# Size and abundance of resident salmon in the Salish Sea: Insights from a culturally unique recreational fishery


## Mark Scheuerell

USGS Washington Cooperative Fish and Wildlife Research Unit
School of Aquatic and Fishery Sciences
University of Washington
Seattle, WA

scheuerl@uw.edu

@mark_scheuerell

# Disclaimer

I take full responsibility for this analysis

# Questions

Has size or catch rate changed over the decades?

Do any changes mirror patterns in size or abundance of Puget Sound Chinook salmon as a whole?

# Temporal trends in derby harvest

# Catch per unit effort

## Things we know:

- Total number of days the derby was open
- Total number of participants
- Total number of fish caught

# Catch per unit effort

## Things we know:

- Total number of days the derby was open
- Total number of participants
- Total number of fish caught

## Things we don't know:

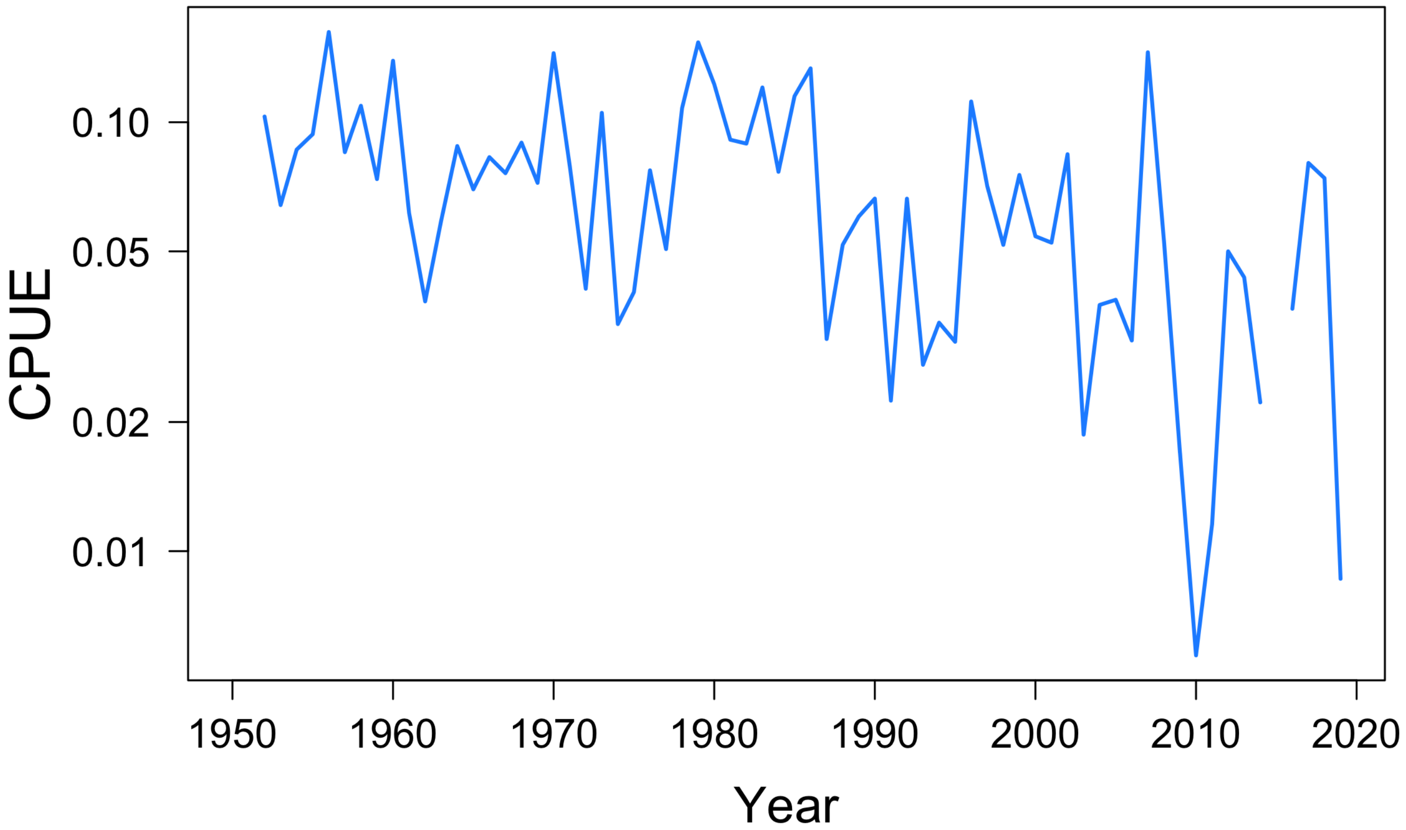
- Total number of days that *each* angler fished

# Catch per unit effort

Thus, we assumed that each angler fished every day the derby was open

$$\text{CPUE} = \frac{\text{fish caught}}{\text{days} \times \text{anglers}}$$

# Time series of CPUE



# Possible state models

## Random walk

$$x_t = x_{t-1} + w_t$$

where $x_t$ is the log(CPUE) at time $t$

# Possible state models

## Random walk

$$x_t = x_{t-1} + w_t$$

## Biased random walk

$$x_t = x_{t-1} + u + w_t$$

# Observation model

Imperfect accounting of effort means we are unsure of the true CPUE

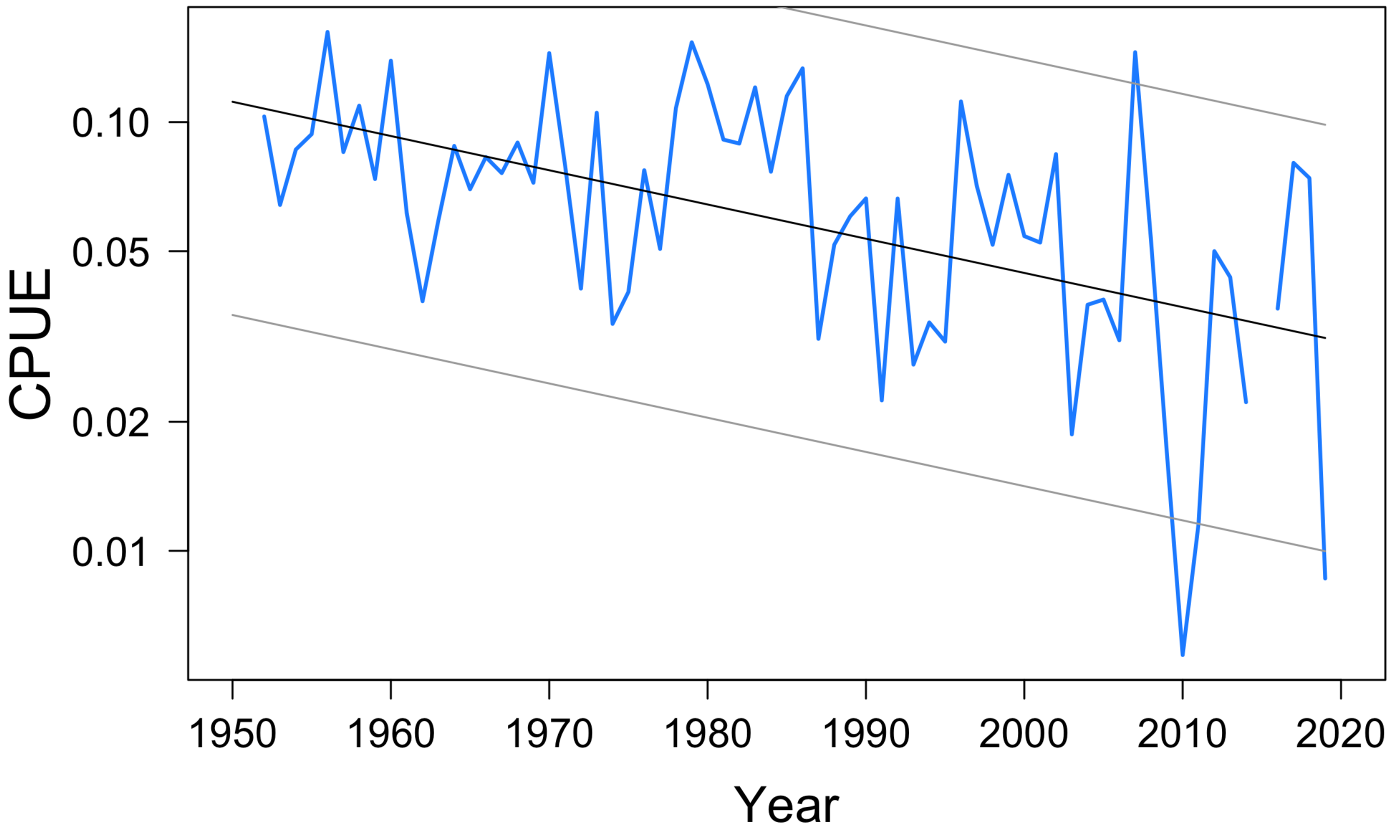
$$y_t = x_t + v_t$$

# Model fitting

## MARSS package for R (Holmes, Ward & Scheuerell 2020)

https://CRAN.R-project.org/package=MARSS

# CPUE has decreased by ~2% per year



# Temporal trends in derby size

# Three metrics of fish size

1) The weight of each of the top five Chinook salmon*

2) The number over 10 pounds

3) The number over 5 pounds

*In *most* years

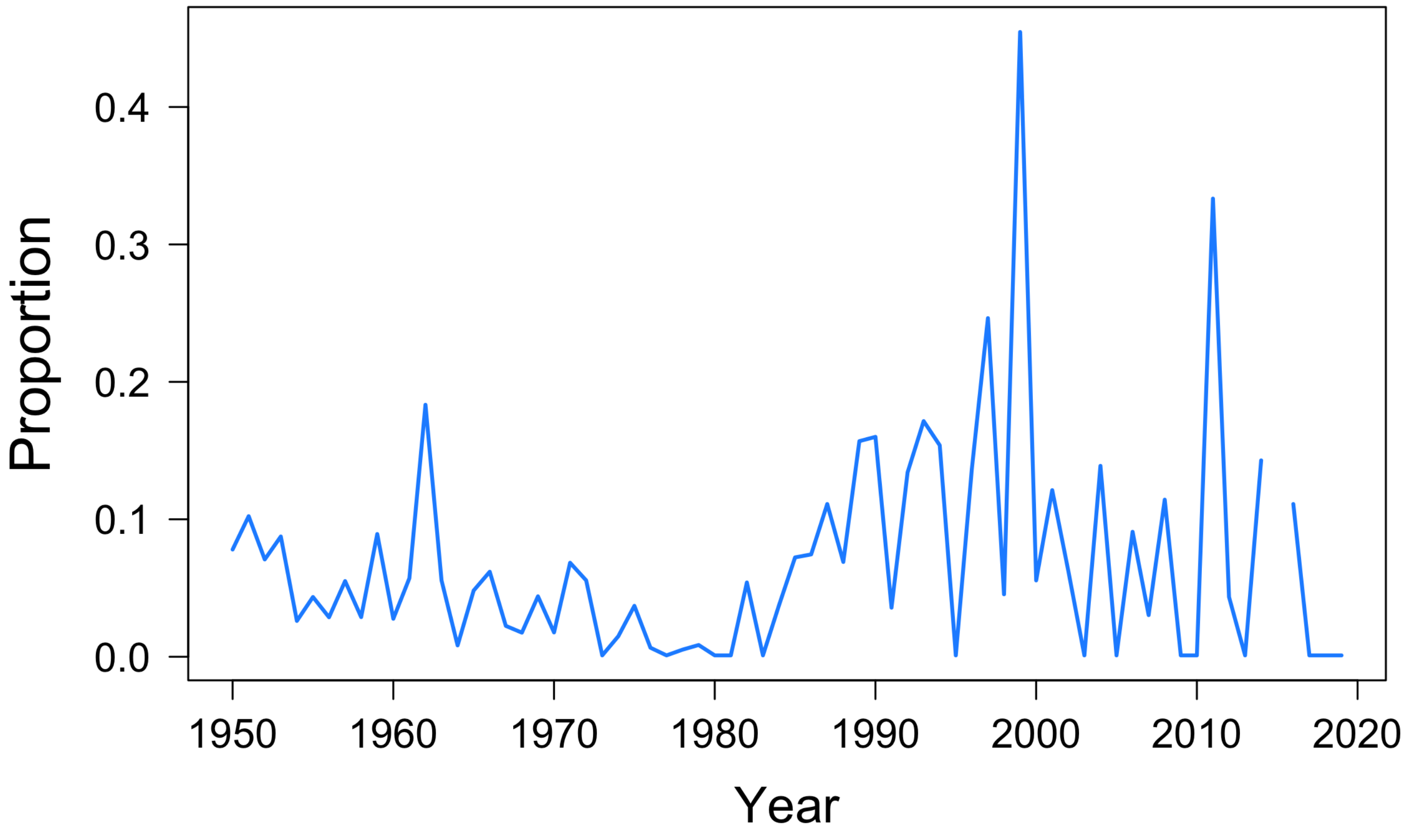
# Three metrics of fish size

1) The weight of each of the top five Chinook salmon

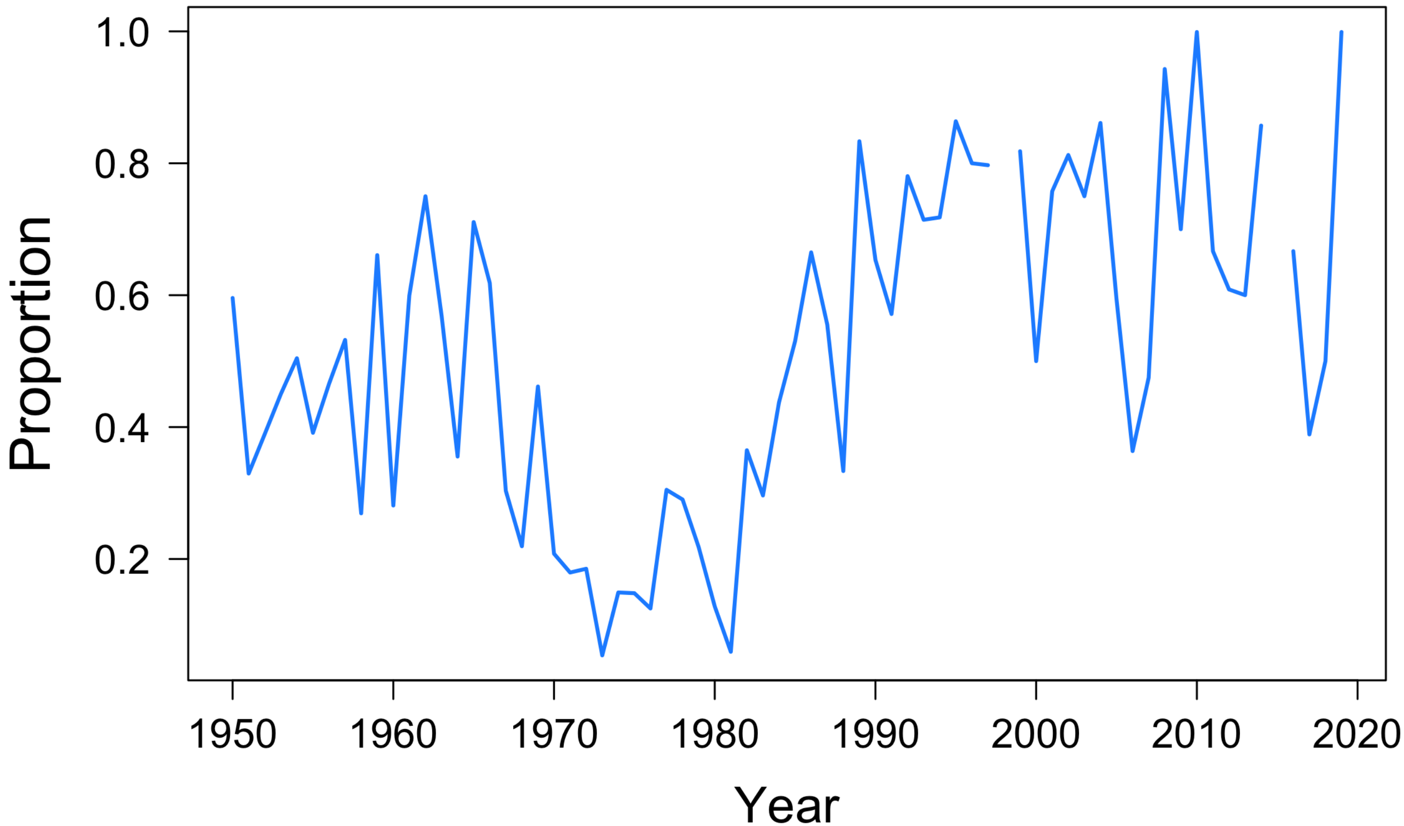
2) The number over 10 pounds

3) The number over 5 pounds

# Proportion of fish over 10 pounds



# Proportion of fish over 5 pounds



# Possible state models

## Random walk

$$x_t = x_{t-1} + w_t$$

## Biased random walk

$$x_t = x_{t-1} + u + w_t$$

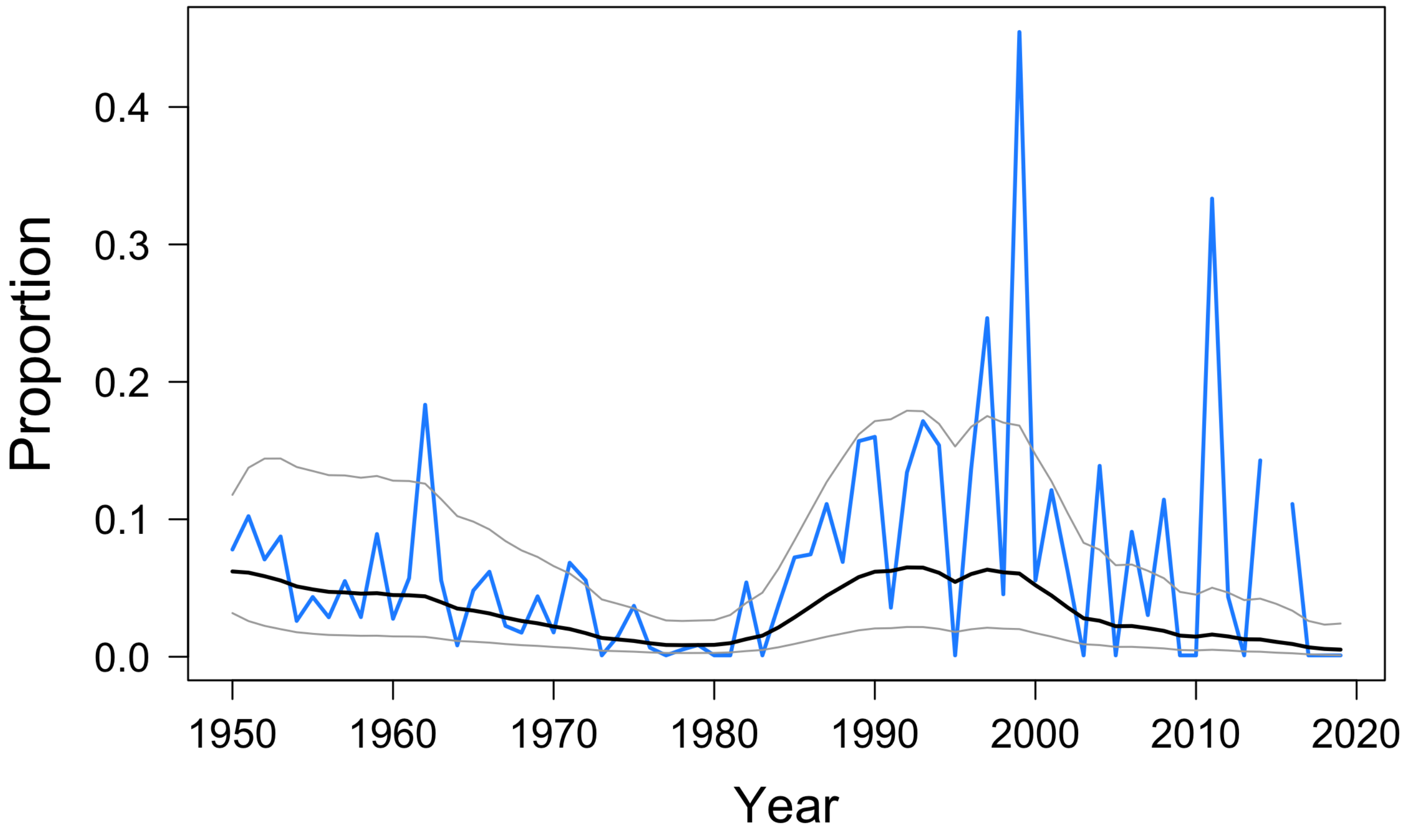
where $x_t = \mathrm{logit}(p_t)$

# Observation model

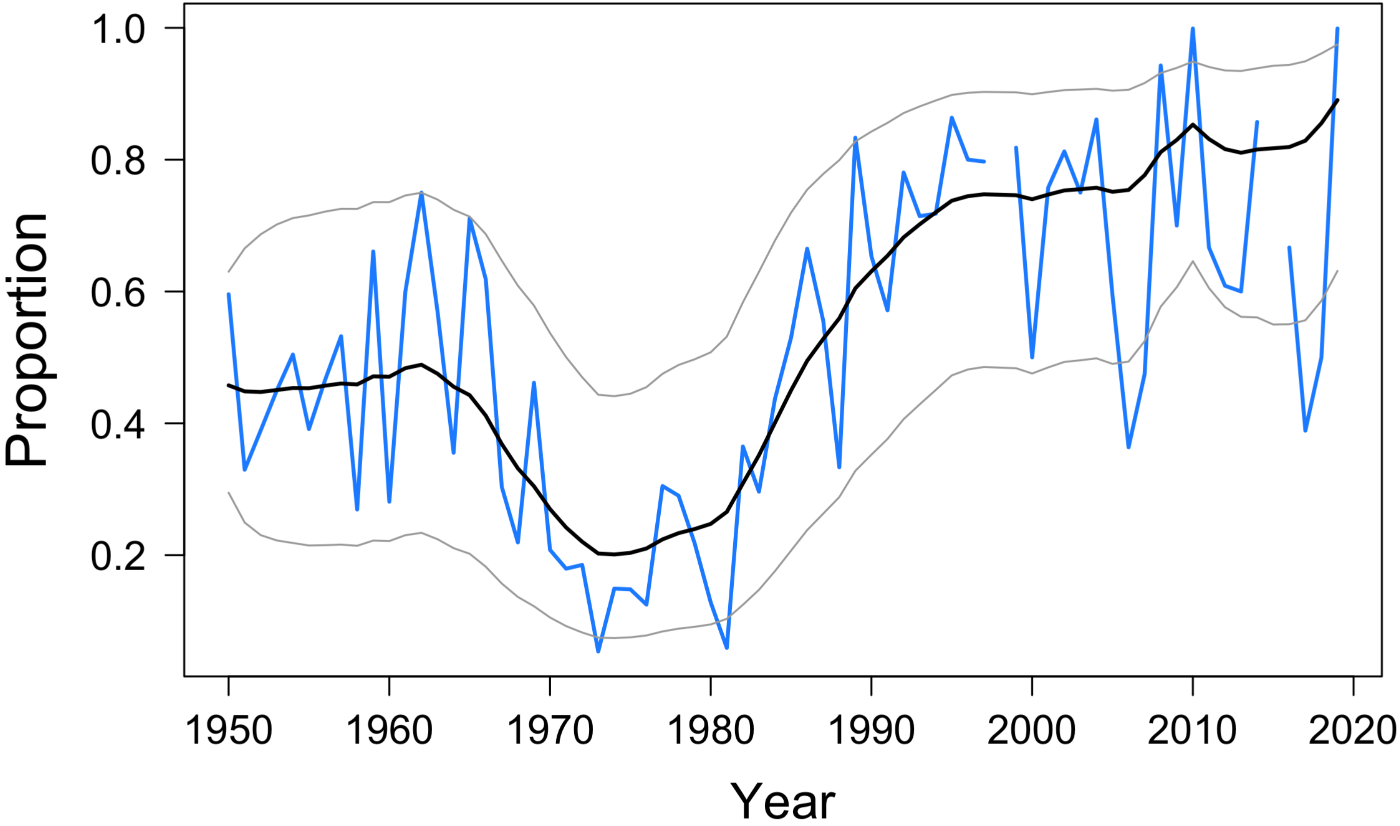
Imperfect sampling means we are unsure of the true size

$$y_t = x_t + v_t$$

# Proportion of fish over 10 pounds

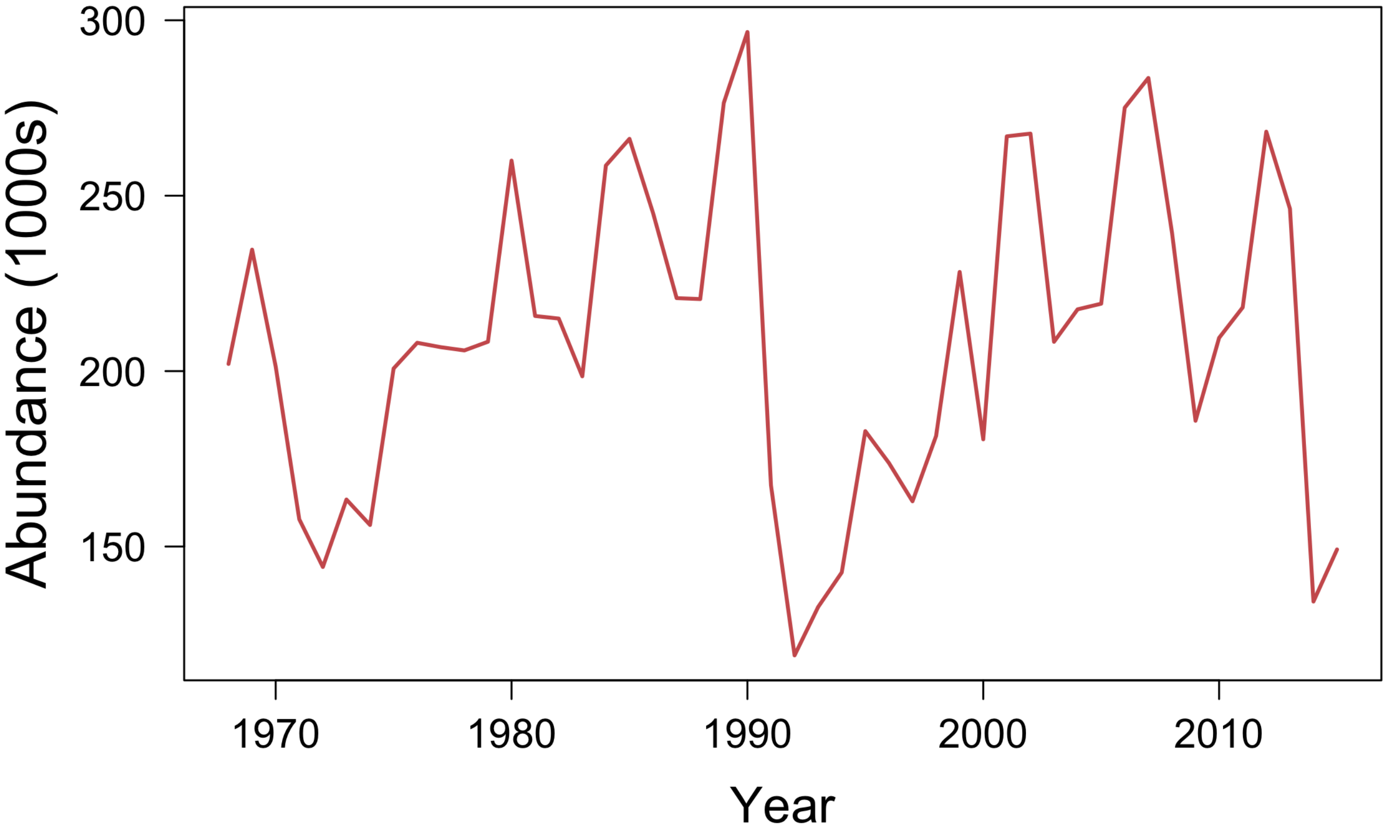


# Proportion of fish over 5 pounds



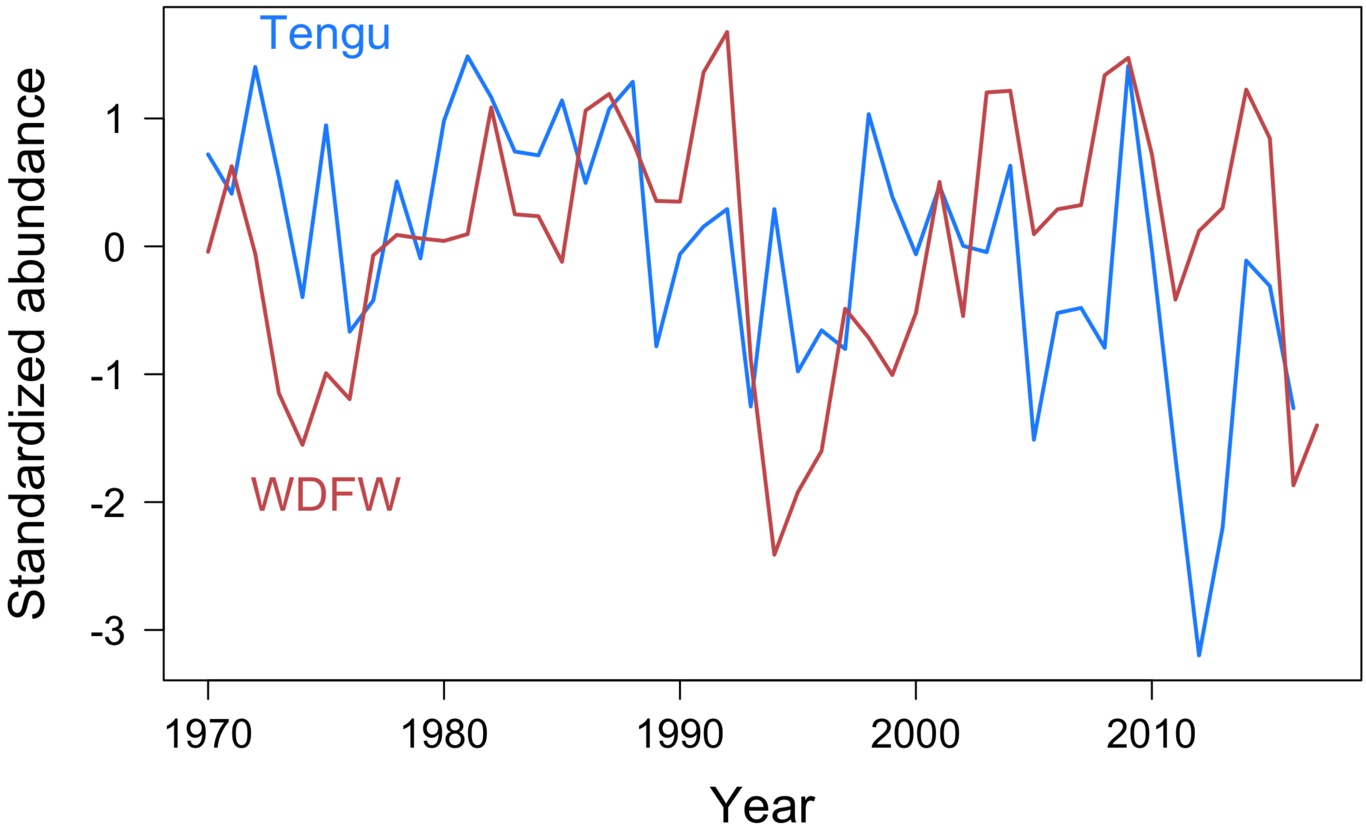
# Comparison of derby & survey catch data

# WDFW survey data




Losee et al (2019) *Fish & Fisheries*

# Time series of both catch indices



# Model forms

## One common state

$$\begin{bmatrix} y_{\text{Tengu}} \\ y_{\text{WDFW}} \end{bmatrix}_t = \begin{bmatrix} 1 \\ 1 \end{bmatrix} x_t + \begin{bmatrix} a_{\text{Tengu}} \\ a_{\text{WDFW}} \end{bmatrix} + \begin{bmatrix} v_{\text{Tengu}} \\ v_{\text{WDFW}} \end{bmatrix}_t$$

$$x_t = x_{t-1} + u + w_t$$

# Model forms

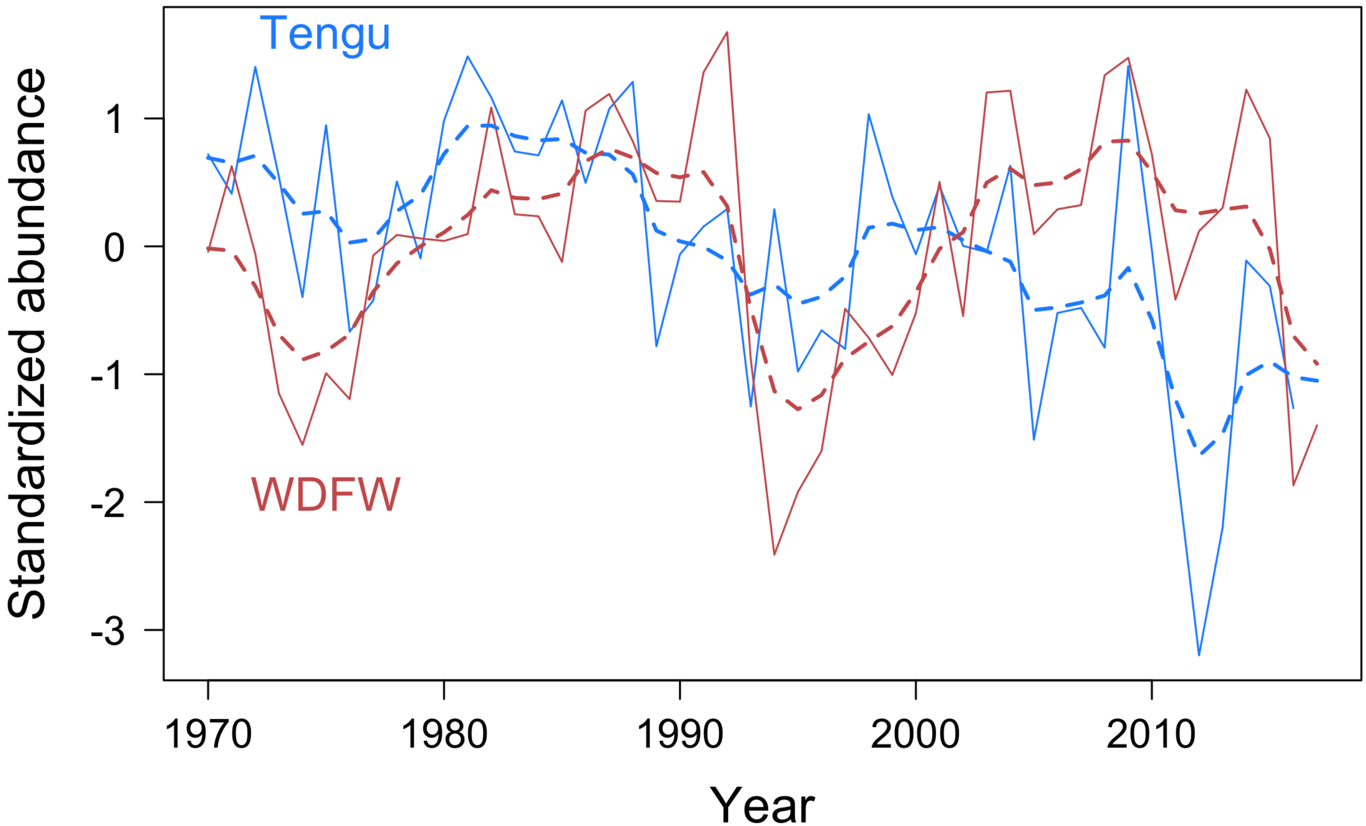
## Two unique states

$$\begin{bmatrix} y_{\text{Tengu}} \\ y_{\text{WDFW}} \end{bmatrix}_t = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_{\text{Tengu}} \\ x_{\text{WDFW}} \end{bmatrix}_t + \begin{bmatrix} a_{\text{Tengu}} \\ a_{\text{WDFW}} \end{bmatrix} + \begin{bmatrix} v_{\text{Tengu}} \\ v_{\text{WDFW}} \end{bmatrix}_t$$

$$\begin{bmatrix} x_{\text{Tengu}} \\ x_{\text{WDFW}} \end{bmatrix}_t = \begin{bmatrix} x_{\text{Tengu}} \\ x_{\text{WDFW}} \end{bmatrix}_{t-1} + \begin{bmatrix} u_{\text{Tengu}} \\ u_{\text{WDFW}} \end{bmatrix} + \begin{bmatrix} w_{\text{Tengu}} \\ w_{\text{WDFW}} \end{bmatrix}_t$$

The data support two unique states with a common decline of ~2.5% per year

# Model fits and data



# Comparison of derby & survey size data

# Three metrics of fish size

1) The weight of each of the top five Chinook salmon*

2) The number over 10 pounds

3) The number over 5 pounds

*In *most* years

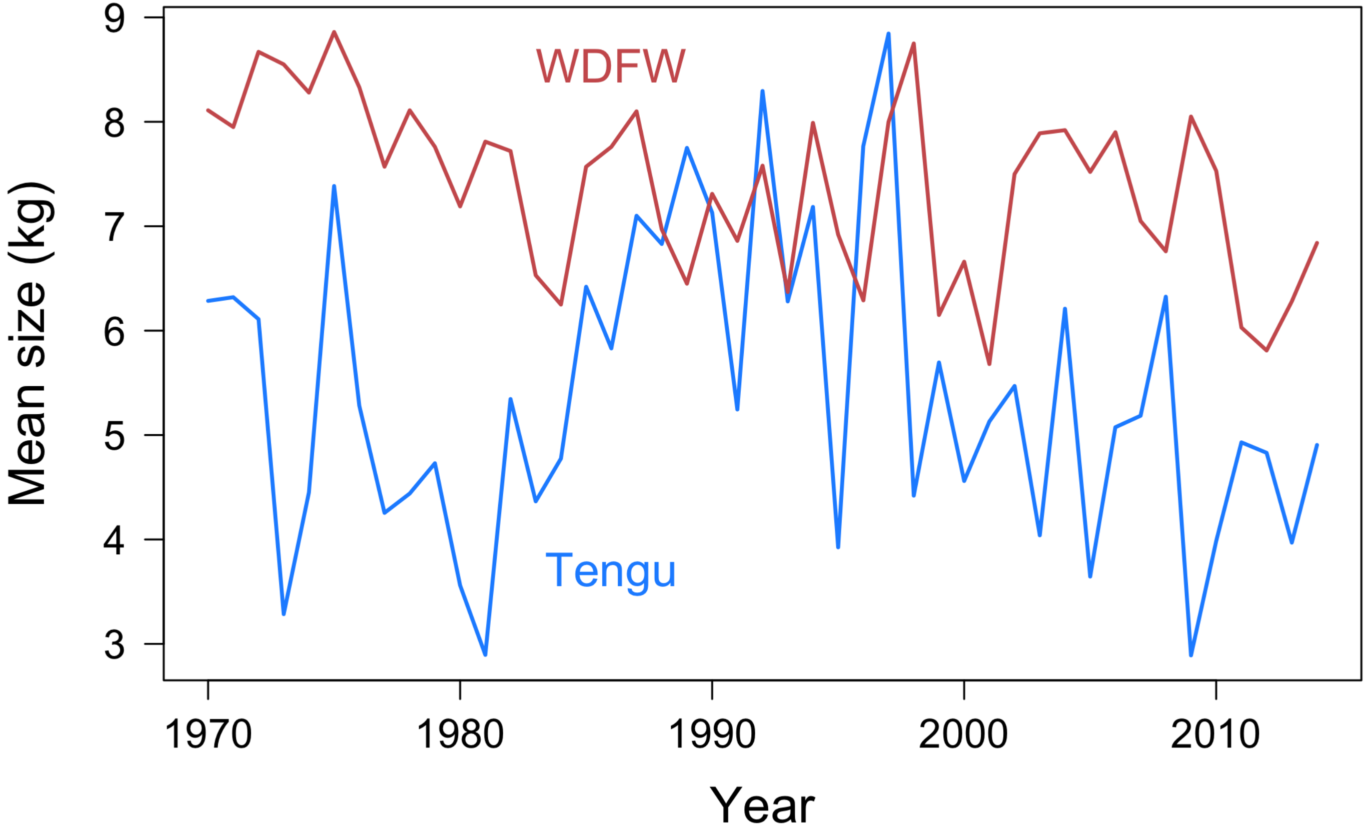
# Three metrics of fish size

1) The mean weight of the *top two* Chinook salmon

2) The number over 10 pounds

3) The number over 5 pounds

# Time series of size



# Model forms

## One common state

$$\begin{bmatrix} y_{\text{Tengu}} \\ y_{\text{WDFW}} \end{bmatrix}_t = \begin{bmatrix} 1 \\ 1 \end{bmatrix} x_t + \begin{bmatrix} a_{\text{Tengu}} \\ a_{\text{WDFW}} \end{bmatrix} + \begin{bmatrix} v_{\text{Tengu}} \\ v_{\text{WDFW}} \end{bmatrix}_t$$

$$x_t = x_{t-1} + u + w_t$$

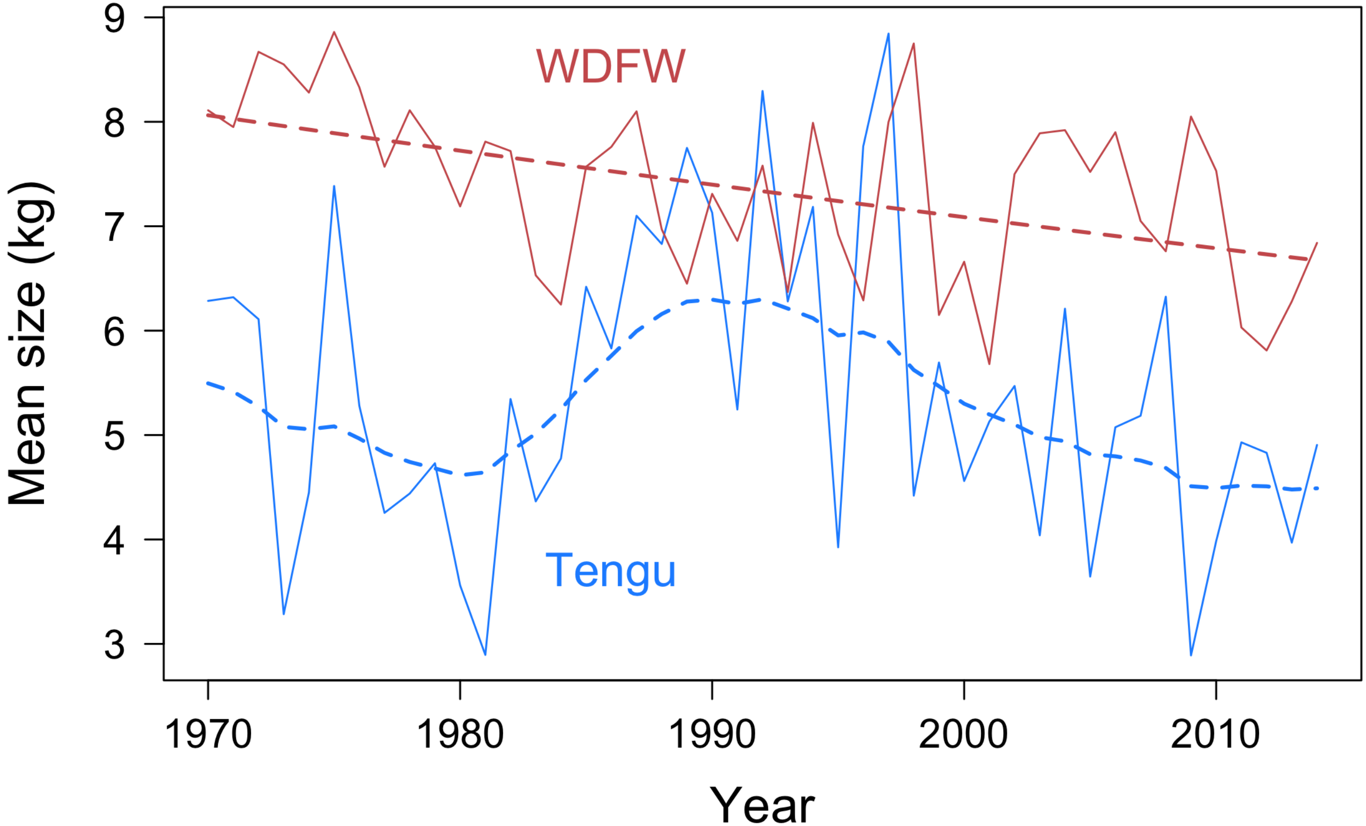
## Two unique states

$$\begin{bmatrix} y_{\text{Tengu}} \\ y_{\text{WDFW}} \end{bmatrix}_t = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_{\text{Tengu}} \\ x_{\text{WDFW}} \end{bmatrix}_t + \begin{bmatrix} a_{\text{Tengu}} \\ a_{\text{WDFW}} \end{bmatrix} + \begin{bmatrix} v_{\text{Tengu}} \\ v_{\text{WDFW}} \end{bmatrix}_t$$

$$\begin{bmatrix} x_{\text{Tengu}} \\ x_{\text{WDFW}} \end{bmatrix}_t = \begin{bmatrix} x_{\text{Tengu}} \\ x_{\text{WDFW}} \end{bmatrix}_{t-1} + \begin{bmatrix} u_{\text{Tengu}} \\ u_{\text{WDFW}} \end{bmatrix} + \begin{bmatrix} w_{\text{Tengu}} \\ w_{\text{WDFW}} \end{bmatrix}_t$$

The data support two unique states with a common decline of ~0.4% per year

# Model fits and data



# Conclusions

Tengu anglers and WDFW surveys seem to be sampling different groups of fish

Both data sources showed evidence for declining abundance and size over time

The Tengu data are an amazing source of information

scheuerl@uw.edu

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