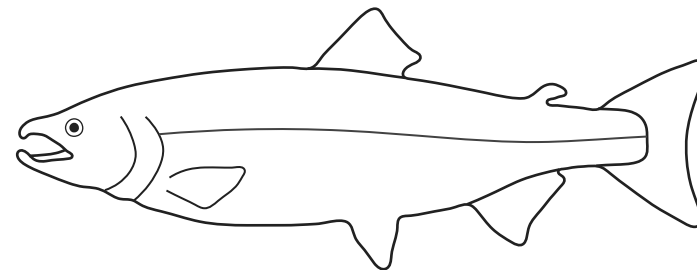


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# Four decades of changing demographic structure in Chinook salmon across the Northeast Pacific



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[www.watershed-watch.org](http://www.watershed-watch.org)



[www.whaleresearch.com](http://www.whaleresearch.com)



[www.timgramsphotography.com](http://www.timgramsphotography.com)

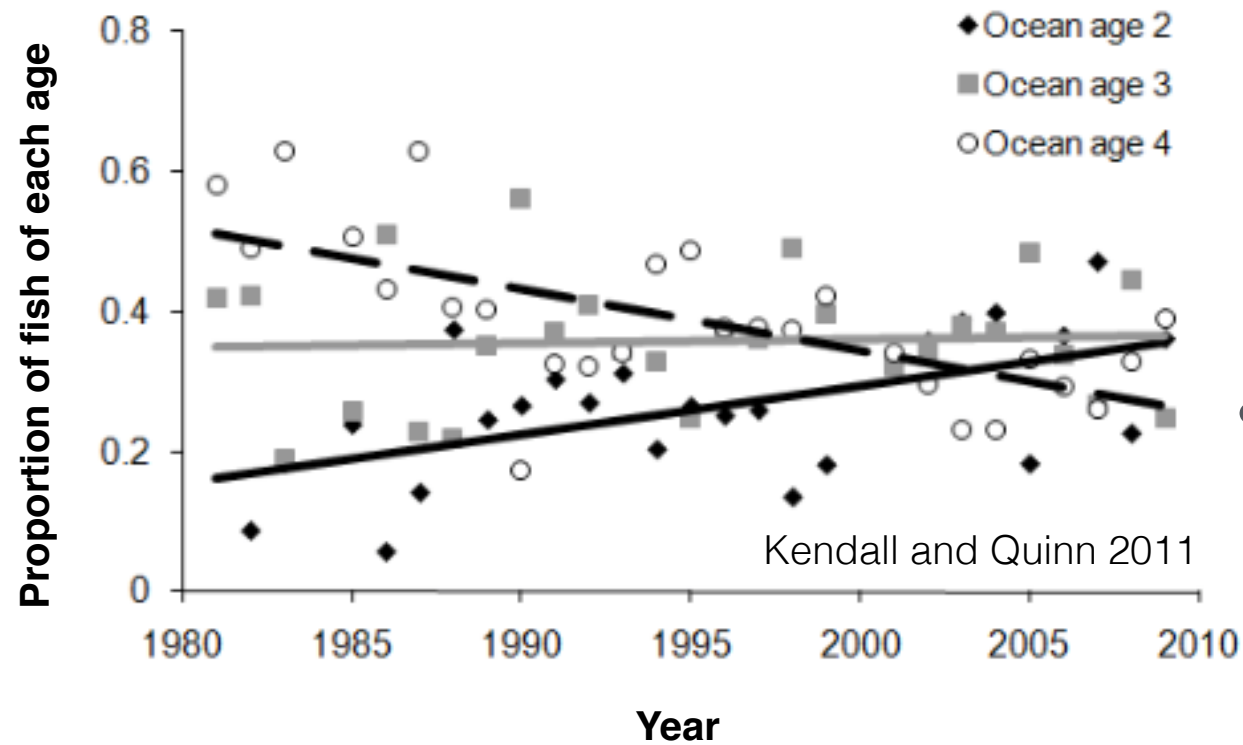


[princeofwalessportfishing.com](http://princeofwalessportfishing.com)

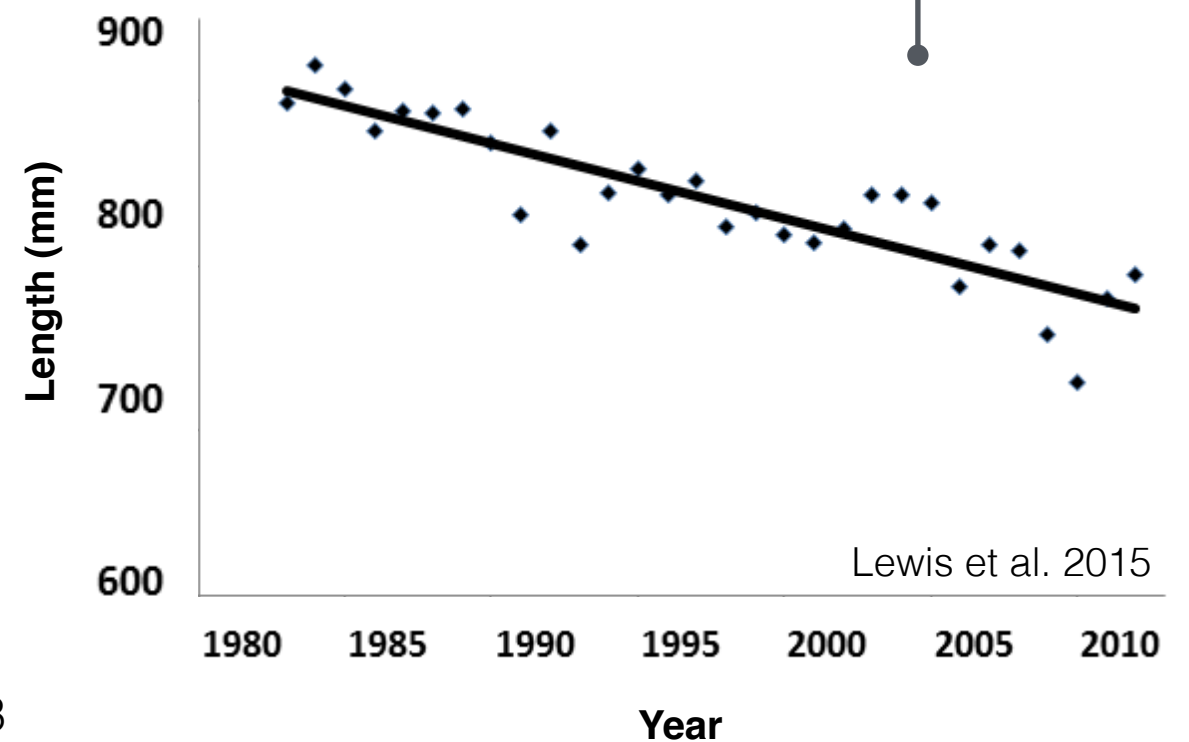
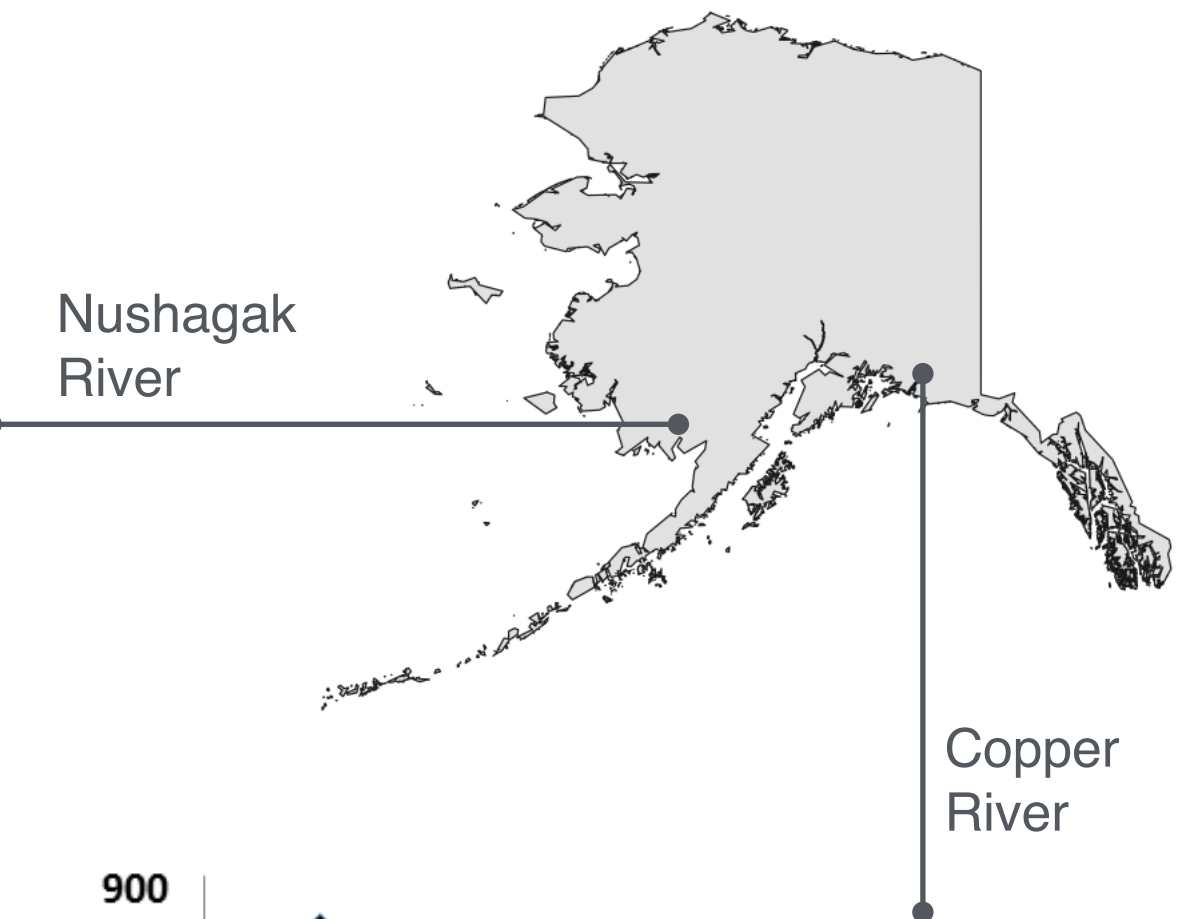


# Background

## Changes in mean age and size of Alaskan Chinook populations



Loss of the largest fish may cause reduced population productivity and negatively affect Chinook fisheries

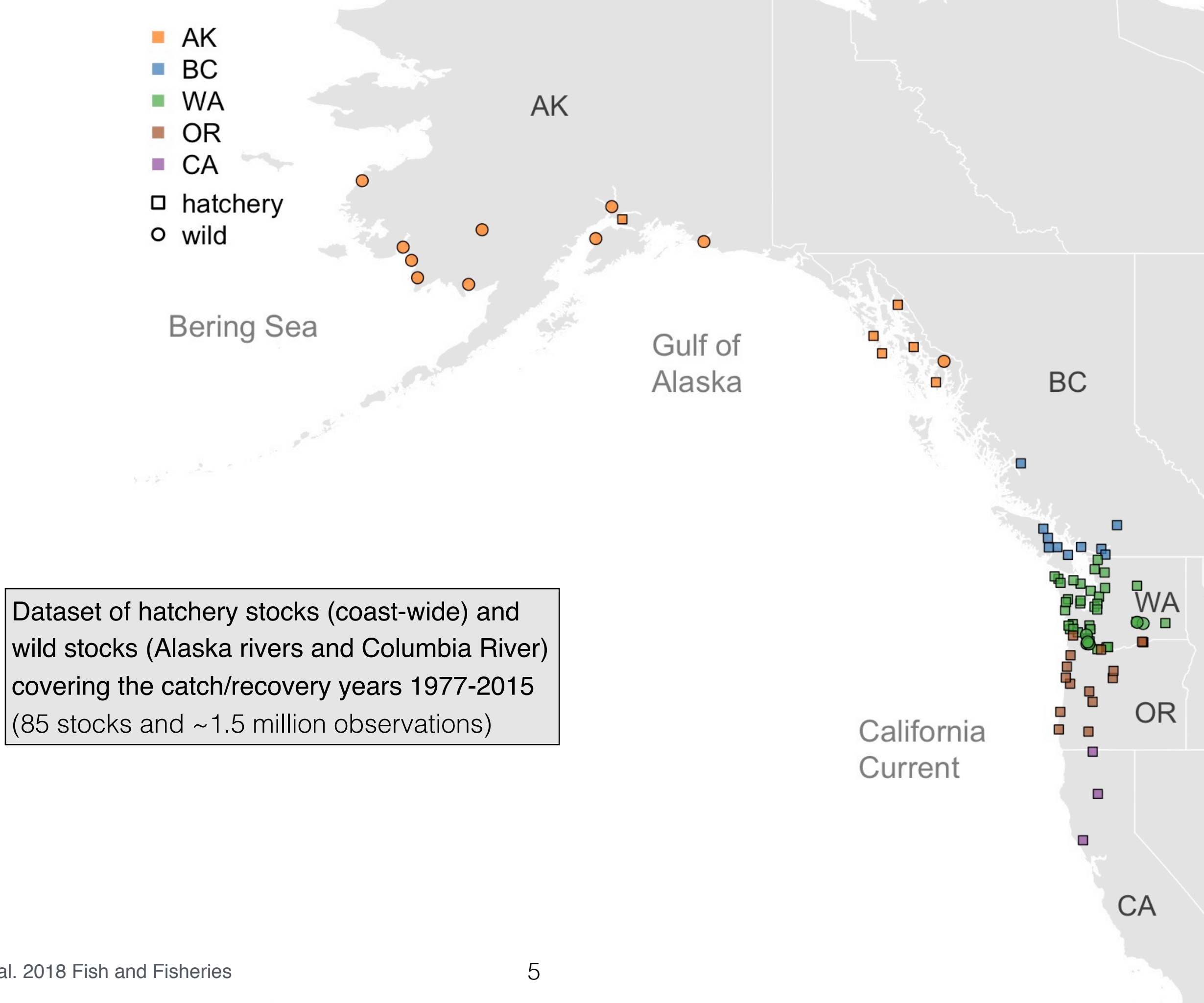




1. Are changes in size and age structure of Chinook occurring coast-wide?
2. Do smaller mean sizes reflect shifts in size-at-age or age composition?
3. What are the drivers of the observed demographic change?







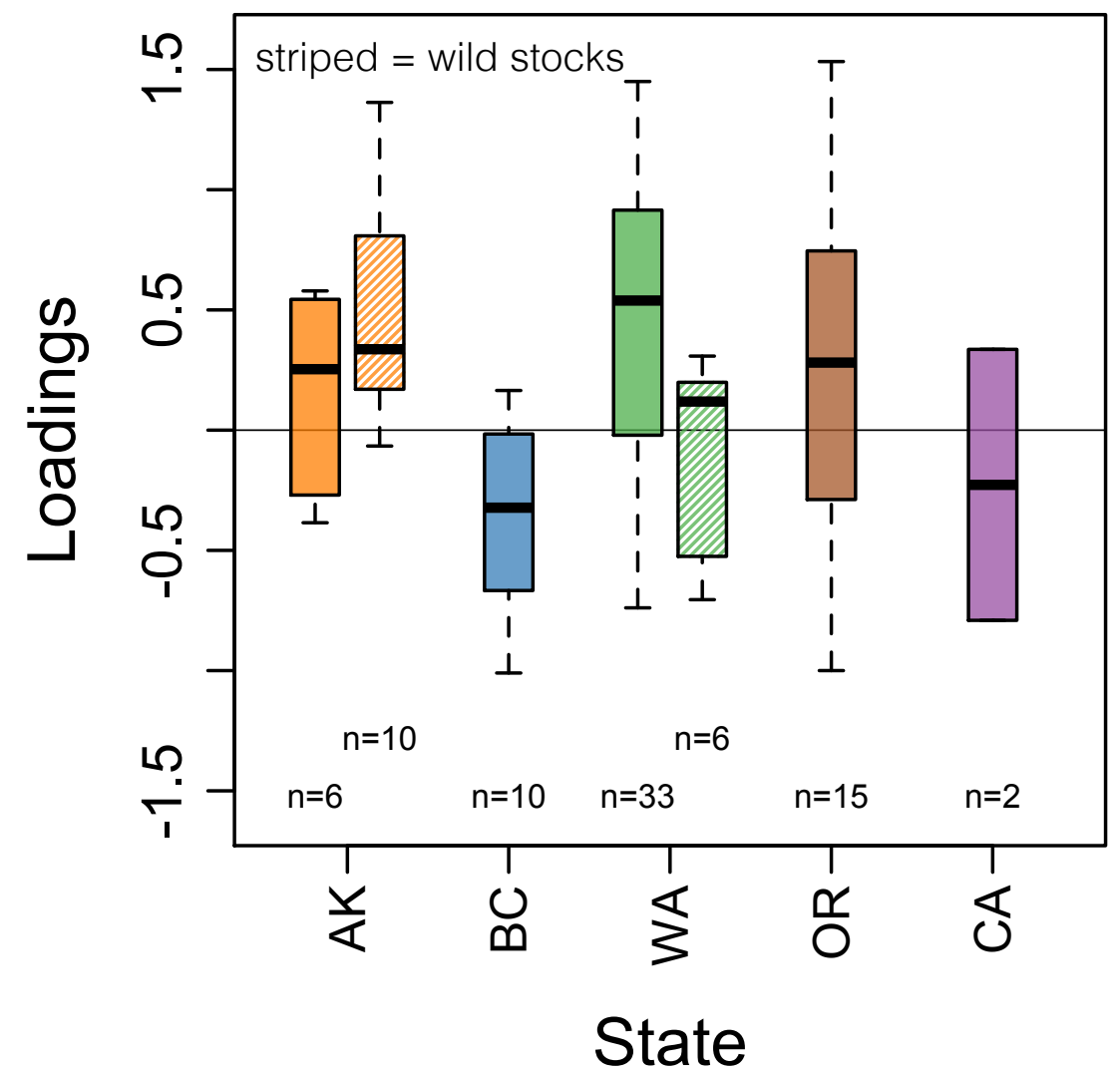
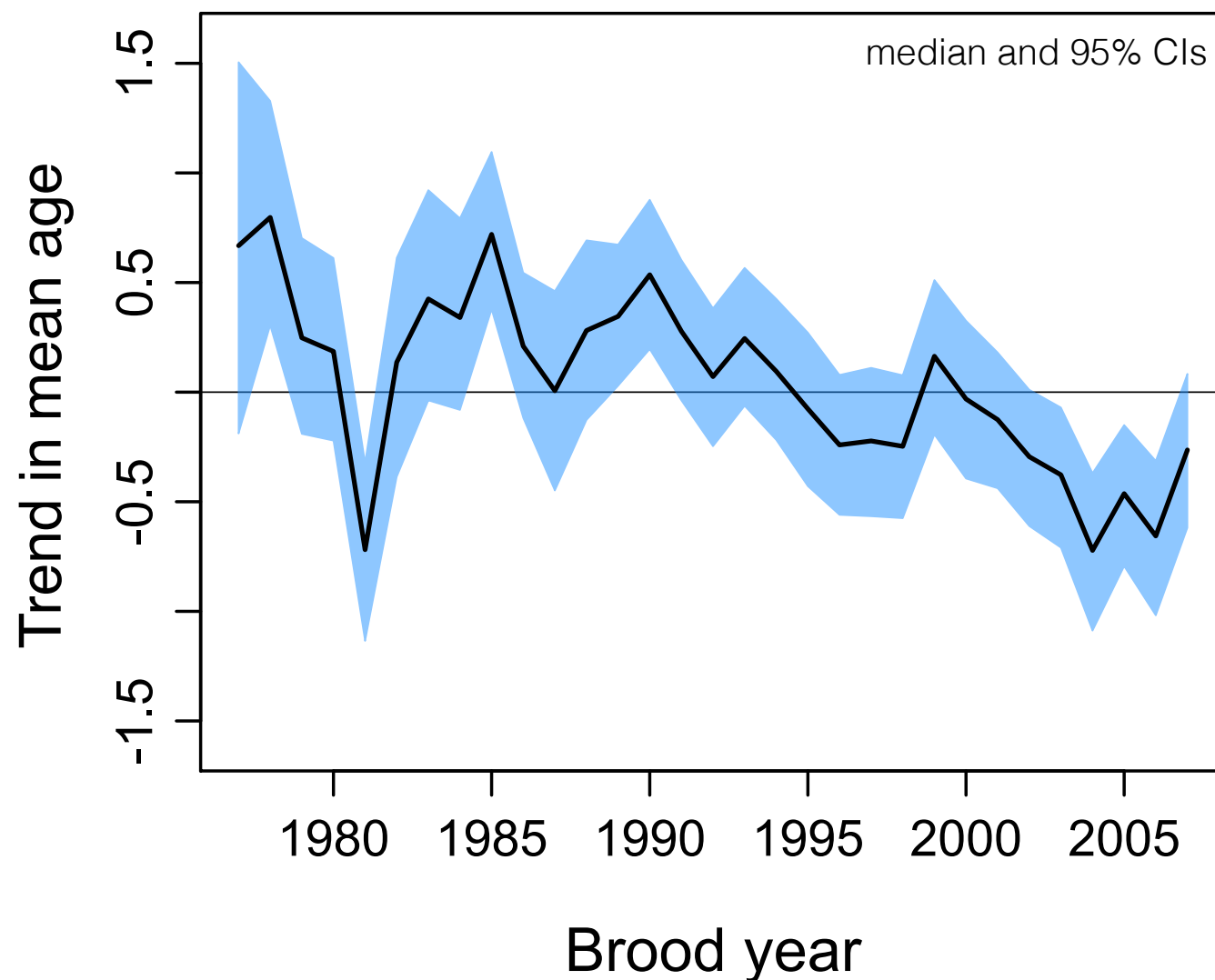


# Age composition

## Spatial-temporal patterns of changes in mean age

### Dynamic Factor Analysis (DFA)

- Using stock-specific time series in mean ocean age
- Extract most common coast-wide trend
- Stock-specific loadings on trend clustered by state



Mean age shows declining trend but not in all populations and regions

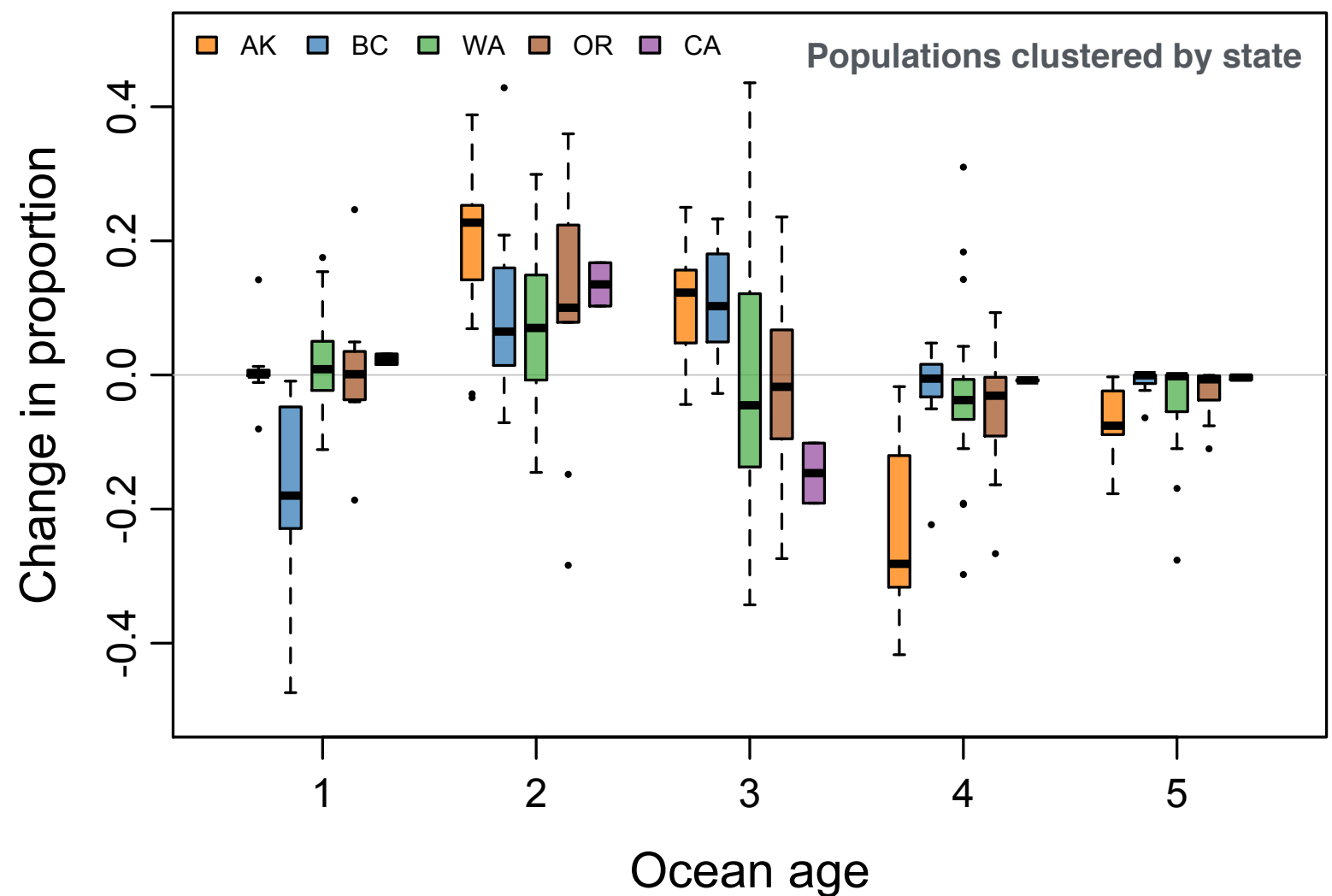
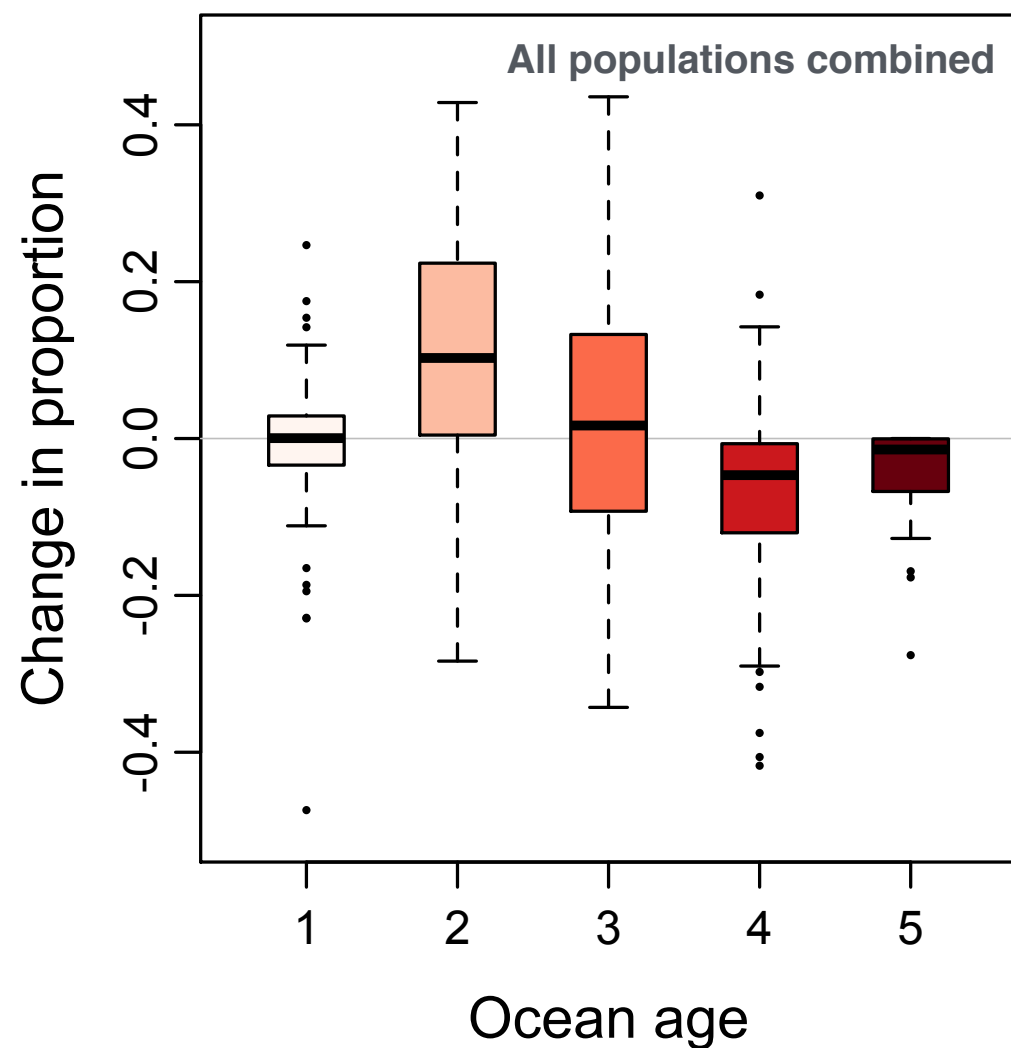


# Age composition

## Changes in age proportions over time

### Multinomial Logistic Regression (MLR)

- Using stock-specific counts of ocean ages 1-5
- Predict age proportions for each stock and year
- Calculate change from early (1978-1982) to late period (2002-2006)



Shifts toward younger ages - fewer ocean-4/5s and more ocean-1/2s

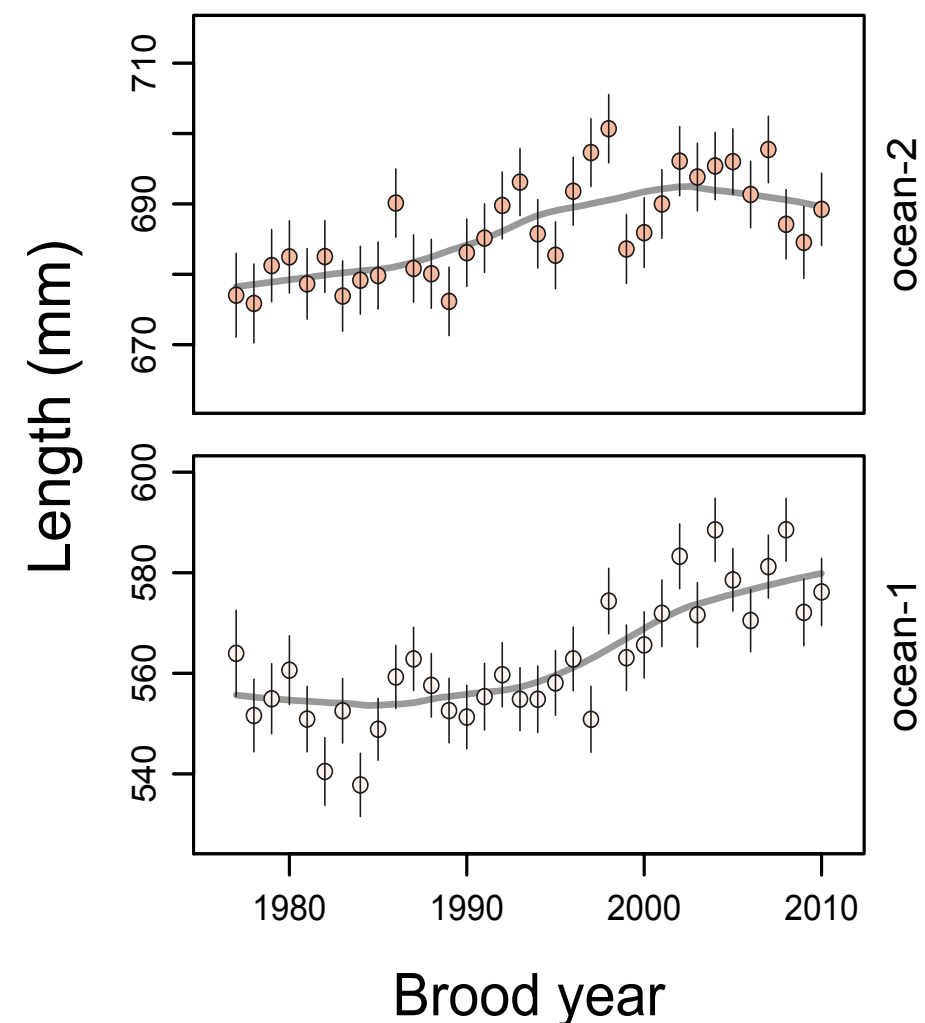
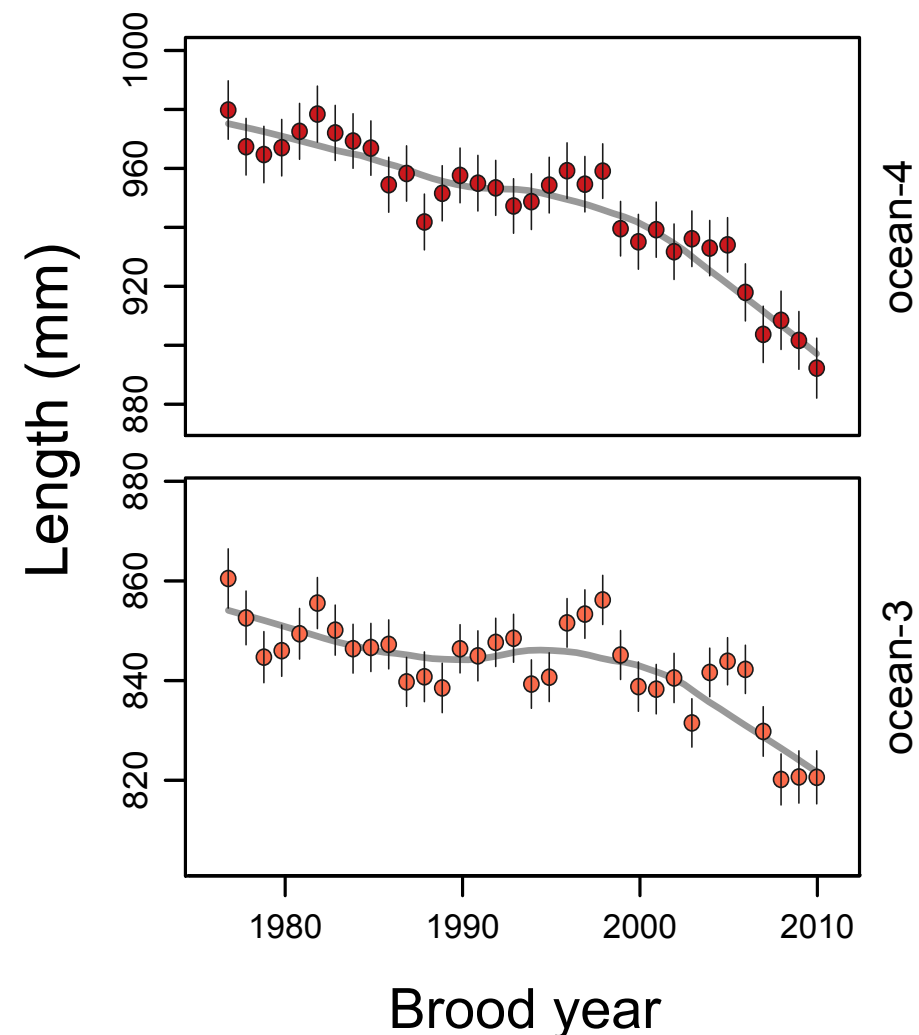


# Size-at-age

## Coast-wide changes in size-at-age over time

### Linear Mixed Effects Models (LME)

- Using individual size-at-age data (one model per ocean age)
- Fixed effect of brood year, run type, rearing type, sex, fishery, FW age, day of year
- Nested random effect for year-in-stock



Size-at-age decreasing in older but stable/increasing in younger fish

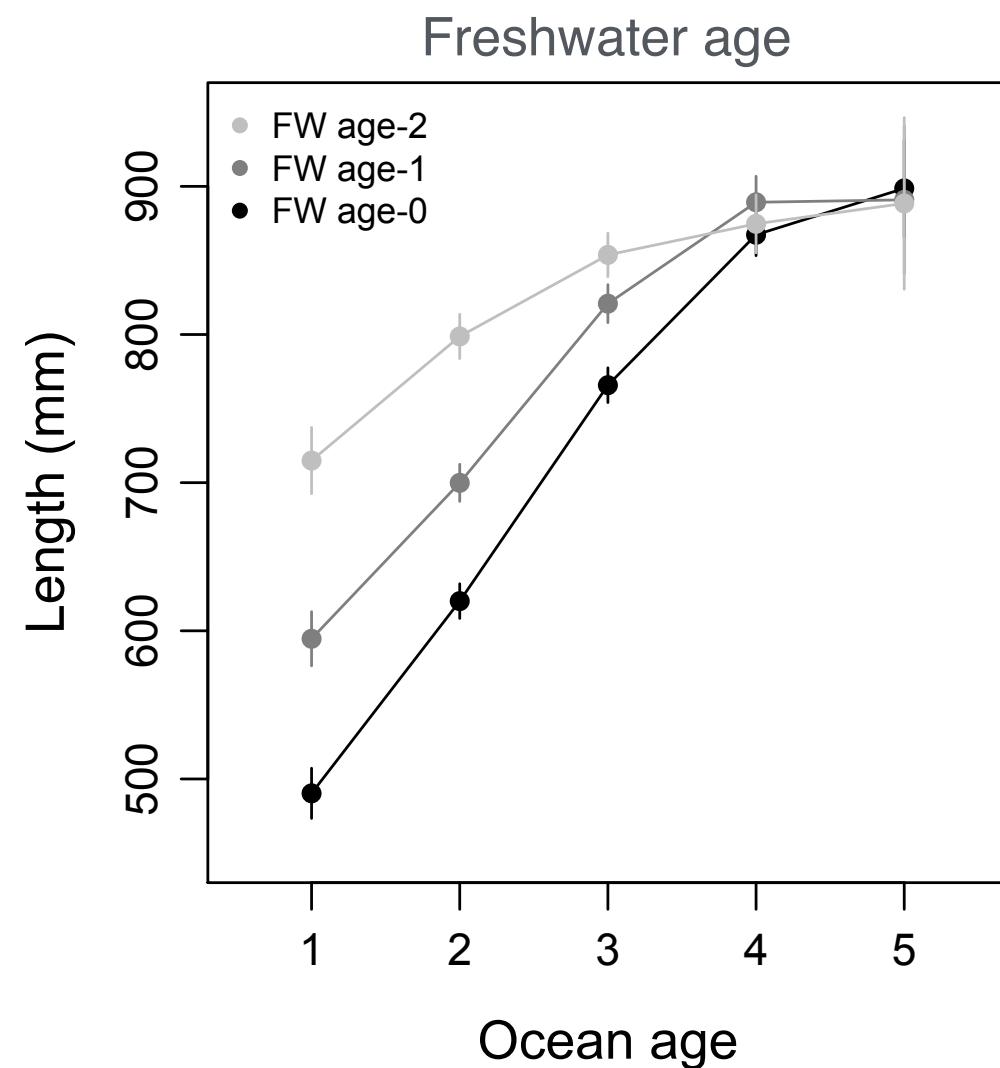
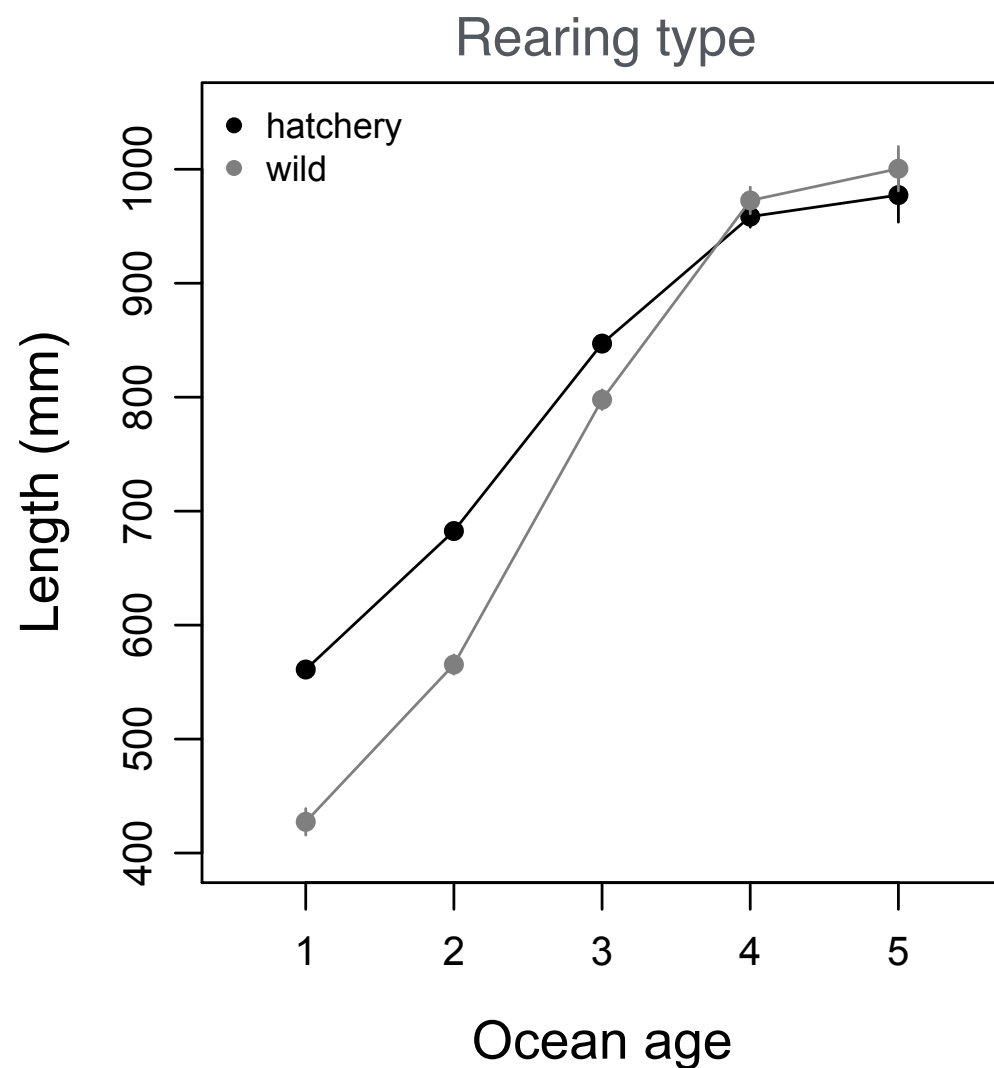


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Different mean size but not size trends by rearing type and freshwater age

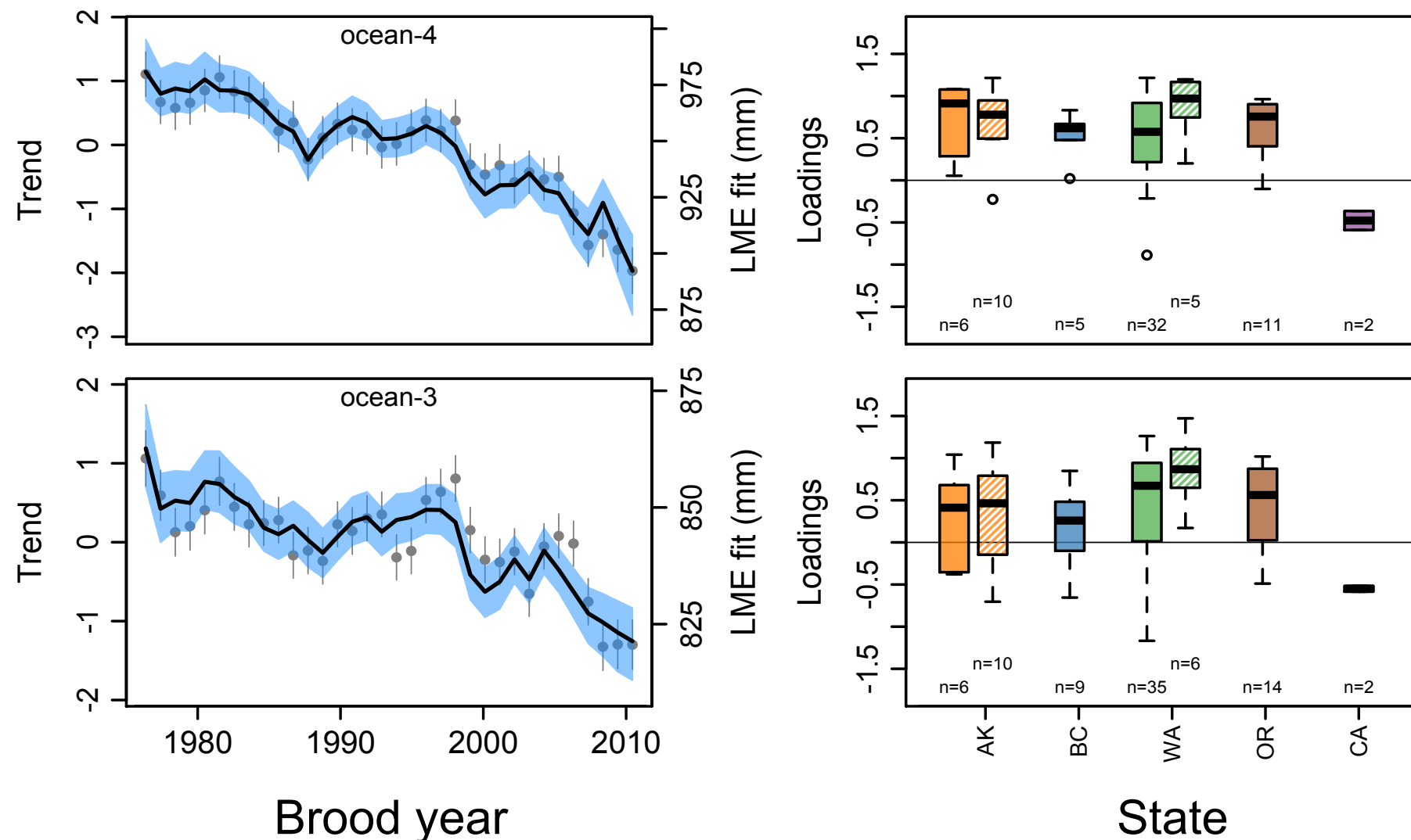


# Size-at-age

## Spatial patterns of changes in mean size-at-age

### Dynamic Factor Analysis (DFA)

- Using stock-specific time series of mean size-at-age
- Extract most common trend in size-at-age for each ocean age
- Stock-specific loadings on trend clustered by state/region



Most populations coast-wide show declining trend in size-at-age of older fish

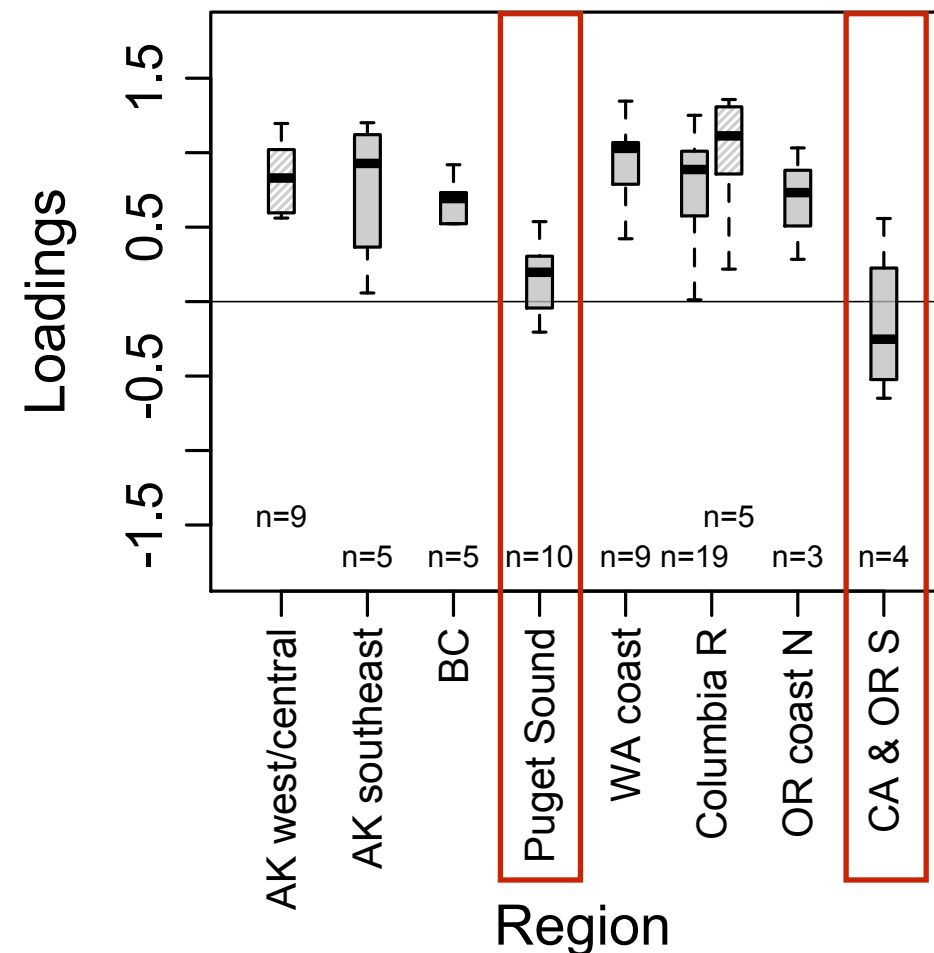
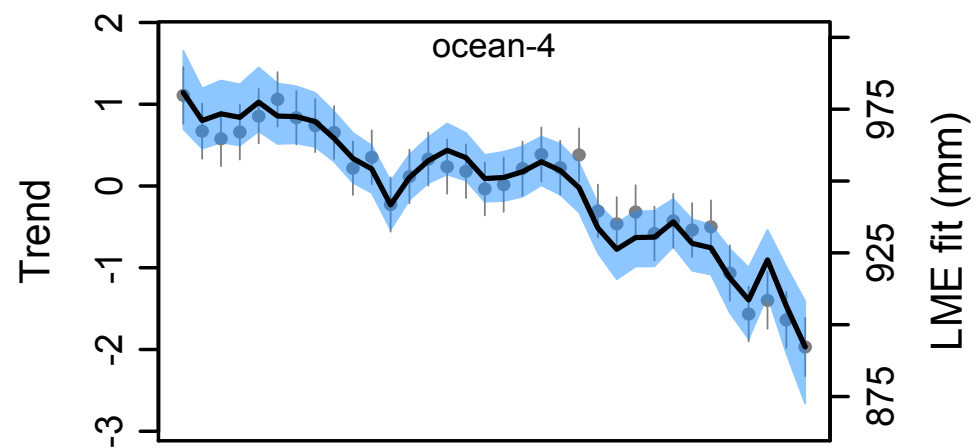


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- Stock-specific loadings on trend by region



Southernmost and Puget Sound populations do not follow the size trends



1. Are changes in size and age structure of Chinook occurring coast-wide?
2. Do smaller mean sizes reflect shifts in size-at-age or age composition?
- 3. What are the drivers of the observed demographic change?**





# Causes of observed change

## Fishing

- ▶ Fishing generally size-selective, **but:**
- ▶ Fisheries well-developed by 1970s, i.e. fishing pressure has since declined, and exploitation rates as well as size limits vary among stocks even within regions

## Climate

- ▶ Temperatures in the NE Pacific show an increasing long-term trend, **but:**
- ▶ Strong climate variability over the past few decades and variability in large-scale ocean climate conditions expressed at inter-annual and inter-decadal time scales

## Hatcheries

- ▶ Large hatchery production and selective breeding of hatchery stocks, **but:**
- ▶ Stable/declining production since ~1990 and declining sizes in wild WAK stocks that experience no introgression and likely less competition from hatchery fish

## Competition

- ▶ Increased competition with pink salmon could cause slower growth, **but:**
- ▶ Slow growth without evolutionary shift in maturation schedule should lead to older age at maturation, and competition need to be indirect via food-web interactions

## Predation

- ▶ Marine mammals have increased in numbers including Alaskan and NRKW, which selectively prey upon Chinook, particularly large individuals, **but:**
- ▶ Predation pressure varies by region/stock and is uncertain for the Bering Sea and along the Aleutian Islands, yet Western AK stocks show clear size declines



- Many Chinook salmon populations are returning at younger ages, though age trends vary within and among regions
- Size of older fish has declined in almost all populations coast-wide, except for the southernmost and some Puget Sound populations
- Common hypotheses are not sufficient to explain size and age trends, and increasing predation pressure is likely contributing to these trends





# Acknowledgements

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- Bill Templin
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