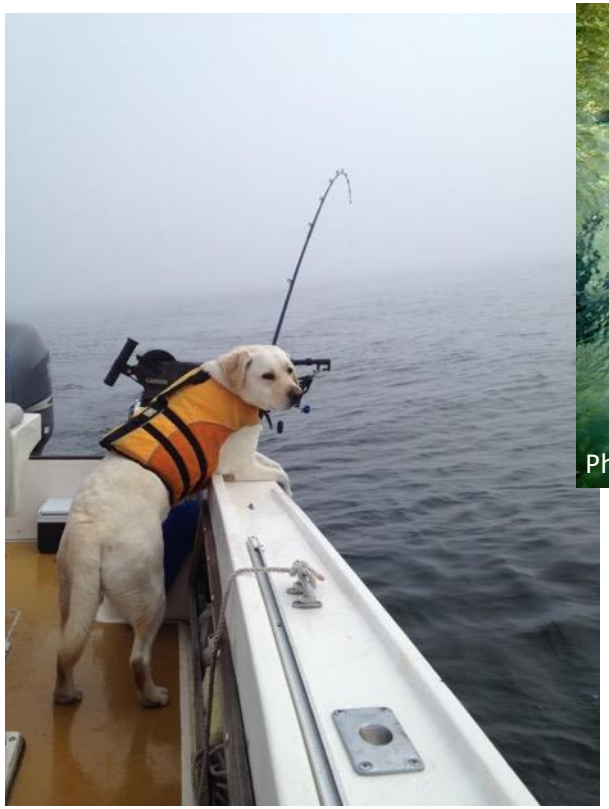
Ecological Thresholds and Temporal Patterns in Chinook Salmon Forecast Performance



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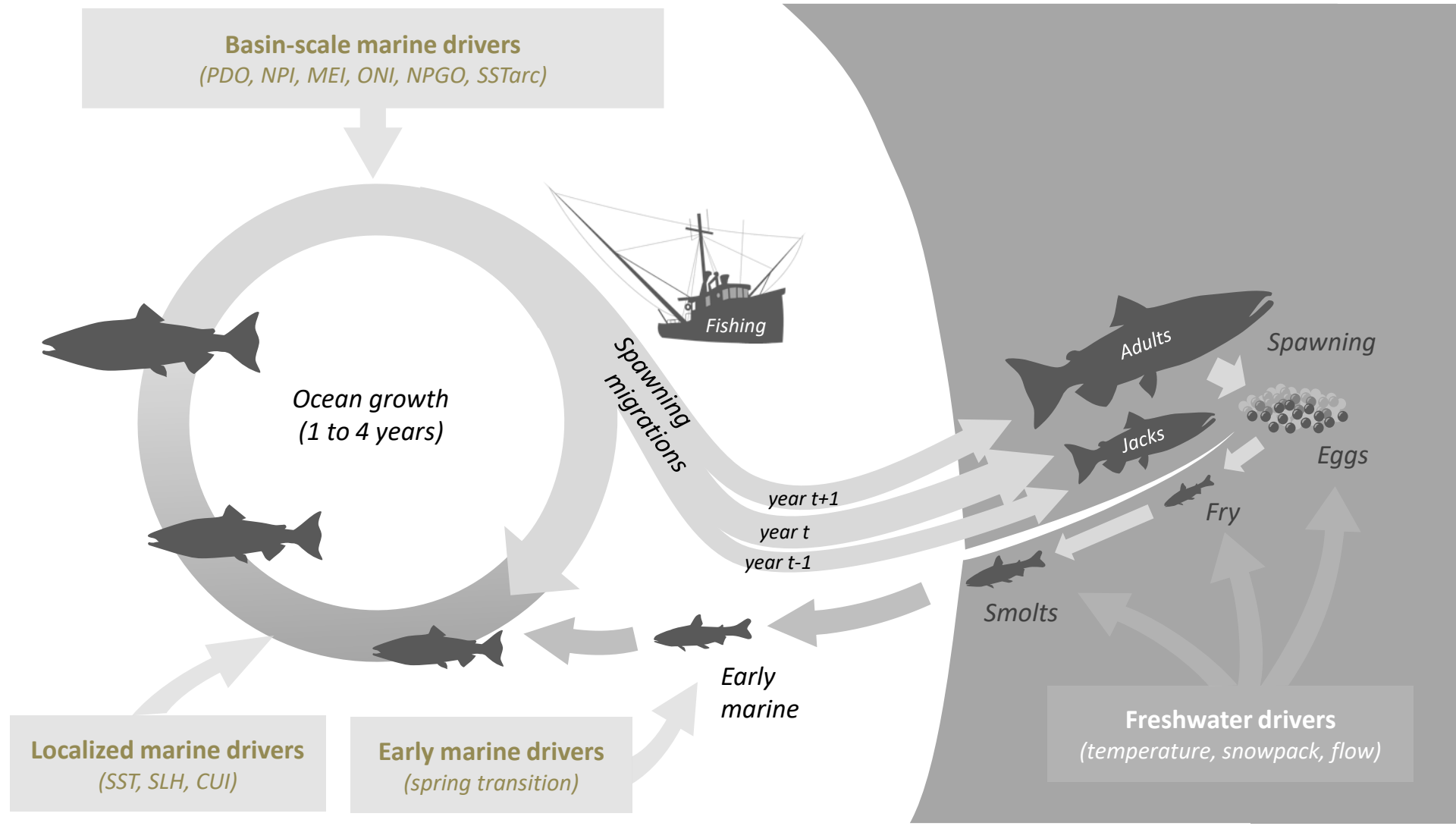
Salmon lifecycle and potential drivers



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Motivation for this work

- California Current Integrated Ecosystem Assessment Team provides annual report to PFMC with multiple environmental indicators
- Call from Council and its advisory bodies for work to identify “threshold” values in some of these indicators that could better inform management
- Council advisory bodies recently noted increasingly variable salmon escapement and challenges in forecasting

- Management uses of abundance forecasts
  - Escapement goals
  - Exploitation rate caps
  - Ecosystem considerations
- Types of forecasts
  - Sibling relationships
  - Production multipliers
  - Environmental models
  - Ensembles
  - Adjustments based on recent performance

Sacramento Fall Chinook Harvest Control Rule

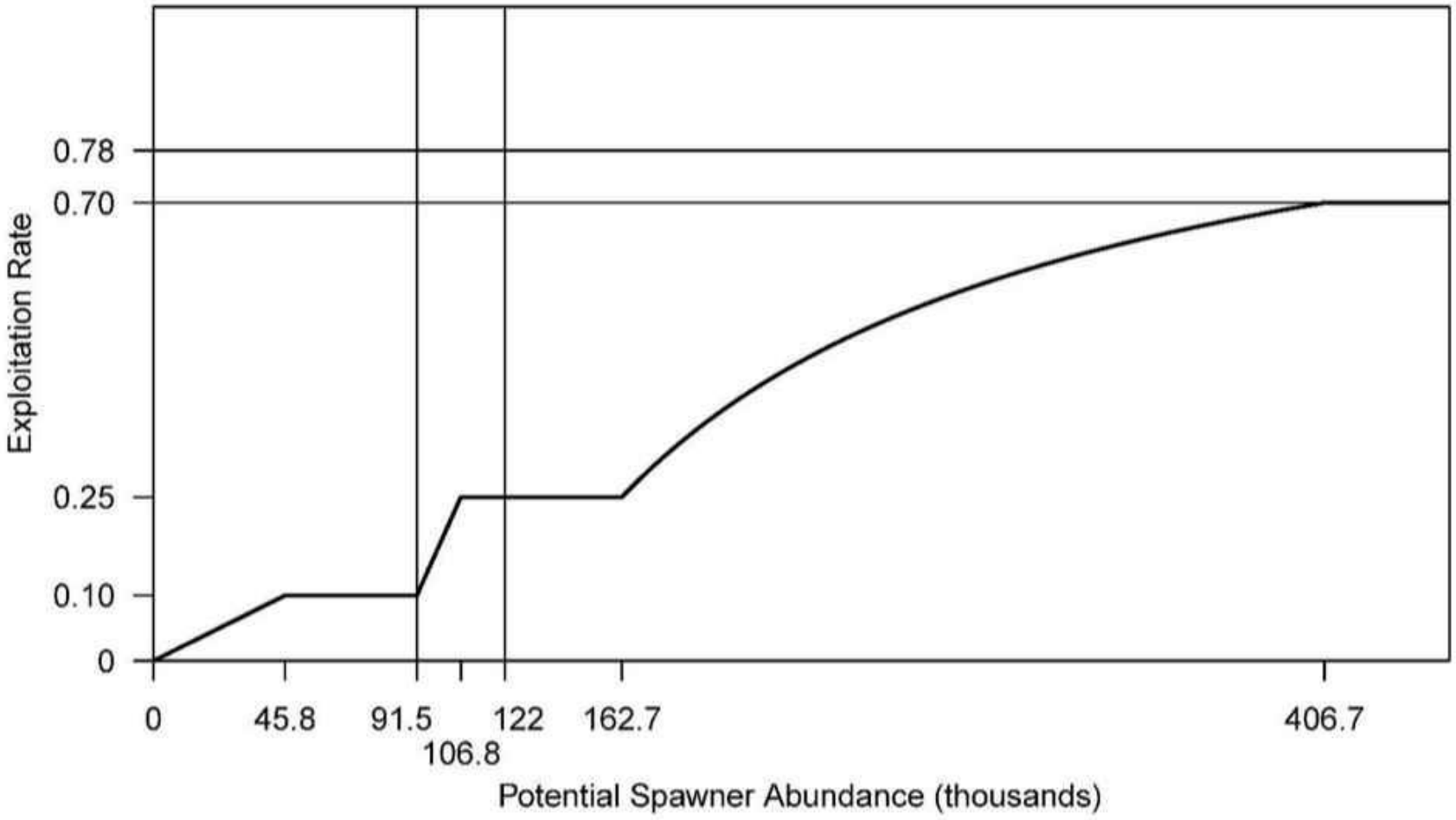

FIGURE A-1. Sacramento River fall Chinook control rule. Potential spawner abundance is the predicted hatchery and natural area adult spawners in the absence of fisheries, which is equivalent to the Sacramento Index. See the salmon FMP, Section 3.3.6, for control rule details.

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Sacramento Winter Chinook Control Rule

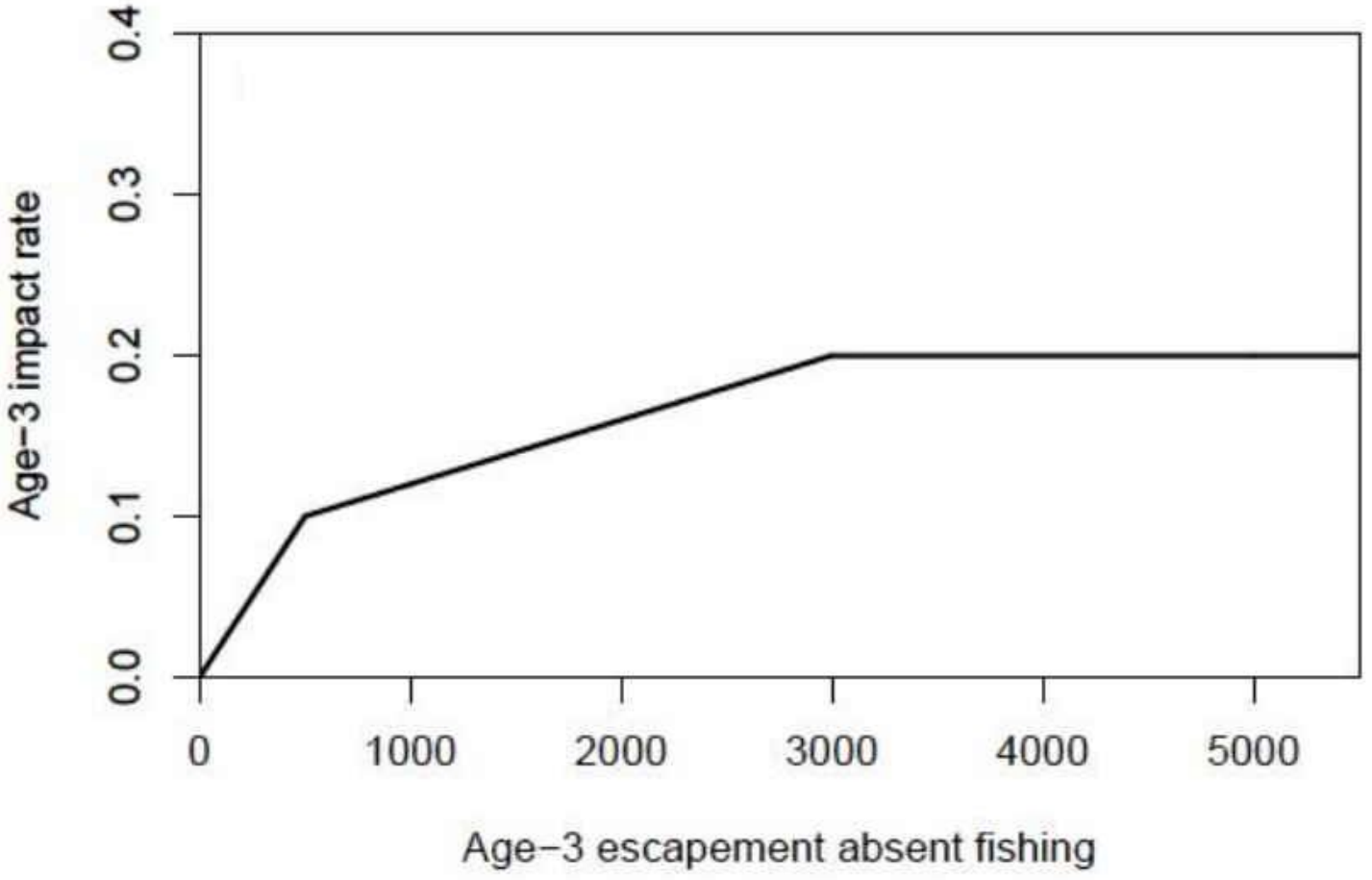

FIGURE A-3. Council Recommended Sacramento River winter Chinook impact rate control rule; which specifies the maximum forecast age-3 impact rate for the area south of Point Arena, California, as a function of forecasted age-3 escapement absent fishing.

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Performance metric

$$P_y = \frac{\frac{f_y - o_y}{o_y}}{\frac{1}{N}\sum_{i=ymin}^{i=ymax}\left|\frac{f_i - o_i}{o_i}\right|}$$

P – performance

y – year

f – forecast

o – observation/postseason estimate

> 0 means overforecast

< 0 means underforecast

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Searching for thresholds

- Looked at forecast performance of priority stocks
  - Ocean fishery: Sacramento and Klamath fall Chinook
    - PFMC indicators, often largest contributors to ocean fisheries
  - SKRW prey: Puget Sound summer-fall Chinook
- Indicators considered
  - Freshwater: flow, temperature, snowpack
  - Local ocean: upwelling, spring transition, SLH, SST
  - Basin/oceanographic: PDO, NPI, MEI, ONI, NPGO, SSTarc
  - Lags scaled to habitat use over lifecycle
- Full disclosure: this resulted in multiple tests!
  - Null model, Bonferroni considerations

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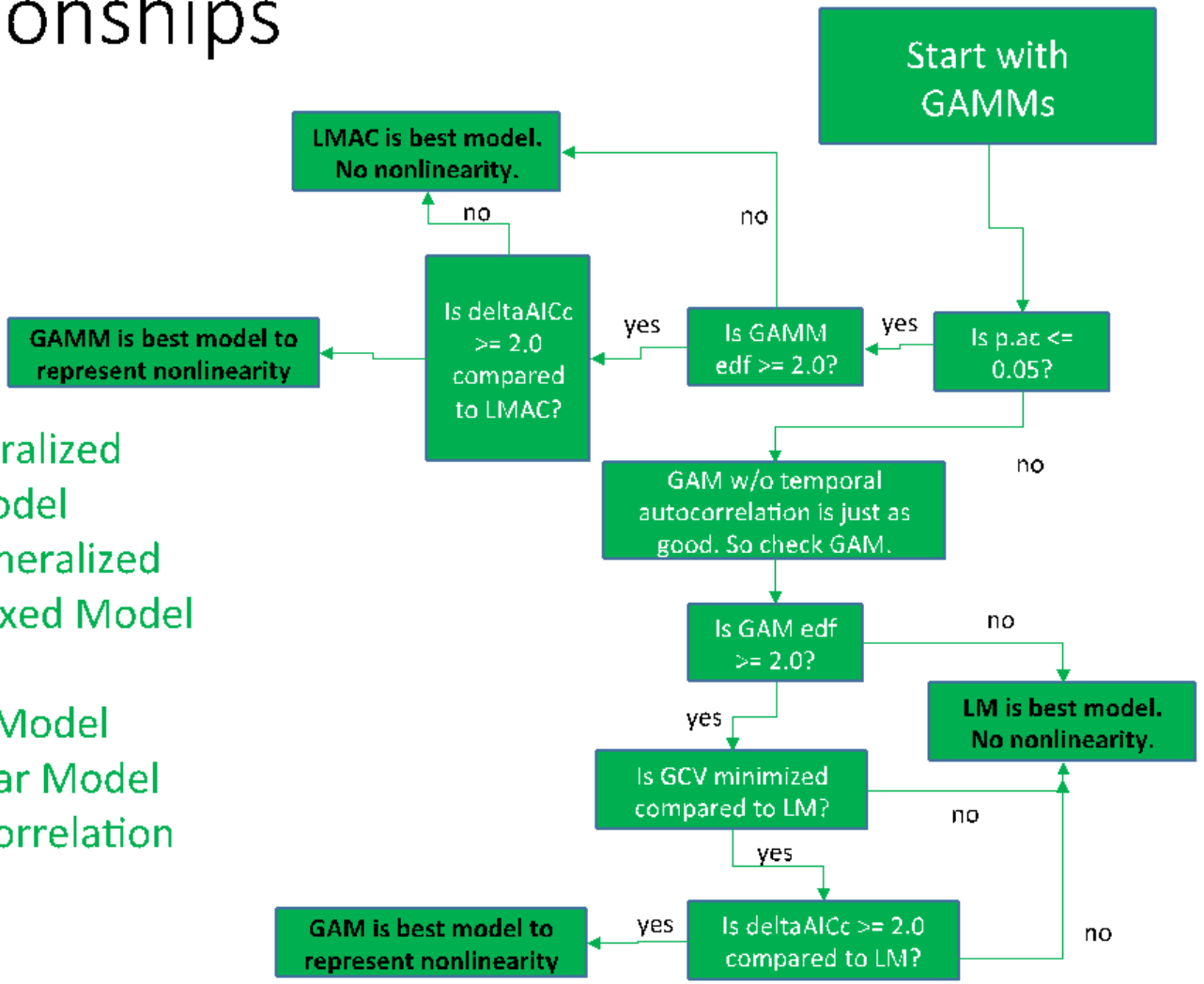
Distinguishing nonlinear state-pressure relationships



GAM: Generalized Additive Model
GAMM: Generalized Additive Mixed Model

LM: Linear Model
LMAC: Linear Model with AutoCorrelation

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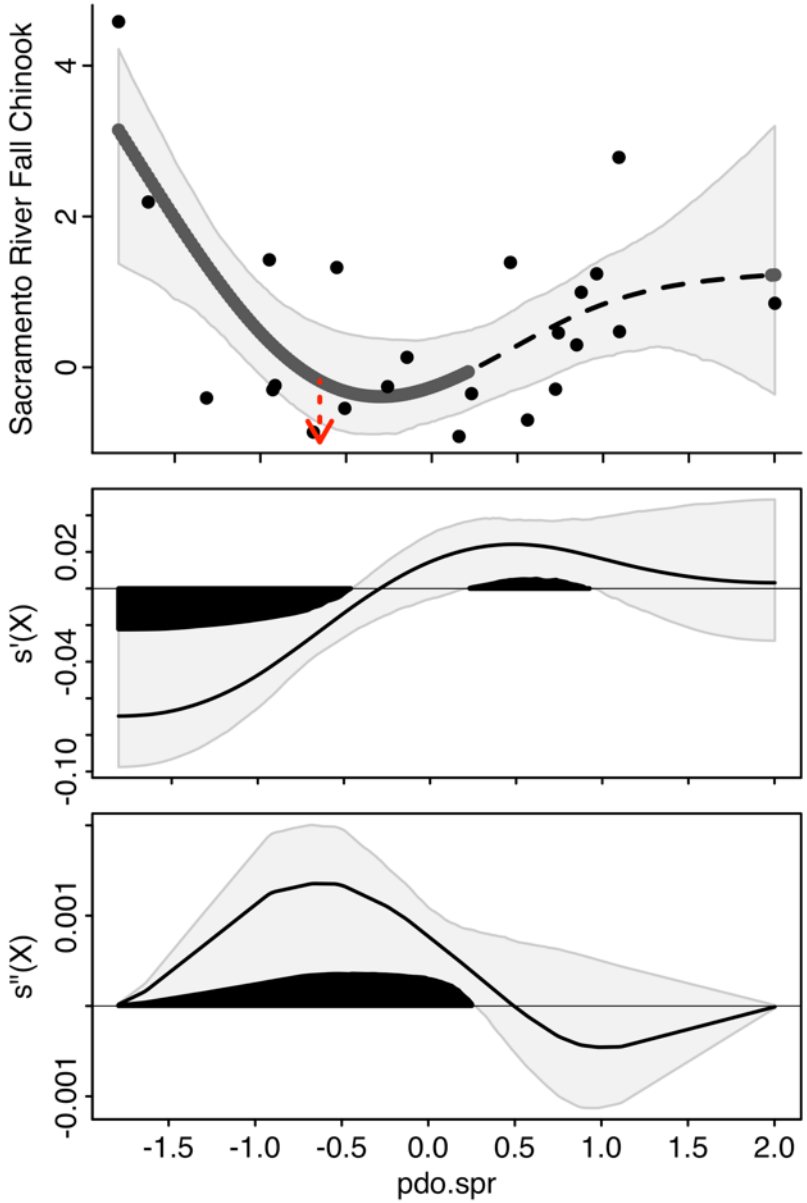
If nonlinear response, is there acceleration?

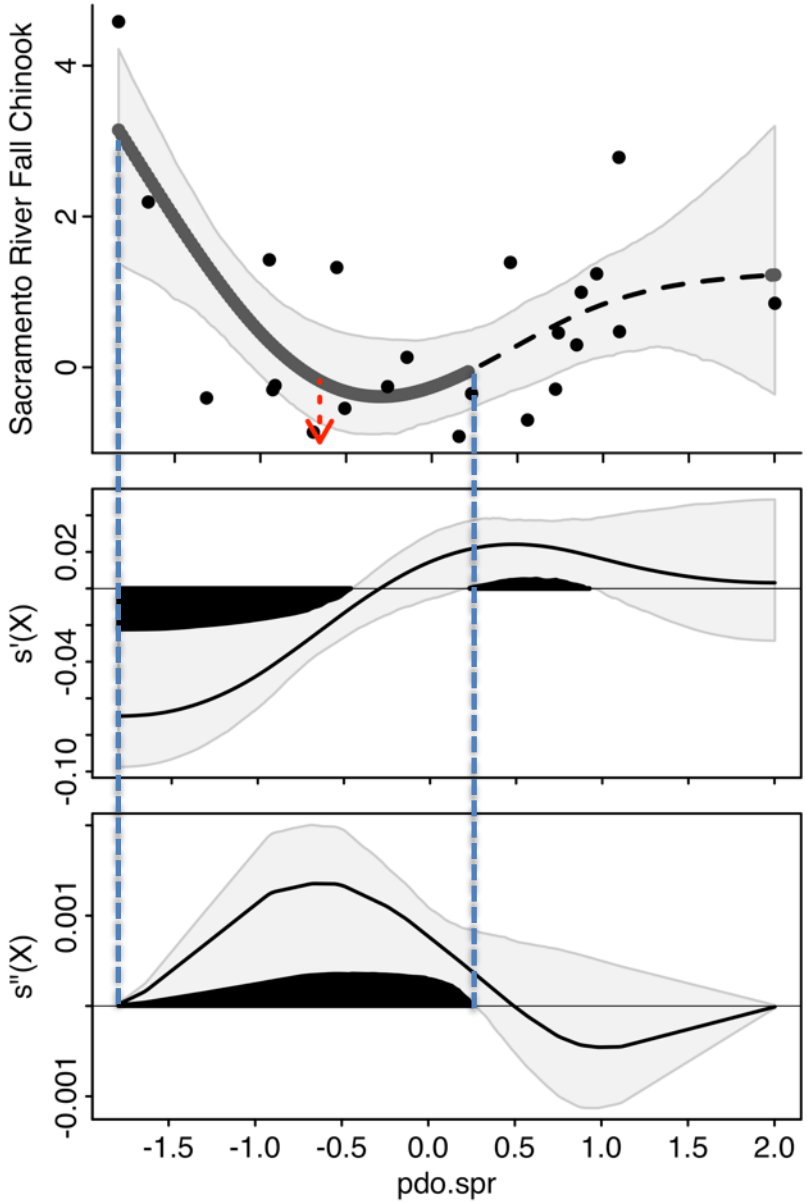


Fitted relationship

First derivative

Second derivative

If nonlinear response, is there acceleration?



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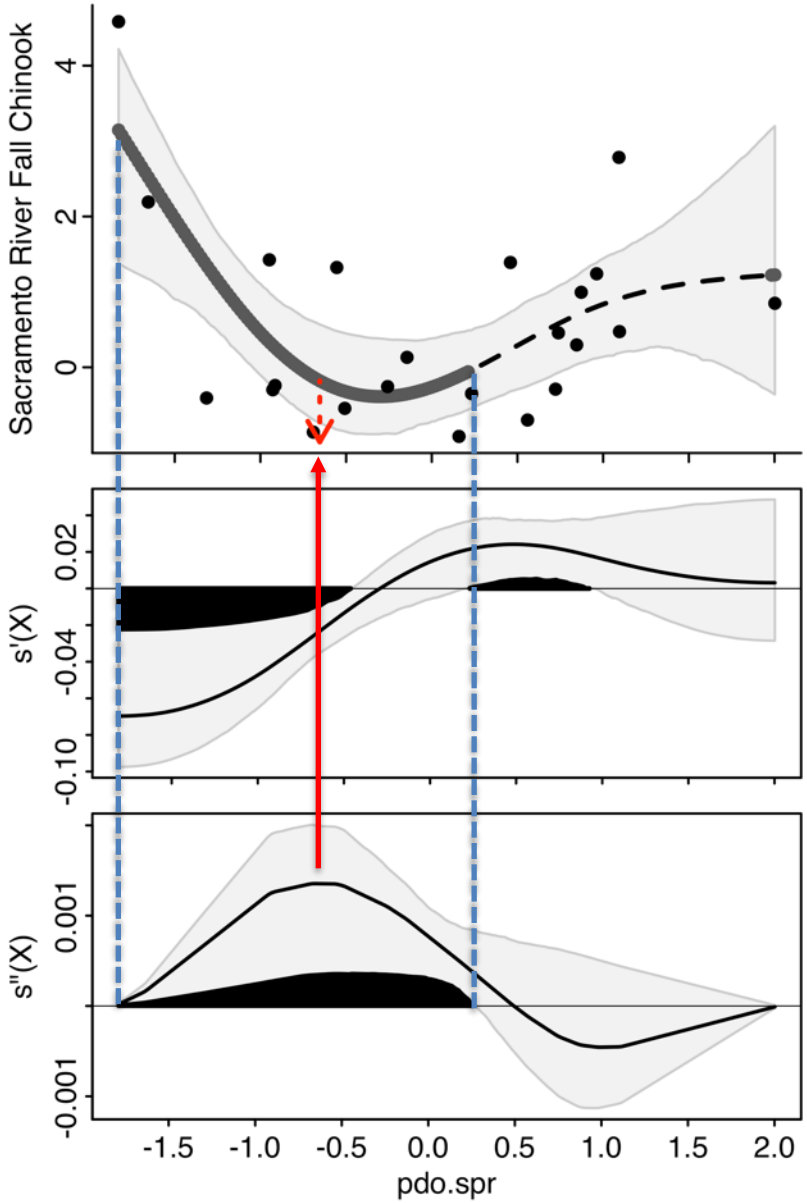


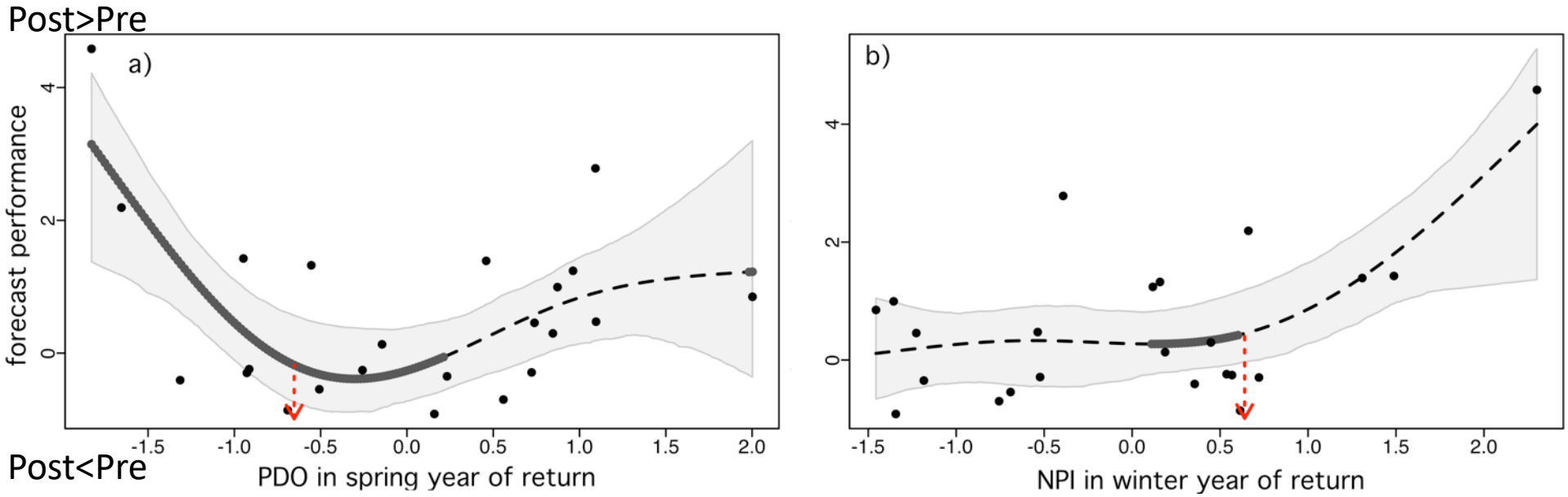
Fitted relationship

First derivative

Second derivative

Results – key fishery stocks

- Klamath fall Chinook: top model (linear) had R^2=0.16, top nonlinear model R^2=0.13, p_{null}=0.81
- Sacramento fall Chinook: two models with R^2>0.40 both nonlinear with thresholds (p_{null}=0.46 or 0.17)



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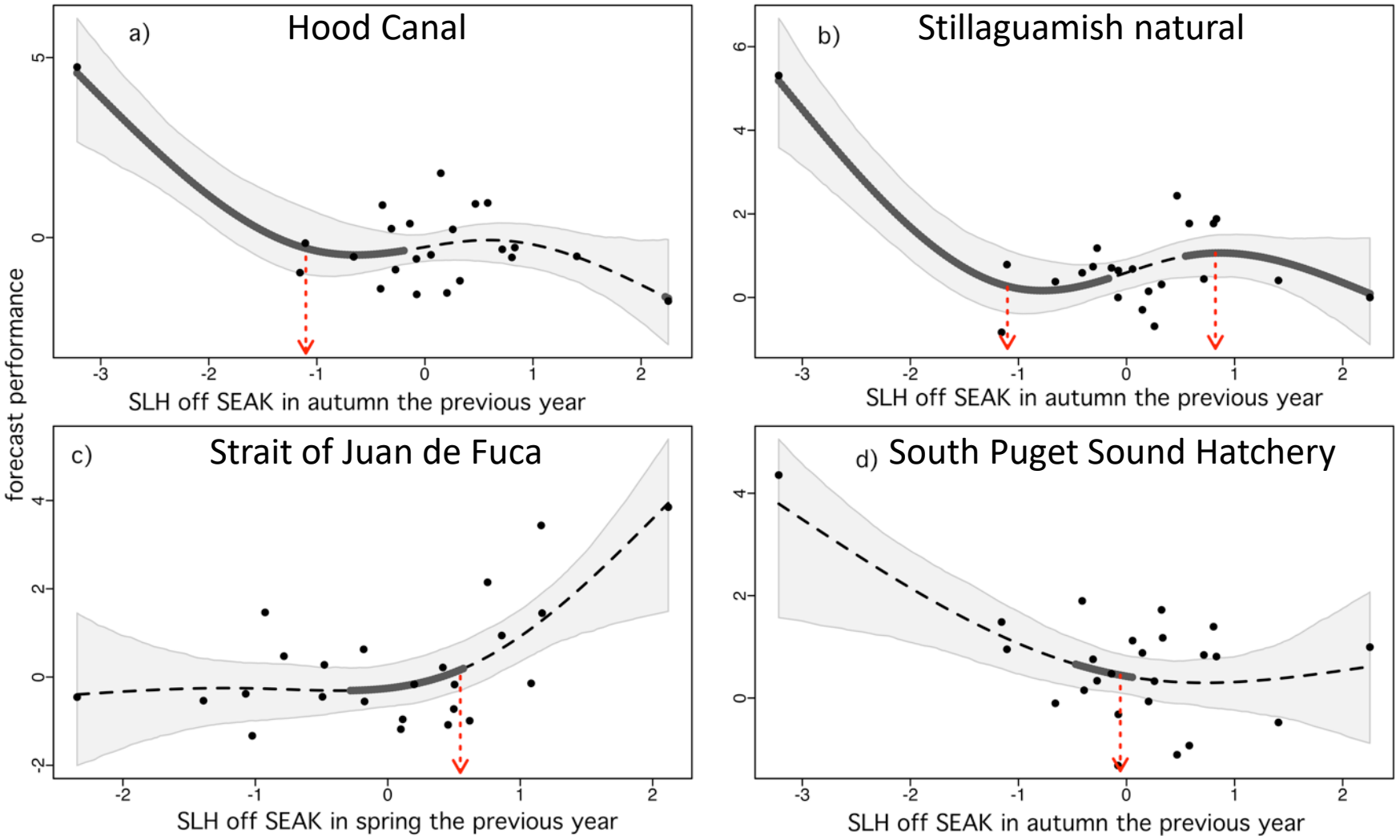
Results – Puget Sound stocks

Stock	obs. R^2>0.5	p_{null}	obs. R^2>0.33	p_{null}
South Puget Sound natural summer-fall Chinook	4	0.15	14	0.0012
Tulalip Hatchery summer-fall Chinook	2	0.91	8	0.55
South Puget Sound hatchery summer-fall Chinook	1	0.55	6	0.20
Hood Canal combined summer-fall Chinook	4	0.31	7	0.51
Stillaguamish natural summer-fall Chinook	2	0.80	6	0.67
Snohomish hatchery summer-fall Chinook	0	1.00	0	1.00
Snohomish natural summer-fall Chinook	0	1.00	6	0.15
Strait of Juan de Fuca combined summer-fall Chinook	0	1.00	3	0.66
Nooksack-Samish combined summer-fall Chinook	0	1.00	1	0.71
Skagit natural summer-fall Chinook	0	1.00	0	1.00

SLH off Alaska the previous year?



Specifically, Sea Level Height in 2013.

Multiple Puget Sound stocks came in well below their forecasts in 2014.

Considerations on thresholds

- R^2>0.50 rare, seen at rates expected by chance
- Rate of R^2>0.33 seen is unlikely by chance alone
- Null model may be too conservative
  - (Not all stock-index-lag combinations equally plausible a priori)
- Mechanistic explanations for many relationships
- Important drivers/lags for different forecast types make sense
- Outliers have a lot of leverage, but this is what you'd expect in a threshold scenario

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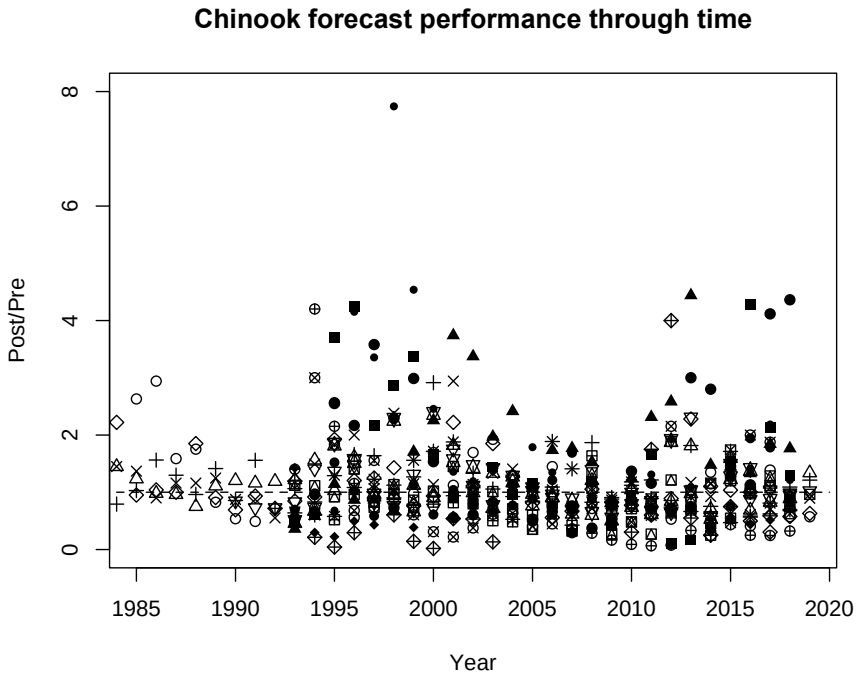
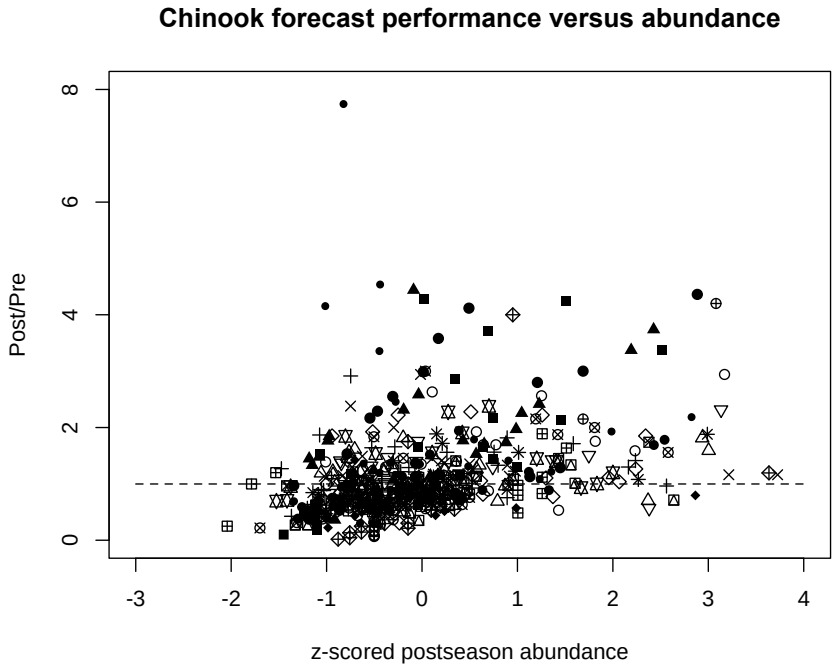
Temporal patterns

- For PFMC's SRKW Workgroup: Is Chinook salmon forecast performance improving through time and does it depend on abundance?

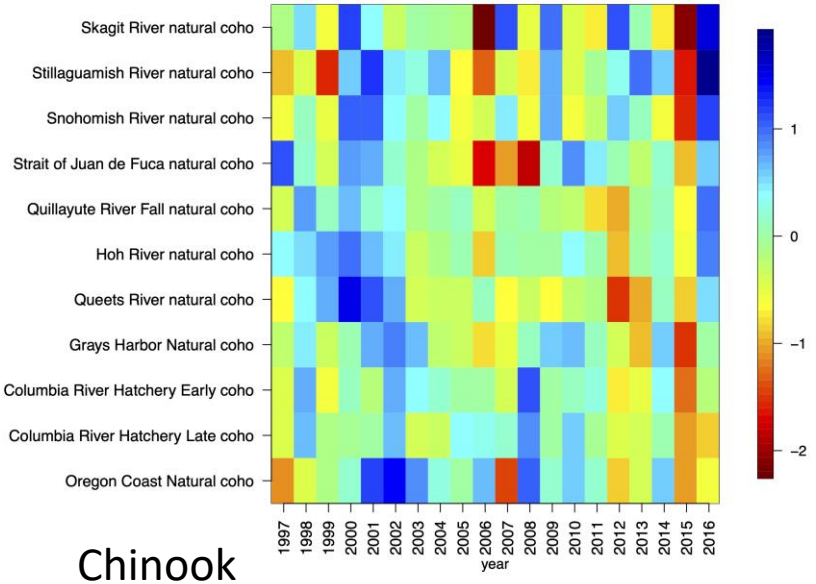




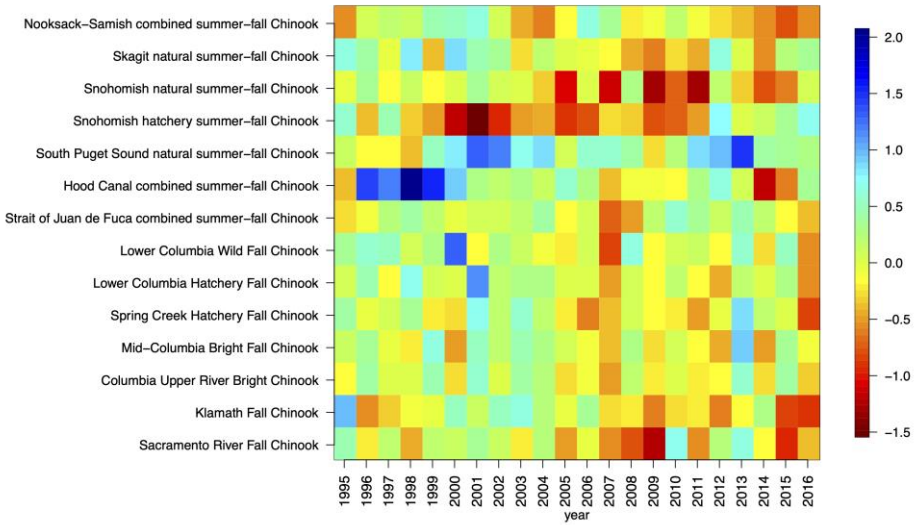
https://www.pcouncil.org/documents/2020/10/f-2-a-srkw-workgroup-report-3-forecast-accuracy-report.pdf/

Synchrony

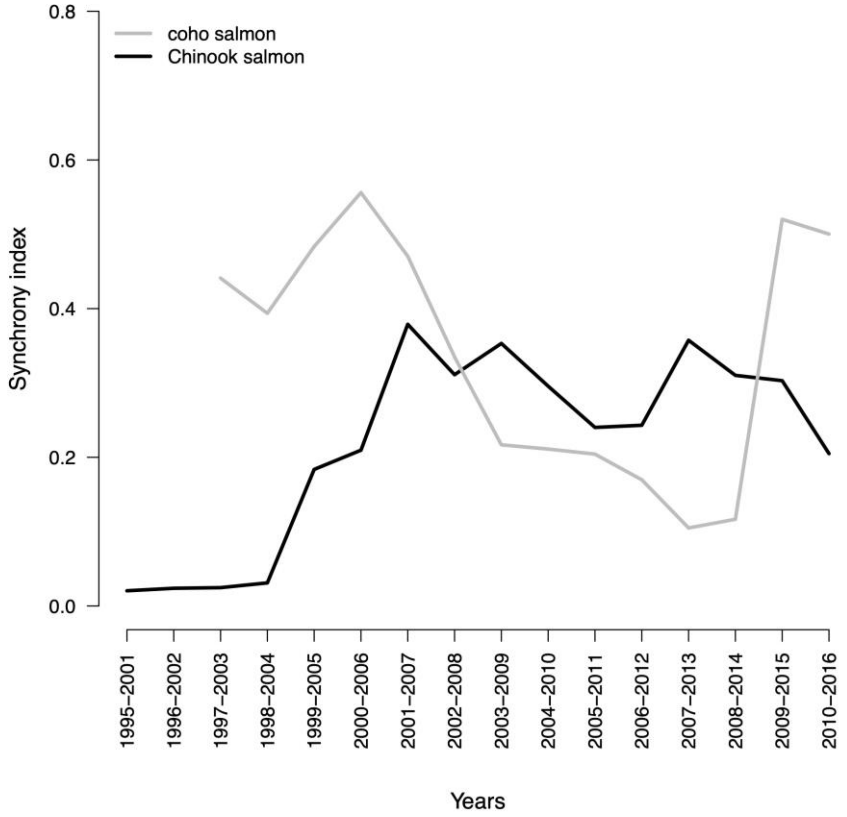
Coho



Chinook



Loreau & de Mazancourt synchrony index



Thanks. Questions?

Thresholds work available from:
ICES Journal of Marine Science
DOI: 10.1093/icesjms/fsz189

Forecasting performance evaluation for PFMC SRKW WG:
https://www.pcouncil.org/documents/2020/10/f-2-a-srkw-workgroup-report-3-forecast-accuracy-report.pdf/

Synchrony work forthcoming from Jenn Gosselin and colleagues

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Photo credit: Zeke Lunder