

# Influences of the marine environment, the portfolio effect, and cohort resonance on Pacific salmon abundance

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# Outline

- Managing population diversity with the portfolio effect
- Cohort resonance
- Species diversity in salmon

# Managing Population Diversity

Sacramento River example: decline in '08, '09 due in part to reduced diversity decreasing stability (i.e., increasing variability).

Management questions:

- What are the sources of diminished diversity?
- How much can we improve stability (i.e., reduce variability?)

Note: Stephanie Carlson described direct approaches to determining sources: testing mechanisms empirically

# What do the time series themselves tell us about the answers to these questions?

(Yamane, et al., in review)

- Choose an expression for stability. Here the coefficient of variation,  $CV = \sigma/m$ , of the total aggregate variability.
- Calculate value of CV for the sum of the tributaries, assuming series are completely unrelated (statistically independent) = minimum possible CV
- Diversity Deficit: the scope for improvement based on difference between actual CVs and minimum possible CVs

# Changing Diversity Deficit Sacramento River Salmon

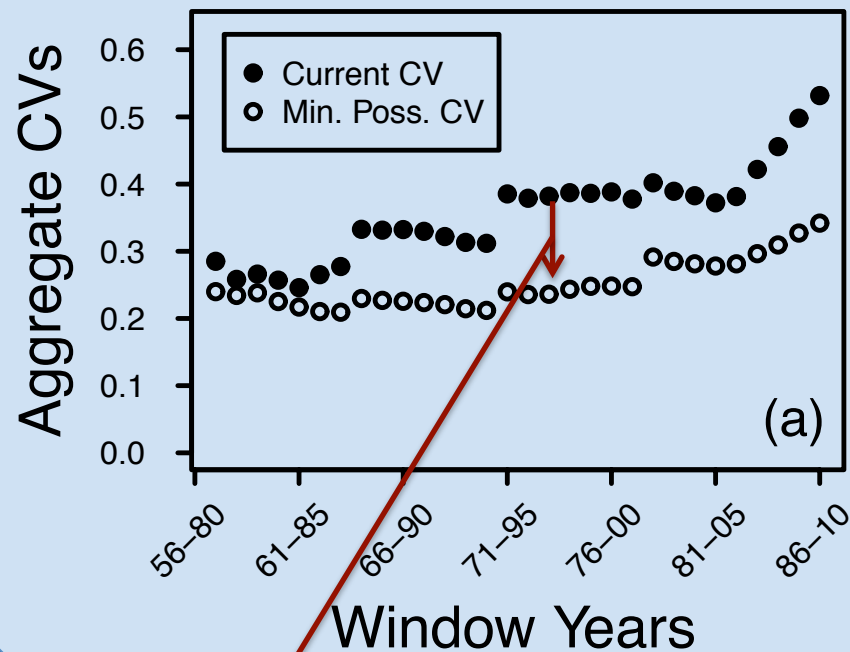


Figure 2

Scope for increasing stability by  
improving diversity

Writing this scope as a percentage of  
the present scope

# Using the Diversity Deficit I: Leave-One-Out analysis

- Calculate what the Diversity Deficit would look like with one tributary removed
- If one tributary has a predominant effect, it will change the Diversity Deficit

# Leave-One-Out Analysis Sacramento River tributaries

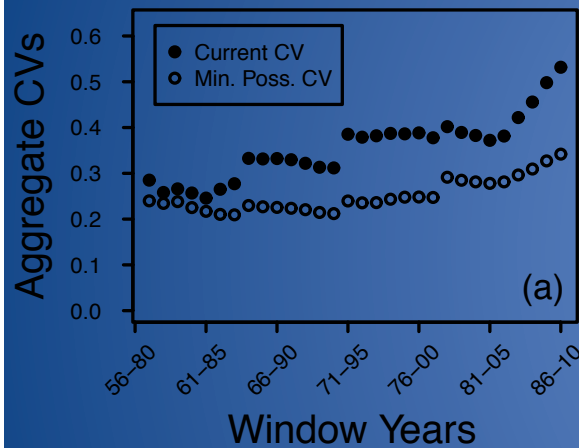


Figure 2

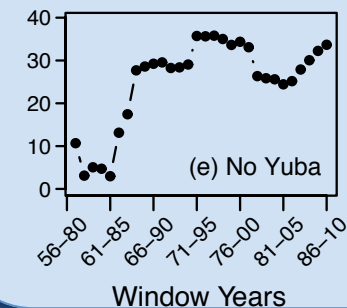
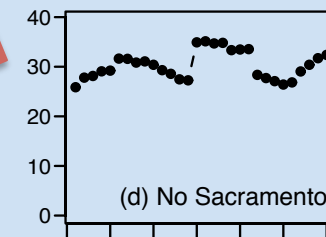
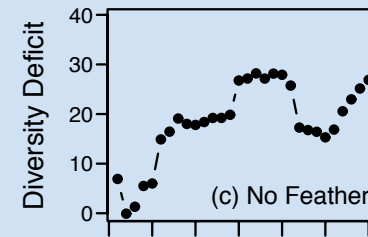
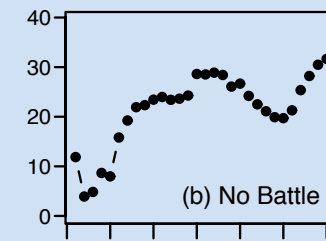
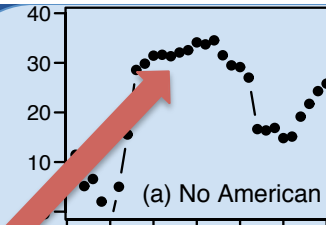
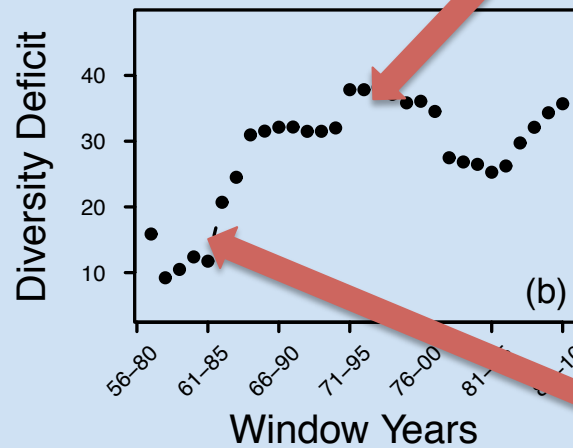


Figure 3

# Using the Diversity Deficit II: How much can we increase stability?

- If we reduced the Diversity Deficit as much as possible (i.e., reduced correlation among tributaries to zero), how much would we increase stability (i.e., reduce CV)?
- Would it have been enough to avoid closing the fishery in '08 and '09?



# If we had achieved maximal diversity by '07-'08, would we have avoided a fishery closure?

Values of returns were less than the acceptable range of minimum escapement.

With reduced variance, a low return event with the same chance of occurrence may have just avoided a fishery closure.

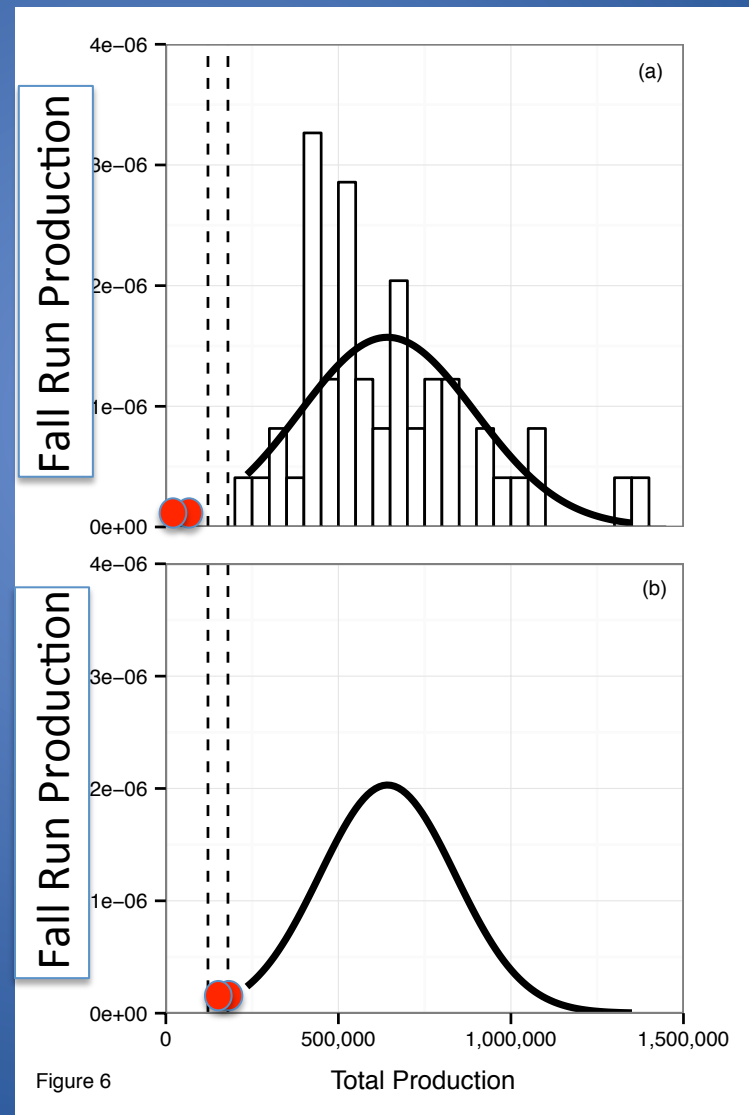


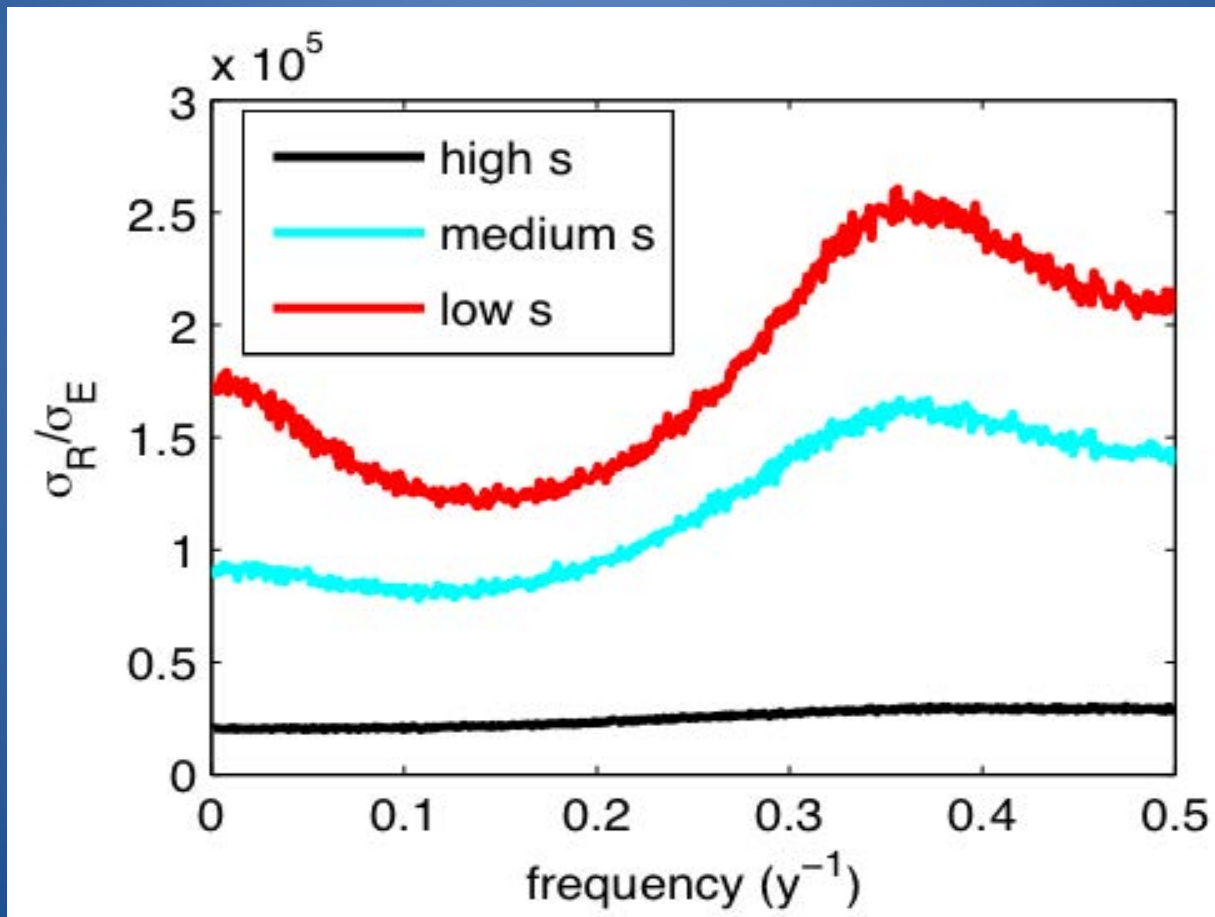
Figure 6

# Cohort Resonance

- A recent discovery (Bjornstad, et al. 2004)
- Age structured populations are more sensitive to particular frequencies of variability in the environment.
- Fishing truncates spawning age structure, making the frequency sensitivity stronger, and increases variability (Worden, et al. 2010)

# Cohort Resonance: Frequency Sensitivity

1. Peak in sensitivity at  $1/(\text{generation time})$ , and at low frequency.
2. Determined by spawning age distribution: e.g., increases with lower survival (e.g., fishing)



Sensitivity to  
Variability vs.  
frequency

e.g., coho  
salmon  
with  
variable  
growth  
rate

Worden, et al.  
(2010)

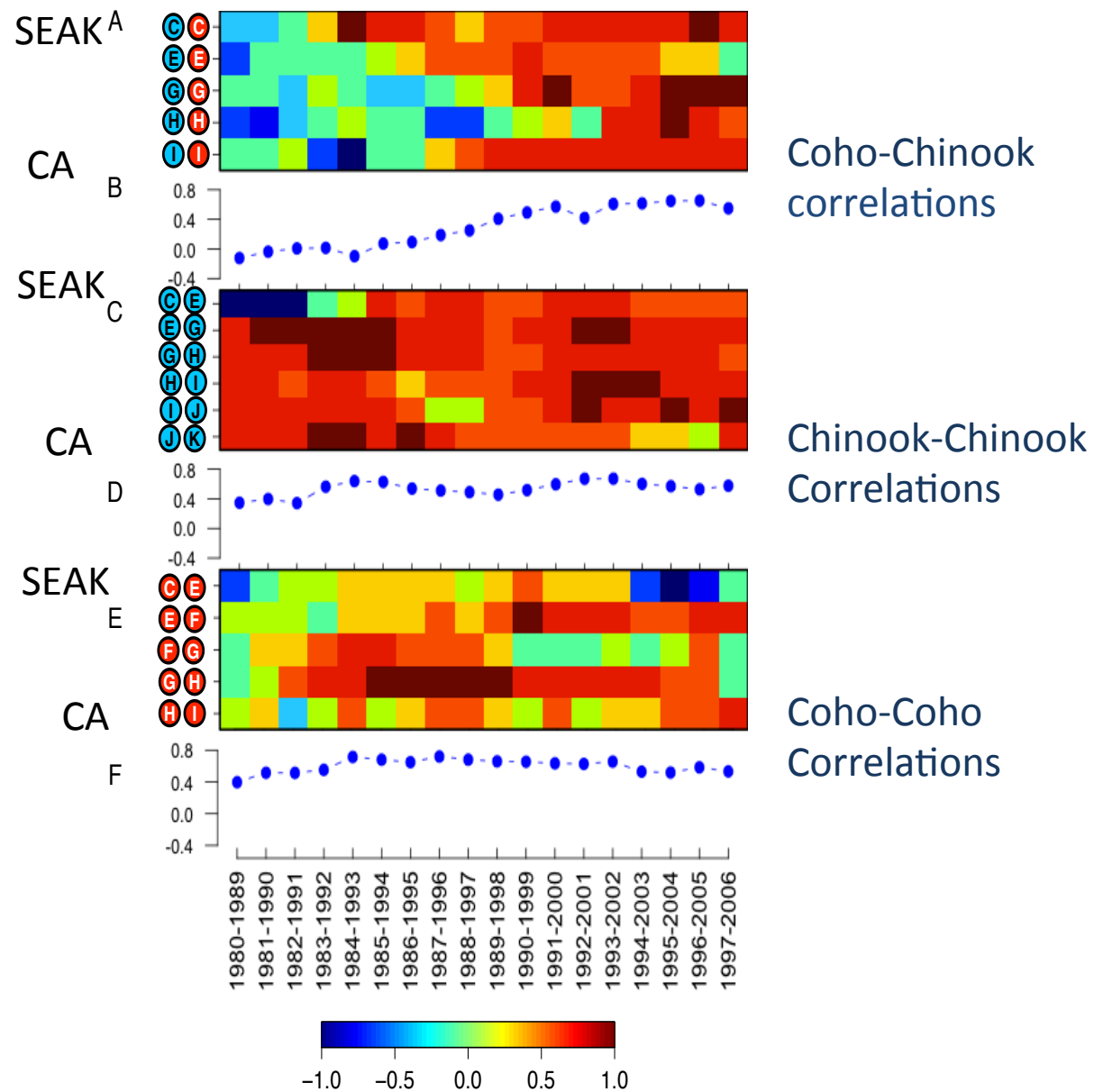
# Consequences

- Portfolio effect depends on cohort resonance
- How?

# Species diversity in salmon

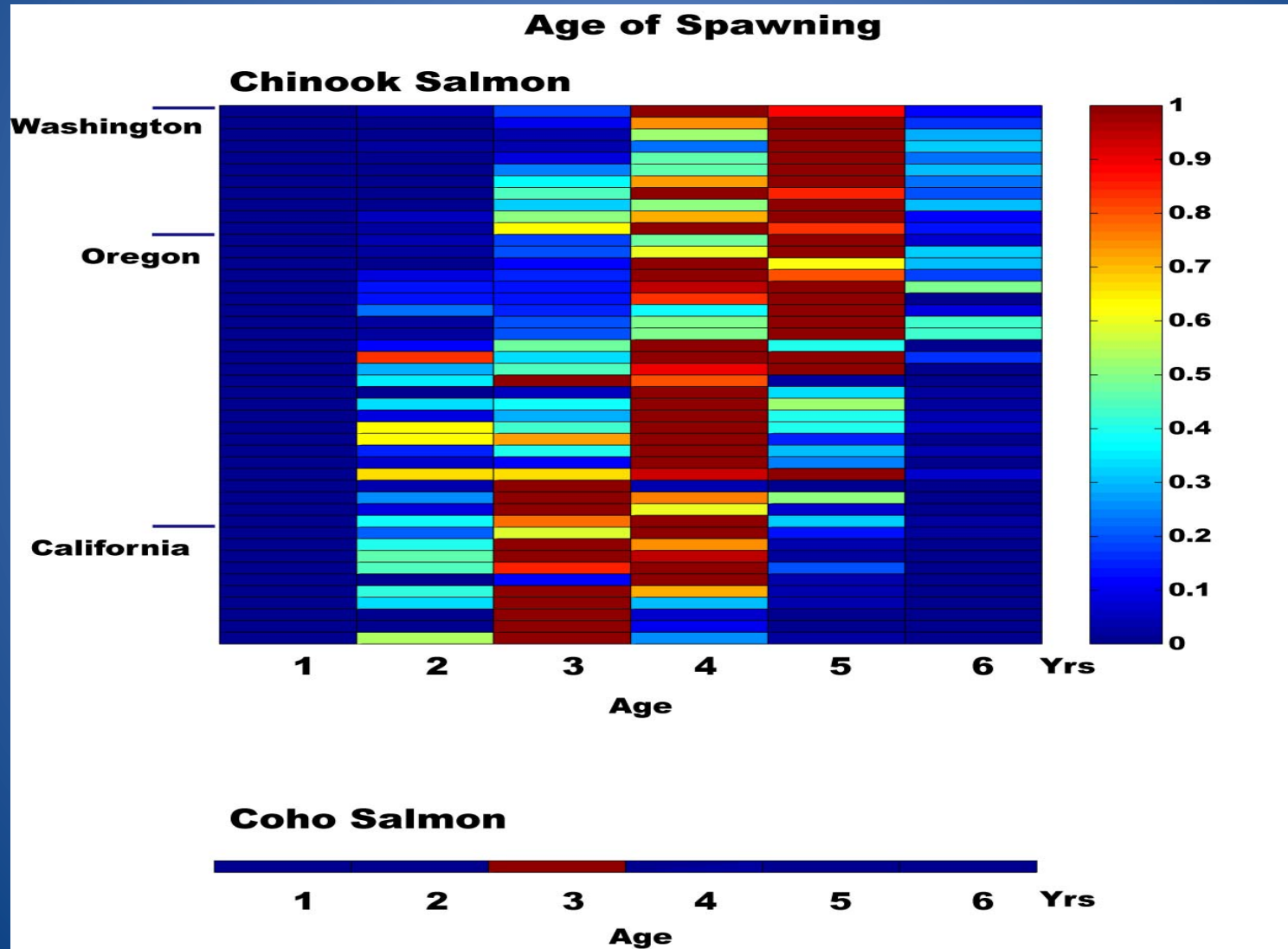
- Thus far, the assets of the portfolio have been populations of the same species in different tributaries. “population diversity”
- When the assets of the portfolio are different species, diversity is termed “species diversity.”
- Kilduff, et al. (2015) is an example of species diversity (coho salmon and chinook salmon).

# Loss of species diversity in salmon

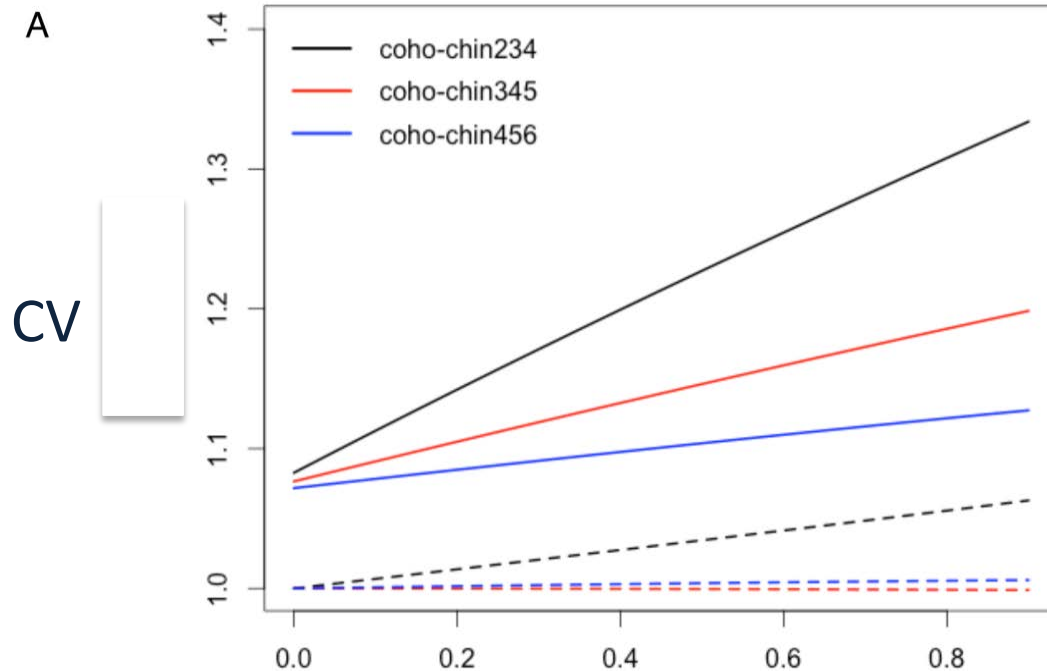


Kilduff, et al. 2015

# Coho and Chinook have different spawning age distributions



# Salmon have less species diversity when life histories are similar



Correlation between  
coho and chinook survival

B

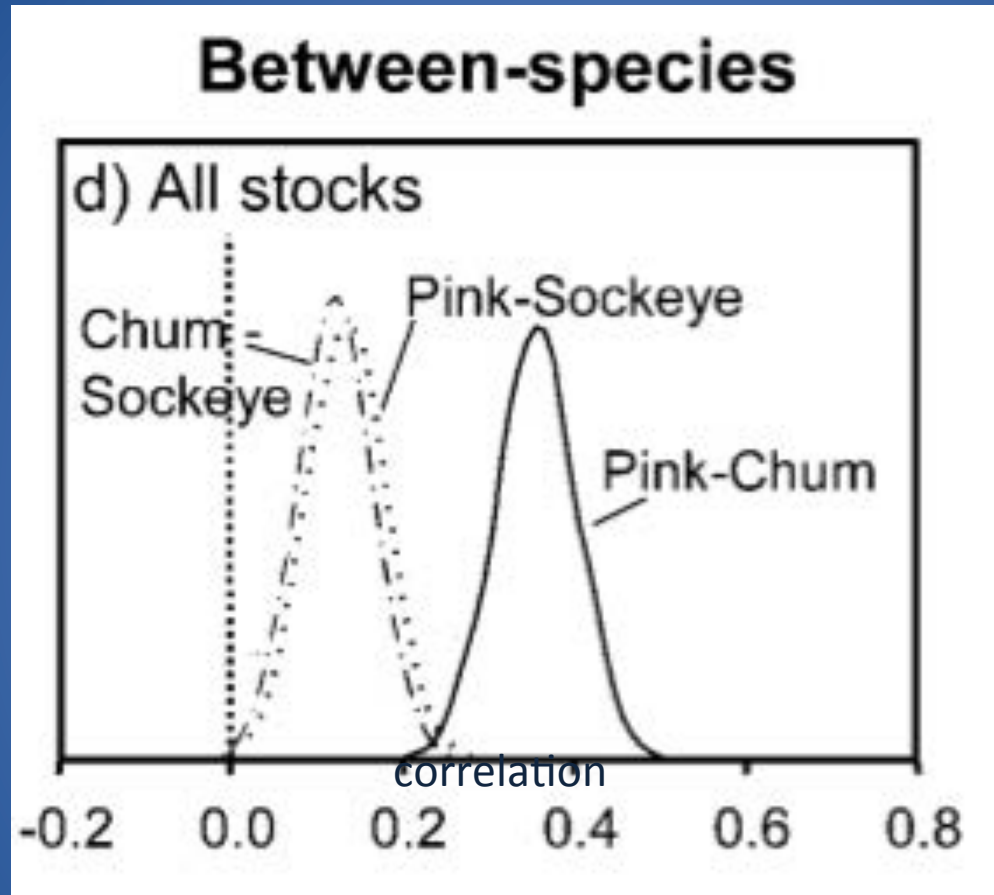
Chinook spawning 2, 3, 4

Chinook spawning 3, 4, 5

Chinook spawning 4, 5, 6



# Another example of species diversity



Distributions of correlations between species at different locations

Explanation: pink and chum salmon have more similar life histories

# Take-to-work messages

- Can manage with Diversity Deficit: 1. time and location of diversity losses, 2. Limit on diversity/stability improvement.
- May have avoided closure with complete restoration of diversity.
- Cohort resonance determines the variability in population diversity and species diversity
- Species diversity depends on similarities in life history in addition to similarities in habitat

Thanks  
for  
listening



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