Retrospective analysis of Skagit River chum salmon productivity

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Skagit River System Cooperative

FCC-NCC Meeting
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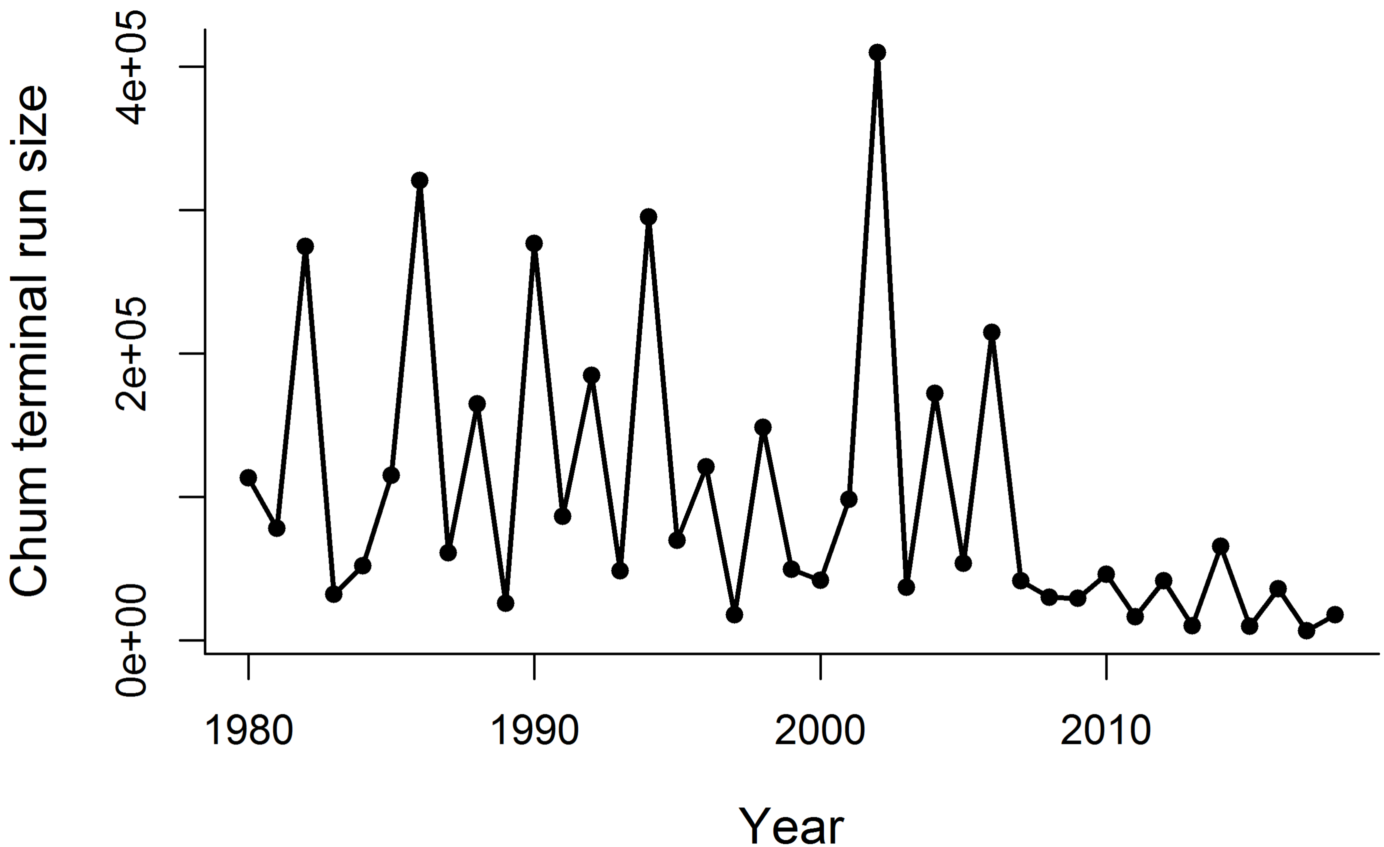
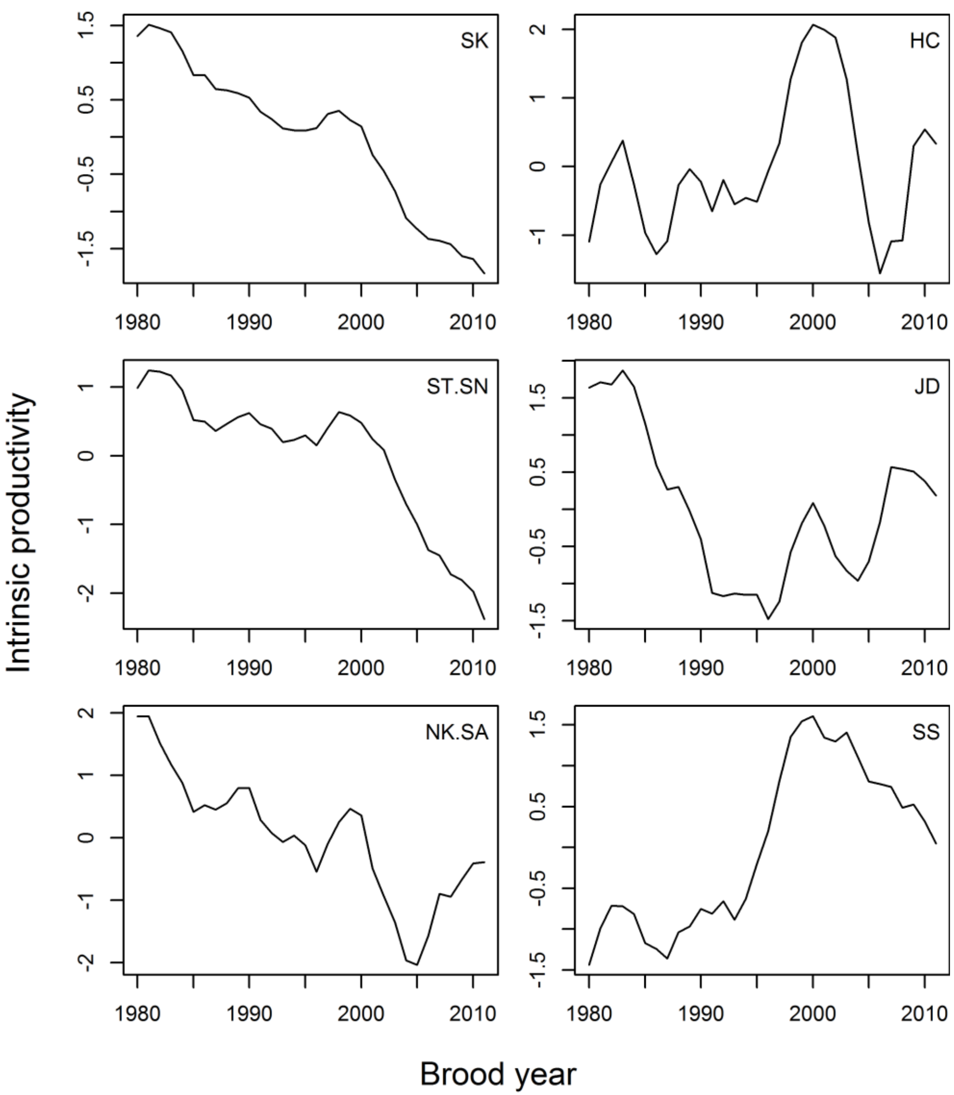
Skagit River Chum Salmon



Talk Outline

- Regional patterns in chum salmon productivity
- Localized patterns and potential drivers of Skagit River chum productivity
- Evaluation of density dependence and survival patterns at individual life stages including.

Regional versus coastal patterns in lifetime productivity



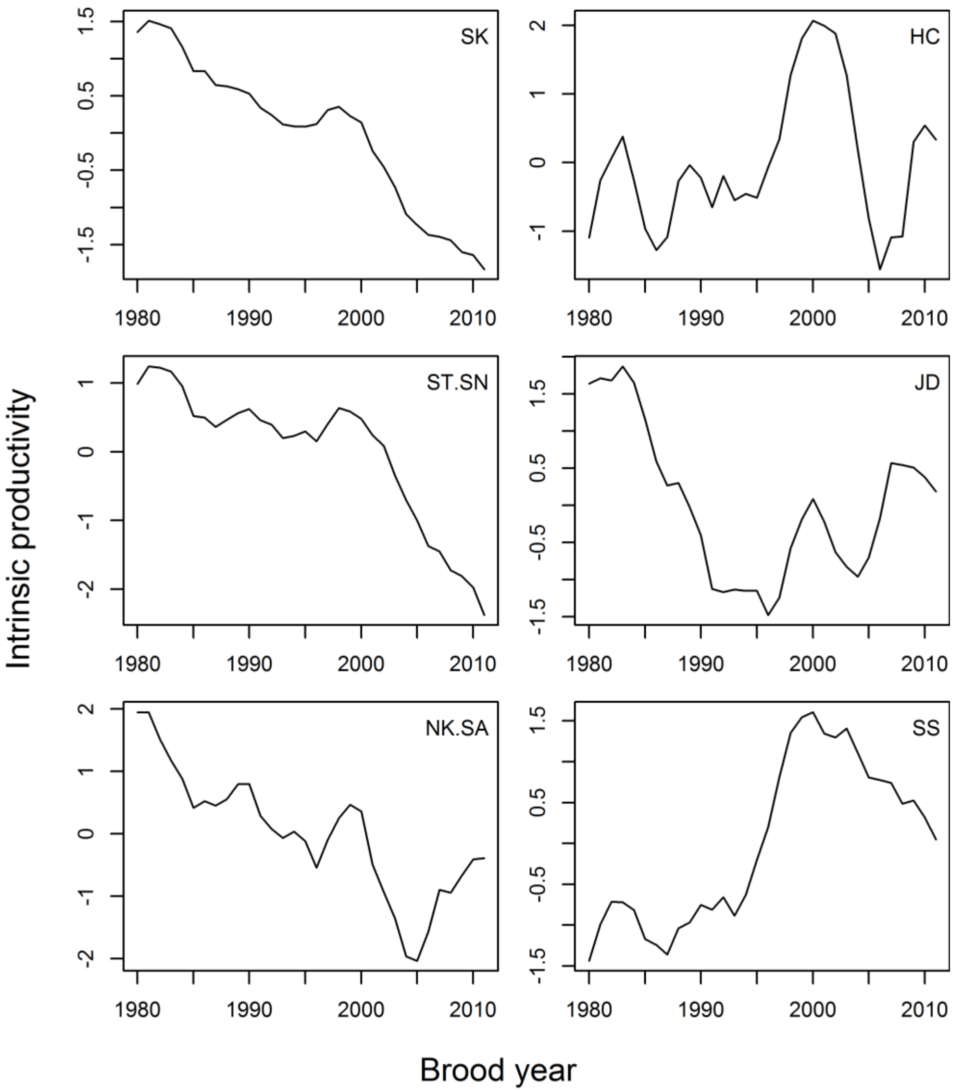
Questions

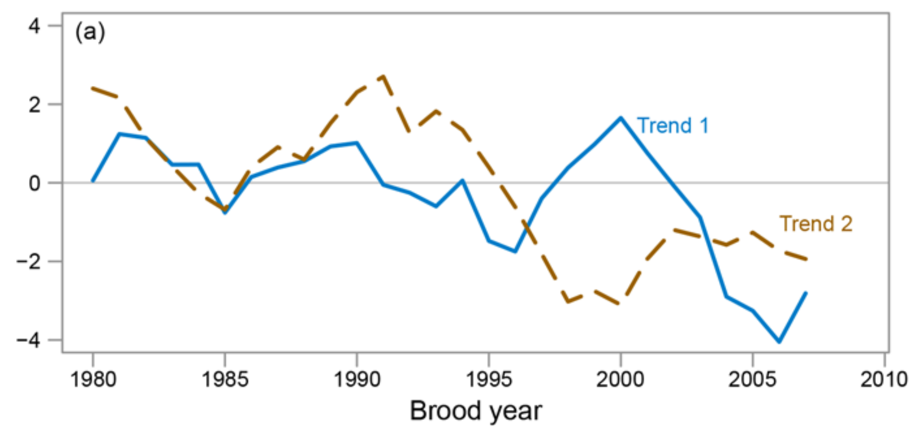
1. Are declines in productivity observed in other subasins throughout Puget Sound?
2. Do the predominant patterns in productivity track those of coastal stocks?

Methods

1. Fit Kalman filter Ricker spawner recruit model to time series of spawners and recruits for six Puget Sound Chum stock complexes.
2. Compare temporal patterns in productivity between stocks (e.g. surviving offspring per spawning adult)
3. Compare productivity trends to those previously estimated for coastal stocks.

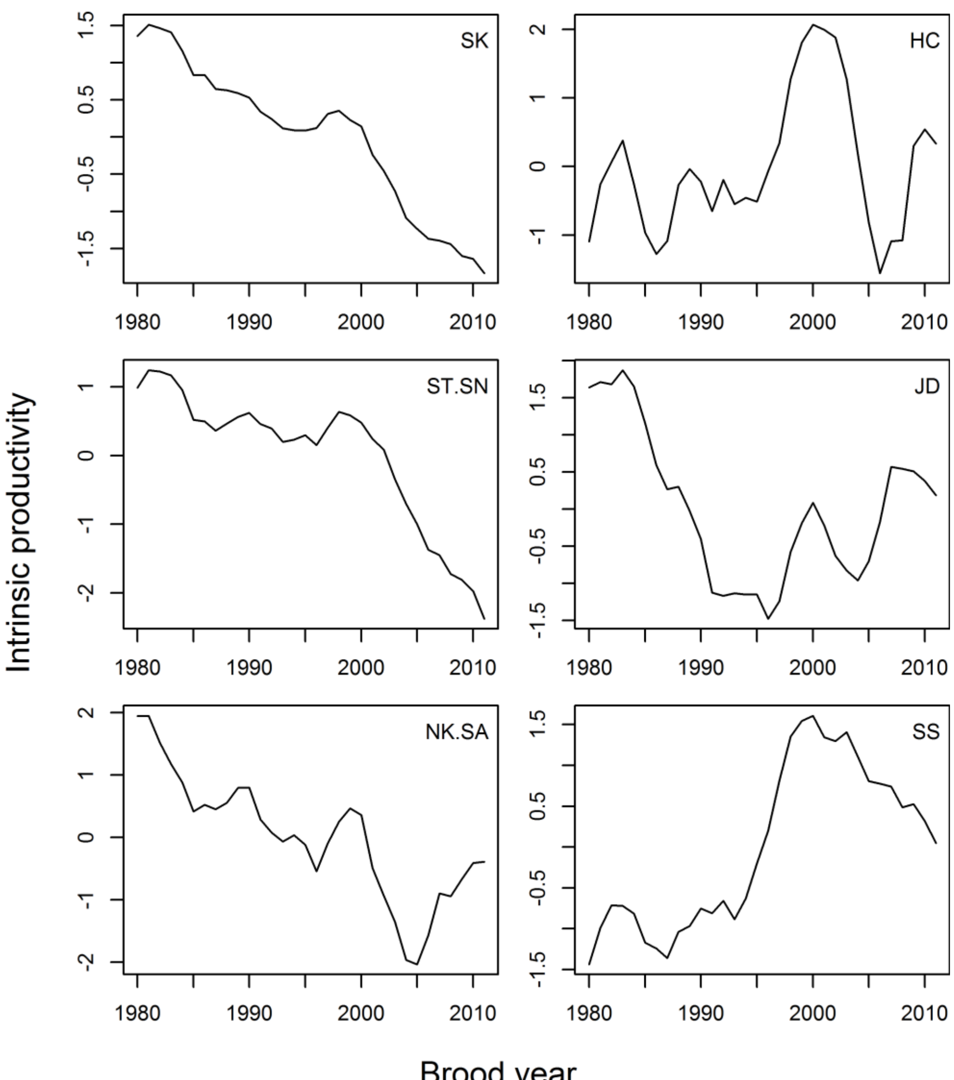
Regional versus coastal patterns in lifetime productivity





From Malik et al. 2016

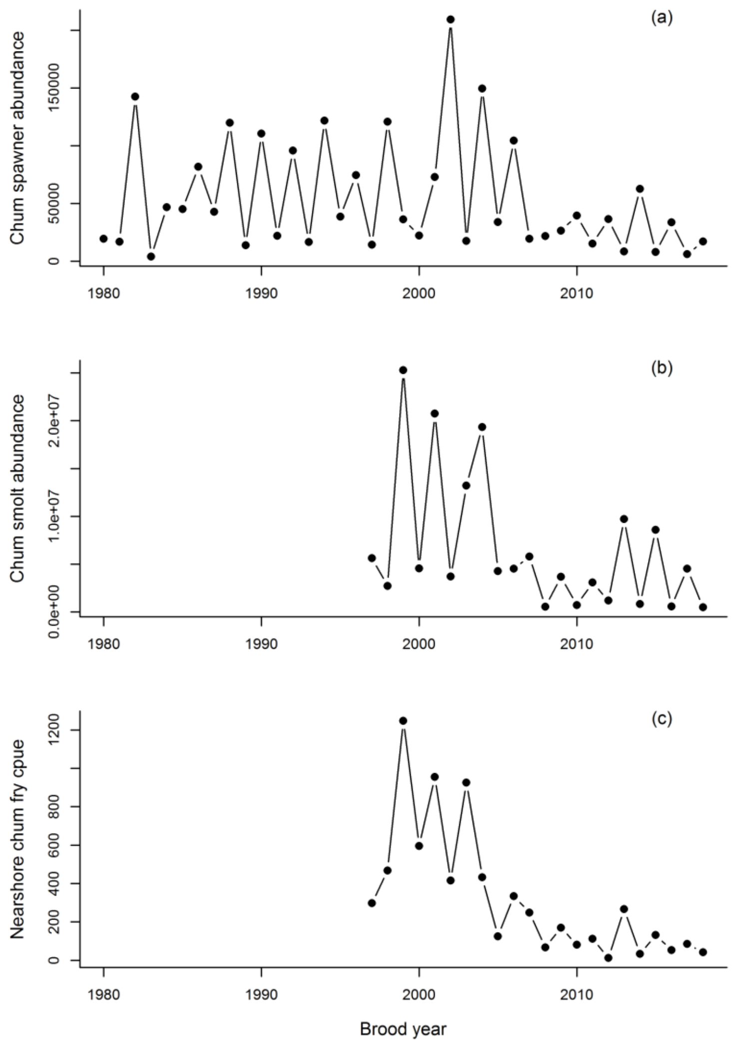
Regional versus coastal patterns in lifetime productivity



Initial conclusions

- Whidbey basin stocks appear to exhibit strong coherence in temporal trends in productivity.
- Whidbey basin productivity trend matches coastwide trend with a strong decline in productivity beginning in the early 2000's.
- Other aggregate stock complexes are more variable.

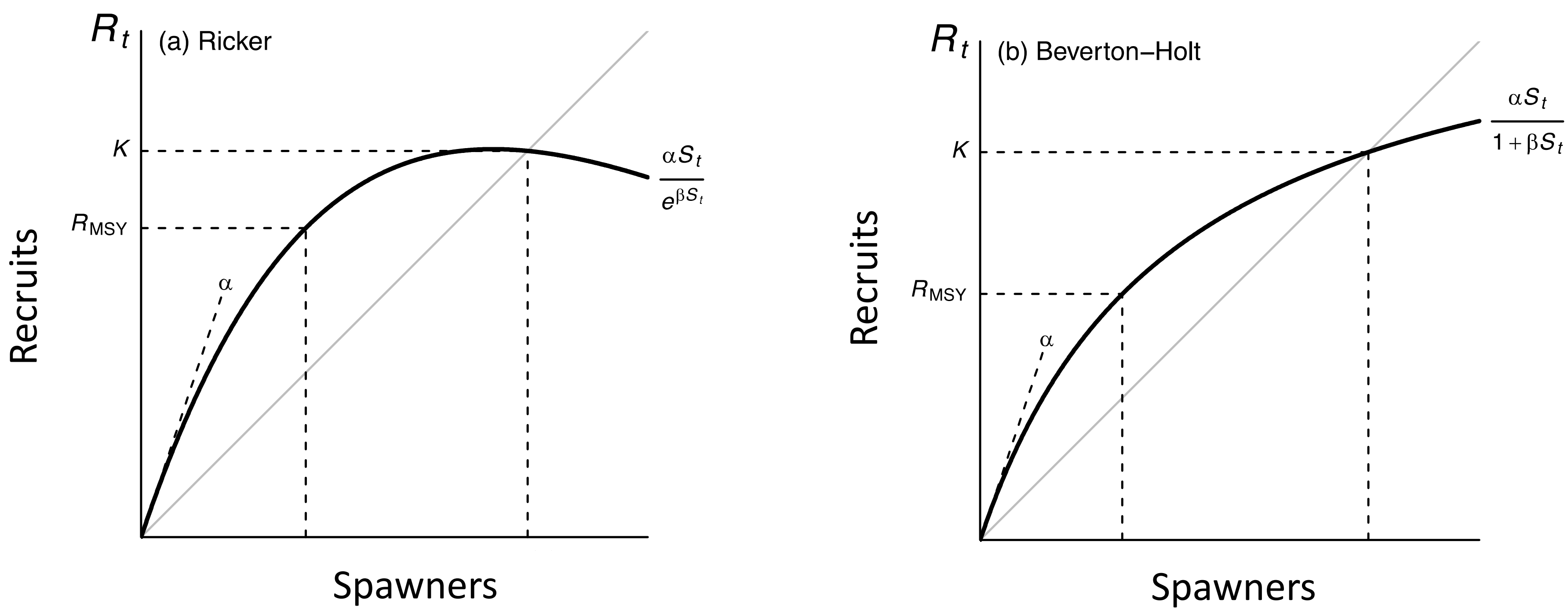
Localized patterns and potential drivers of Skagit Chum salmon productivity



Questions

1. How are the observed patterns in abundance explained by population dynamics?
2. Can we identify an initial suite of drivers of chum salmon productivity that are biologically based?

Productivity model



Integrated Population Model

Models for age structure, environmental variation nested within larger stock-recruit model

Separate, nested models for natural variation and observation error

Advantages over conventional method

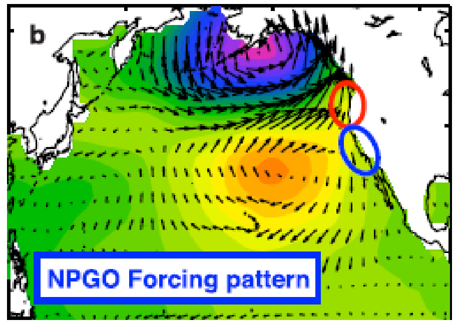
- Handles uncertainty and error in a more statistically robust manner
- Provides estimates of uncertainty for biological observations
- Allows for missing data points
- Accounts for autocorrelation

Applying hierarchical life cycle model to Skagit Chum data

- Data include 39 years (1980 - 2018) of:
  1) Escapement estimates
  2) Harvest estimates from terminal fishery and greater Puget Sound
  3) Age composition (Ages 3 – 5)

- Thus far include covariates for:
  1) Winter peak flow (peak November – March)
  2) Spring flow (peak March – June)
  3) NPGO (average DEC – March)
  4) North Puget Sound pink salmon escapement

Predictors for productivity model



Di Lorenzo 2011 *Geophys Res Letters*
Malick et al. 2017. Fisheries Oceanography

FRESHWATER

Winter Peak Flow
November - March

Spring Peak Flow
March - June

Spawners

MARINE

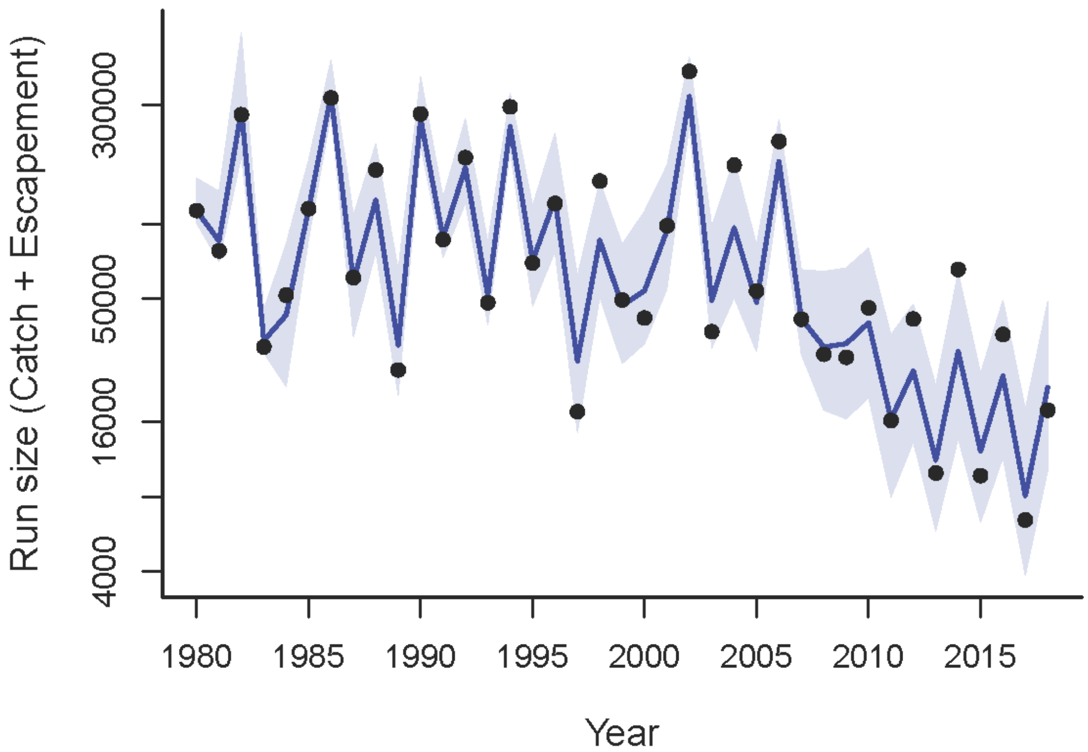
North Pacific Gyre Oscillation (NPGO)
Average Dec - March

Indicator of ocean conditions in winter period prior to ocean entry by salmon smolts

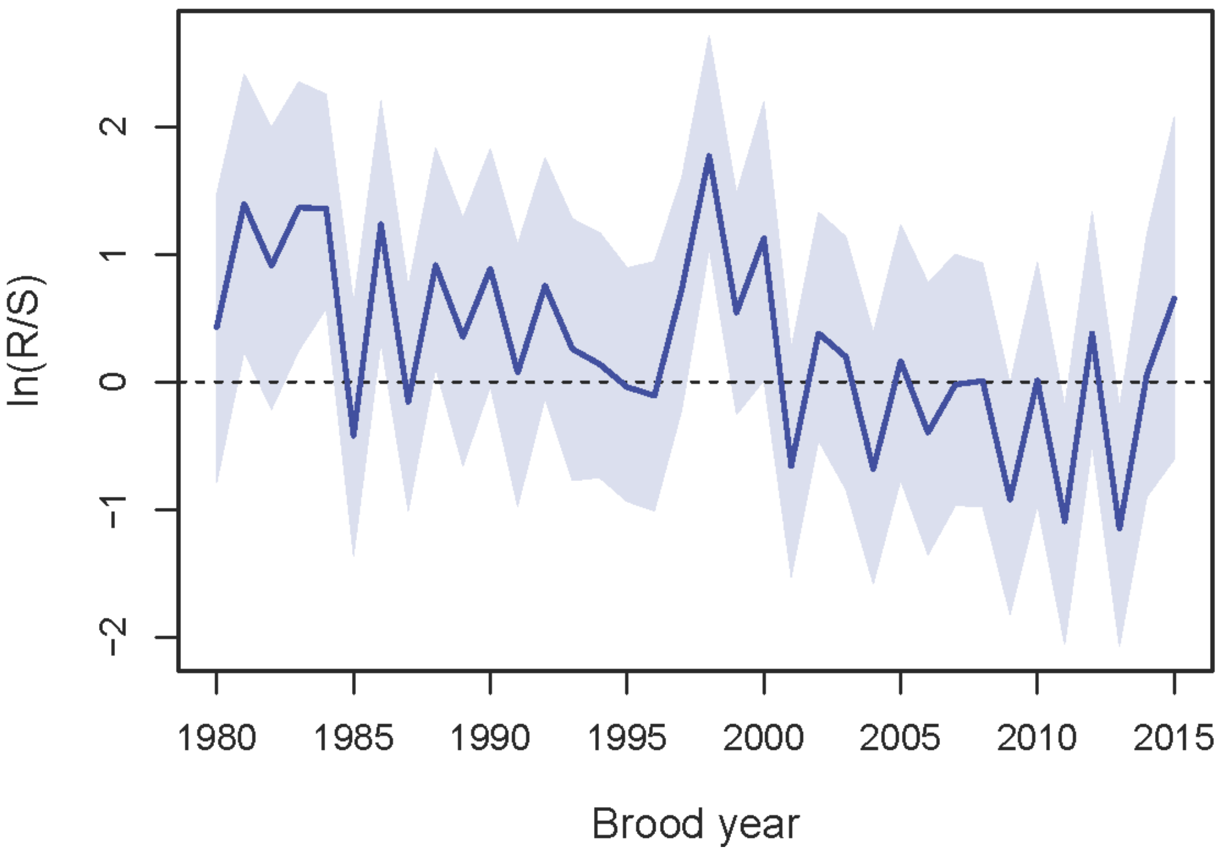
Year 0 Year 1 Year 2 Year 3 Year 4 Year 5

P_N Whidbey basin pink salmon escapement

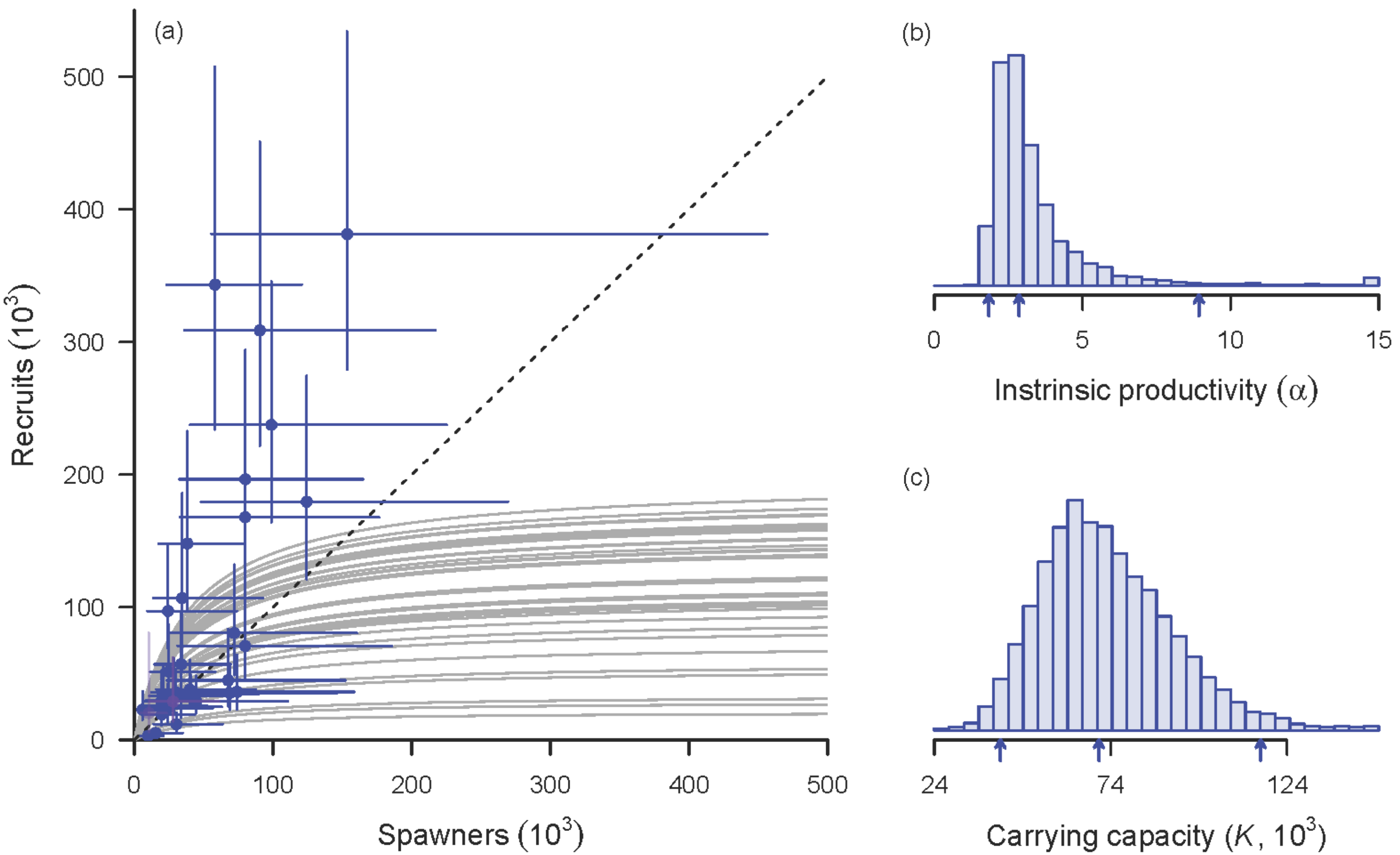
Model fit to observed run size



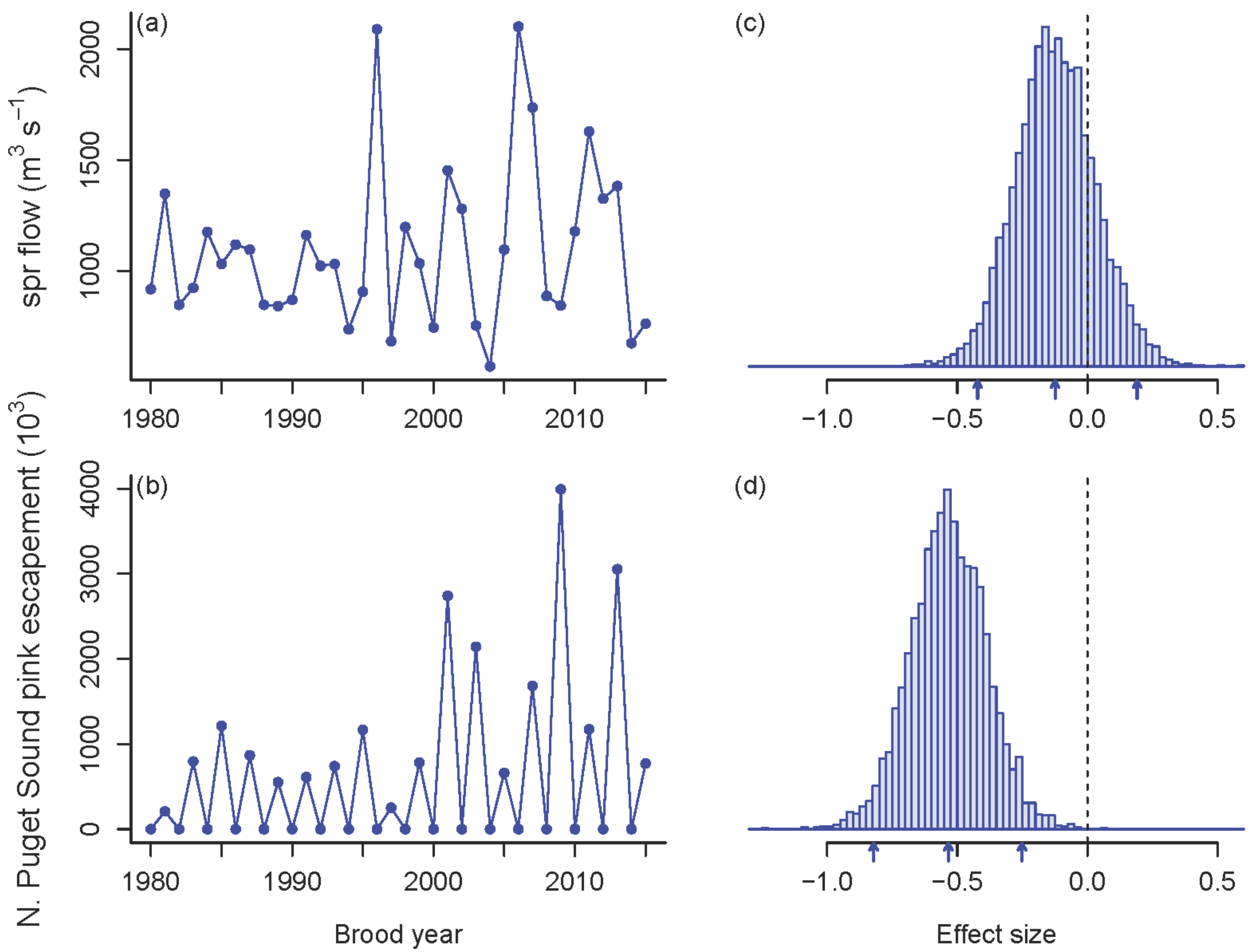
Skagit River Chum salmon productivity



Estimated relationship between spawners and adult recruitment

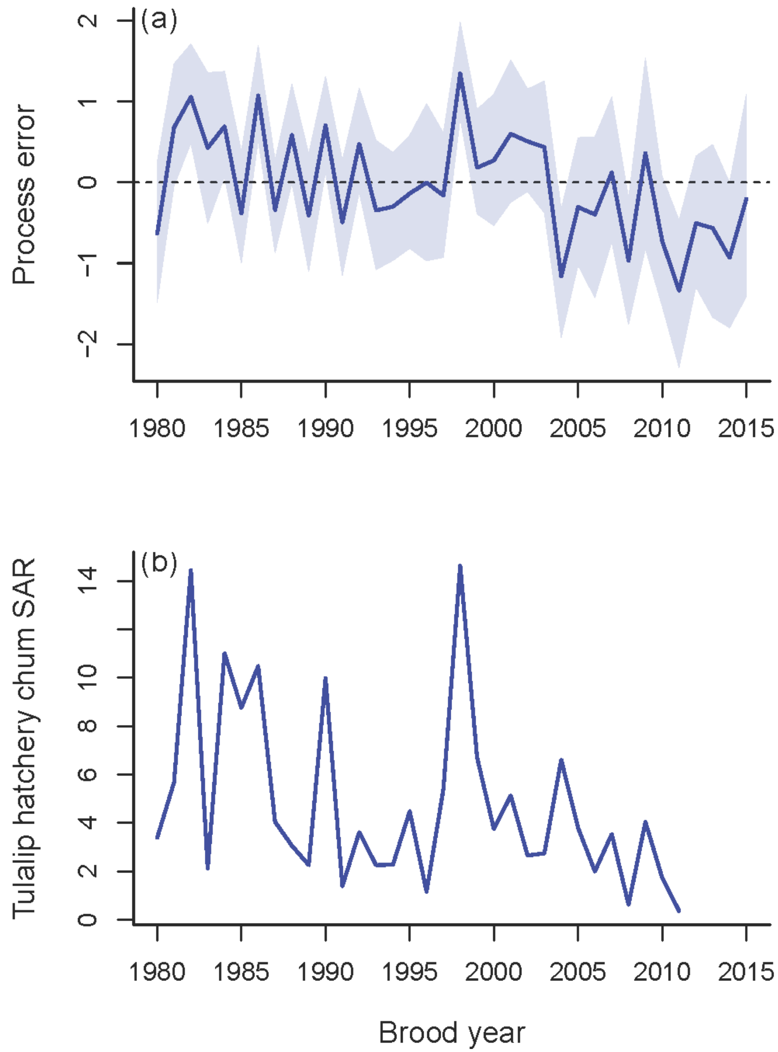


Covariate effects

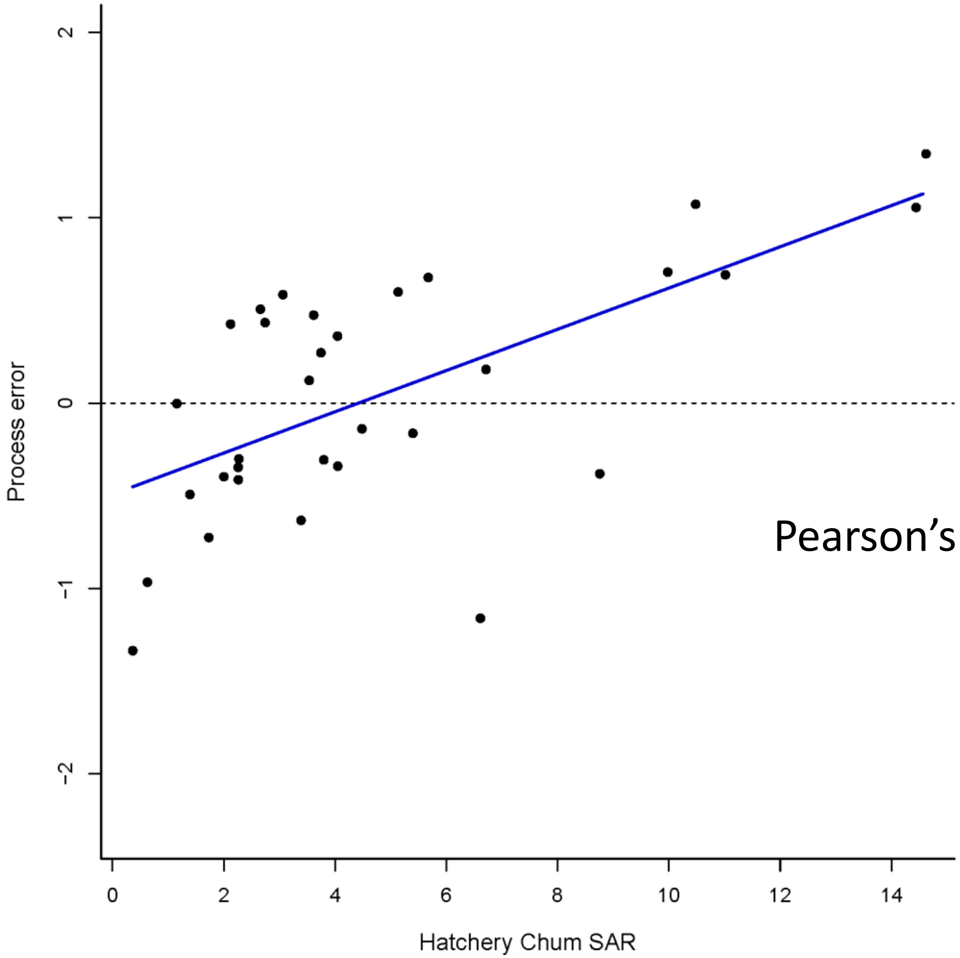


Process Errors

- Unexplained variance
- Index of population productivity after accounting for density dependent and covariate effects
- What additional explanatory variables might correlate with model process errors?



Process Errors



Pearson's r = 0.56 (95% CI 0.39 – 0.69)

Conclusions thus far

- At the entire aggregated chum lifecycle, both density independent and density dependent models are equally supported by the data. **May be a result of data quality issues with escapement, lack of preterminal harvest data, etc.**

- Skagit Chum productivity has exhibited a temporal pattern of decline consistent with a previously identified coastwide pattern. **Indicative that a large-scale driver may be influencing chum stocks in a similar manner.**

- Chum productivity is negatively correlated with spring flow conditions. **Here we hypothesize that the mechanism may be strong spring flows may prematurely push chum out of the river into nearshore habitats resulting in a potential mismatch between phenology and food availability.**

- Chum productivity is negatively correlated with Whidbey basin pink escapement. **Here we hypothesize that large escapements of pink salmon result in a large abundance of pink fry that have the potential to compete with chum salmon fry during their early marine residence period.**

Nearshore abundance and phenology of Chum salmon fry

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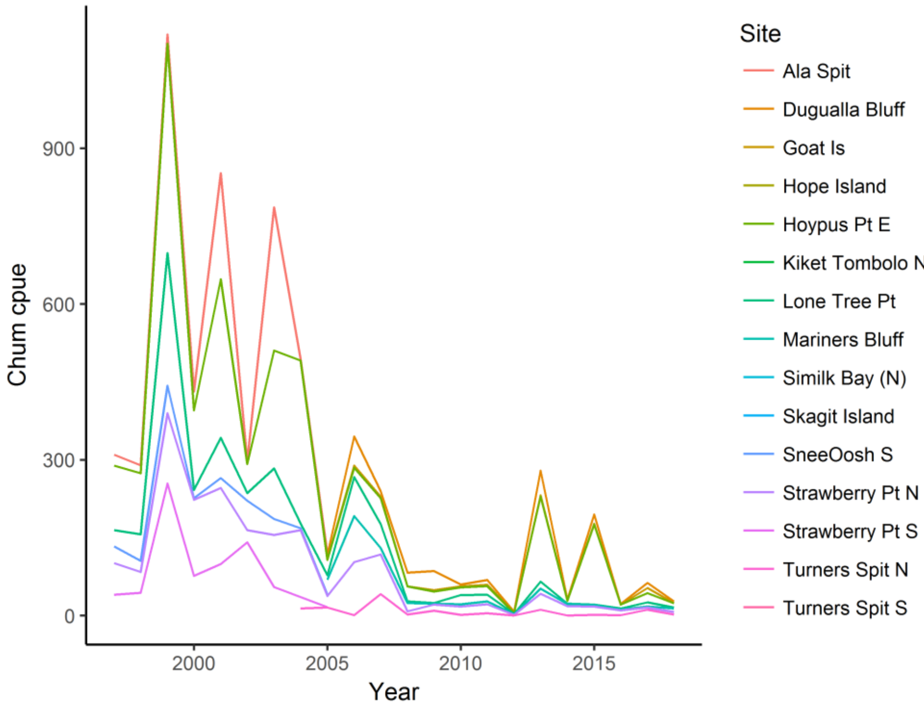


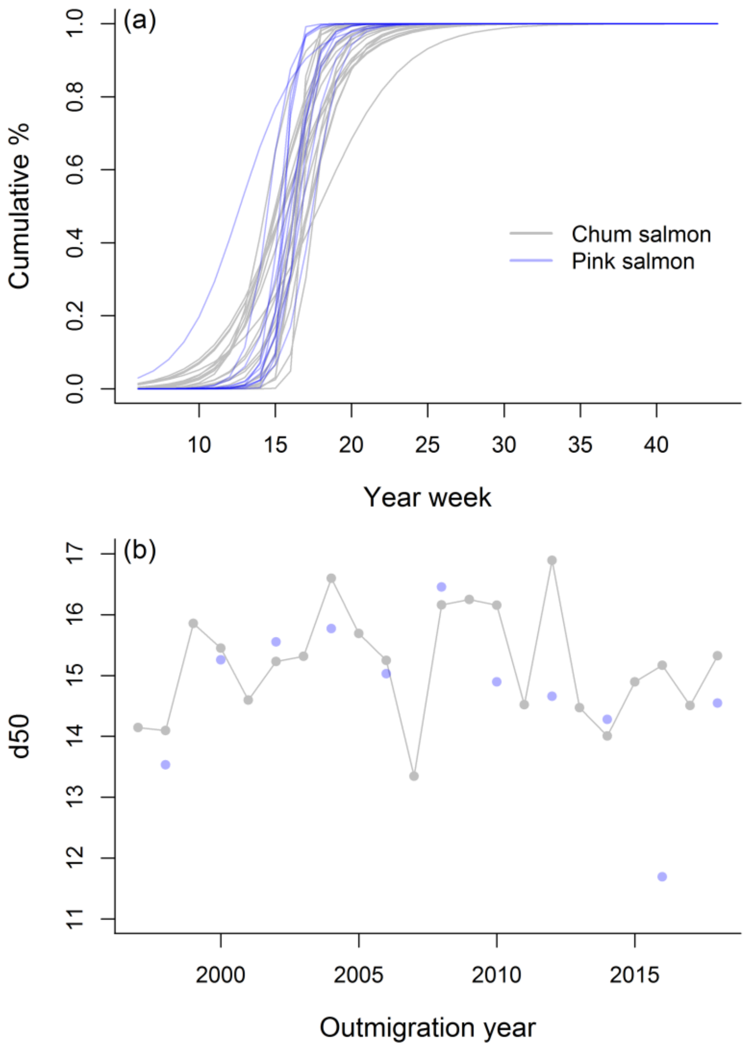
Questions

1. How has phenology varied across time?
2. Is timing associated with spring flow conditions and the density of conspecifics?

Methods

1. Fit cumulative normal distribution models to cumulative CPUE versus week
2. Estimate the week (d50) at which 50% of the cumulative CPUE is reached
3. Fit linear models to time series of estimated d50 with explanatory variables for average spring flow and density of conspecifics.

Nearshore abundance and phenology of Chum salmon fry



Model	*.adjRsq	df	logLik	AICc
*f + s + f*s + I*	0.28	5	-23.41	60.57
I	0.00	2	-28.79	62.21
f	0.03	3	-27.88	63.10
s	-0.04	3	-28.72	64.78
f + s	-0.01	4	-27.79	65.93

Initial conclusions

Nearshore timing can vary significantly from year to year and appears to be negatively correlated with both spring flow and the density of conspecifics.

Seasonal growth of chum salmon fry in the nearshore

Chum productivity is negatively correlated with Whidbey basin pink escapement. **Here we hypothesize that large escapements of pink salmon result in a large abundance of pink fry that have the potential to compete with chum salmon fry during their early marine residence period.**

Questions

1. Do chum fry exhibit significant variability in annual growth during the period of nearshore residency?
2. What potential factors influence chum fry growth in the nearshore?

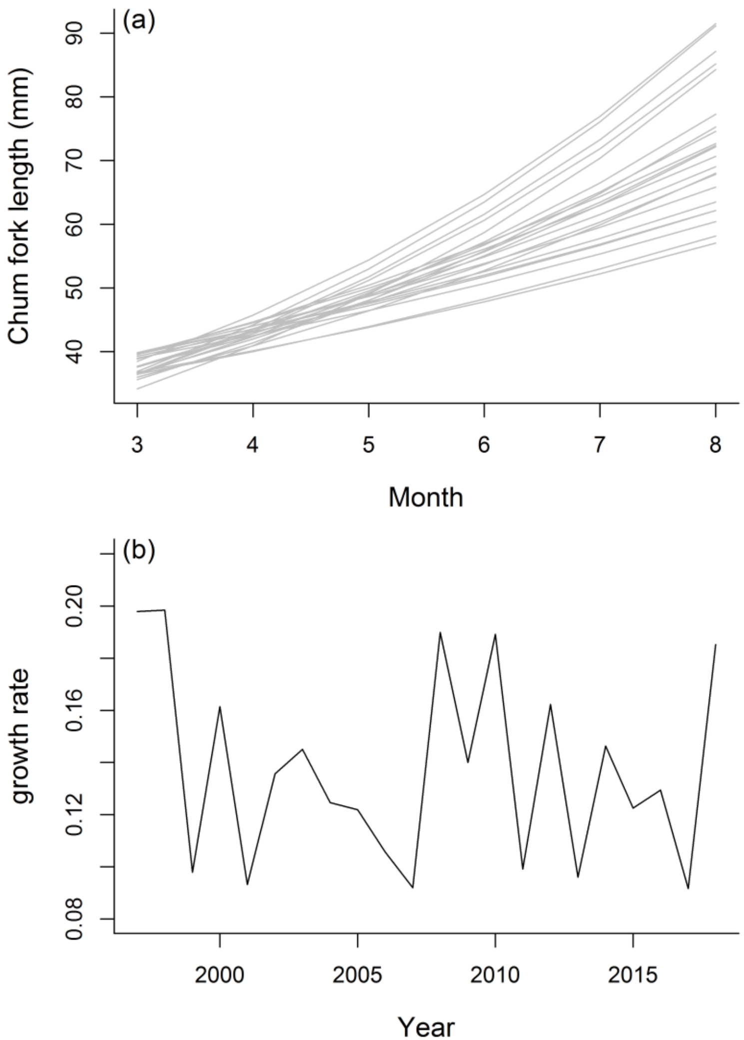
Methods

1. Fit exponential growth functions to relationship between fork length of chum fry and month for each year. Estimate the annual growth rate across the March through August time period.
2. Fit linear models to time series of estimated growth rates with potential explanatory variables including the density of conspecifics and average water temperature.

Initial conclusions

- Annual growth rates of chum salmon fry during the period of nearshore residency are highly variable.
- Of the models evaluated, neither water temperature or the density of conspecifics are significantly corelated with chum growth rates.

Seasonal growth of chum salmon fry in the nearshore



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- Annual growth rates of chum salmon fry during the period of nearshore residency are highly variable.
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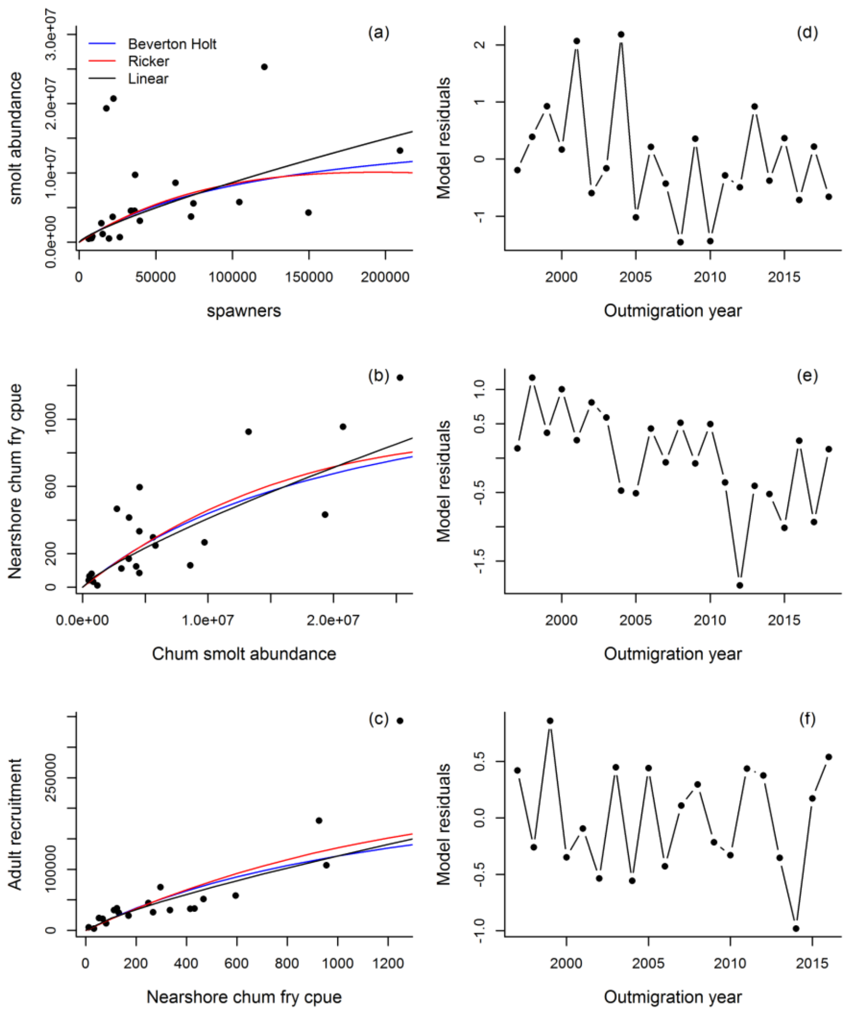
Evaluation of density dependence



Questions

1. Is there evidence for density dependence at individual life stages?
2. Are there temporal trends in survival at each life stage transition?

Methods

1. Fit three candidate models including density independent, Ricker, and Beverton Holt to each monitored life stage transition for outmigration years 1997 - 2018.
2. Extracted model residuals from model with highest data support.

Initial conclusions

- For each life stage transition, each model is equally supported (e.g. data support nearly identical)
- Of the three life stage transitions evaluated, only the smolt to nearshore transition exhibited a declining trend.

Initial conclusions and recommendations

- Efforts to improve the precision and accuracy of Chum escapement estimates would improve our ability to evaluate the population dynamics of Skagit River chum.

- This study didn't attempt to address spatial distribution of spawners over time. **Has the reduction in chum productivity resulted in a spatial contraction of spawners and resulted in a negative feedback that has further reduced the productivity of the population?**

- Although marine survival appears to be the predominant driver of the observed trend in productivity of Skagit River chum, our analysis suggests that some localized factors including spring flow conditions and pink salmon abundance may influence annual variability in lifetime survival. **Further studies are needed to better understand the mechanisms that may be driving these relationships.**

- Of the three quantified life-stage transitions, only the smolt to nearshore fry transition exhibited a predominantly negative trend over the study period. **Further studies are needed to better understand this pattern.**