Association between pinniped abundance and survival for individual populations of adult spring/summer Chinook salmon in the lower Columbia River

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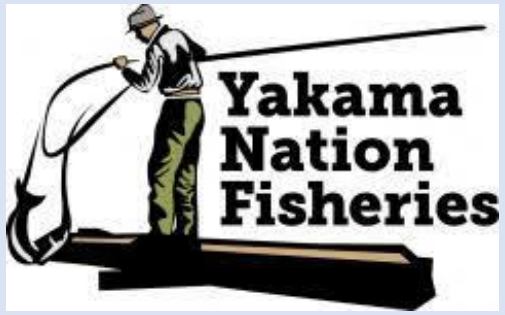
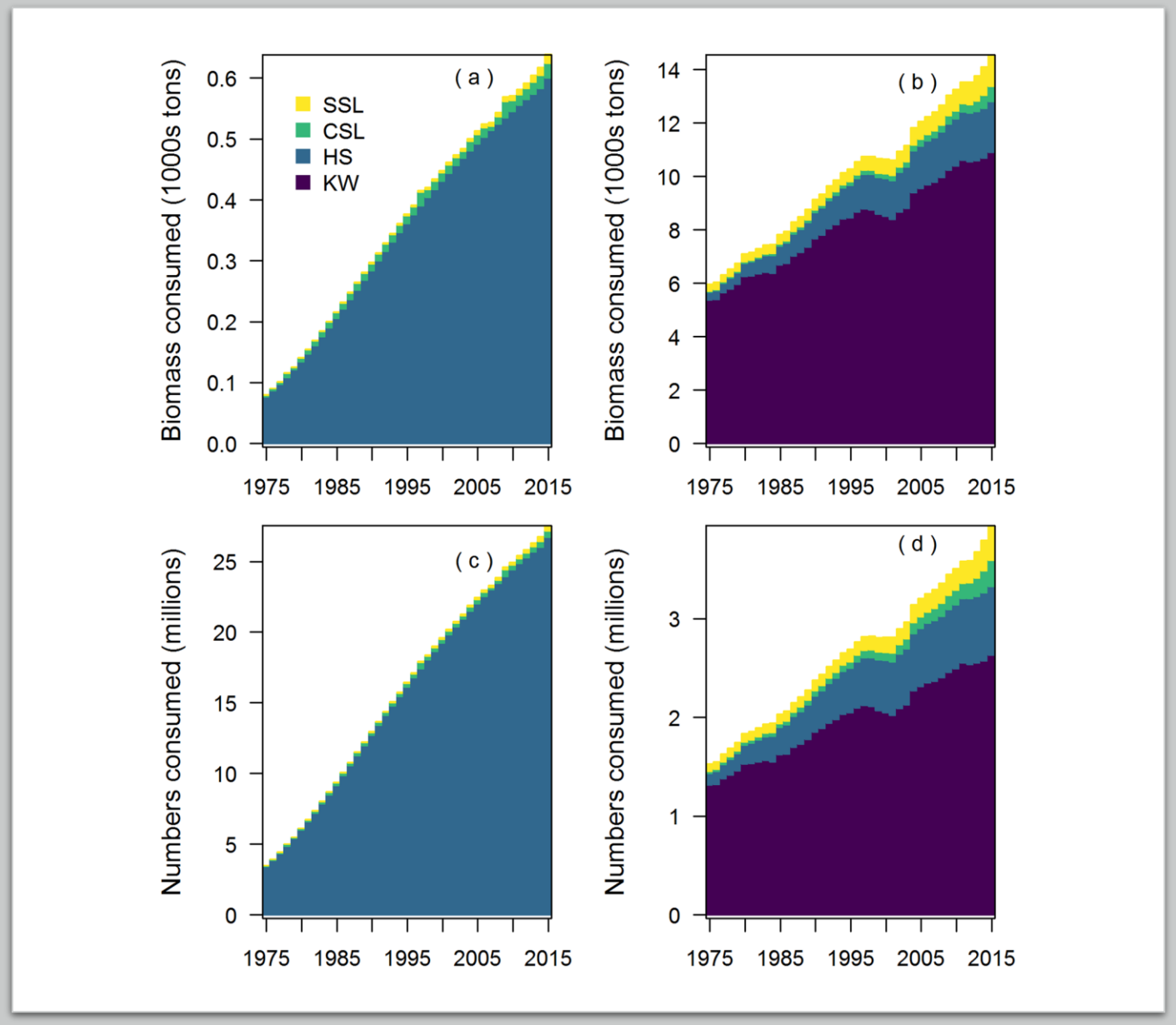


Coastwide marine mammal predation of Chinook salmon from the west coast of North America

- Marine Mammal Protection Act of 1972
  - successful in recovering many populations
- Has led to increased consumption of Chinook salmon



Chasco et al. 2017, Scientific Reports

Northwest sea lions at dams

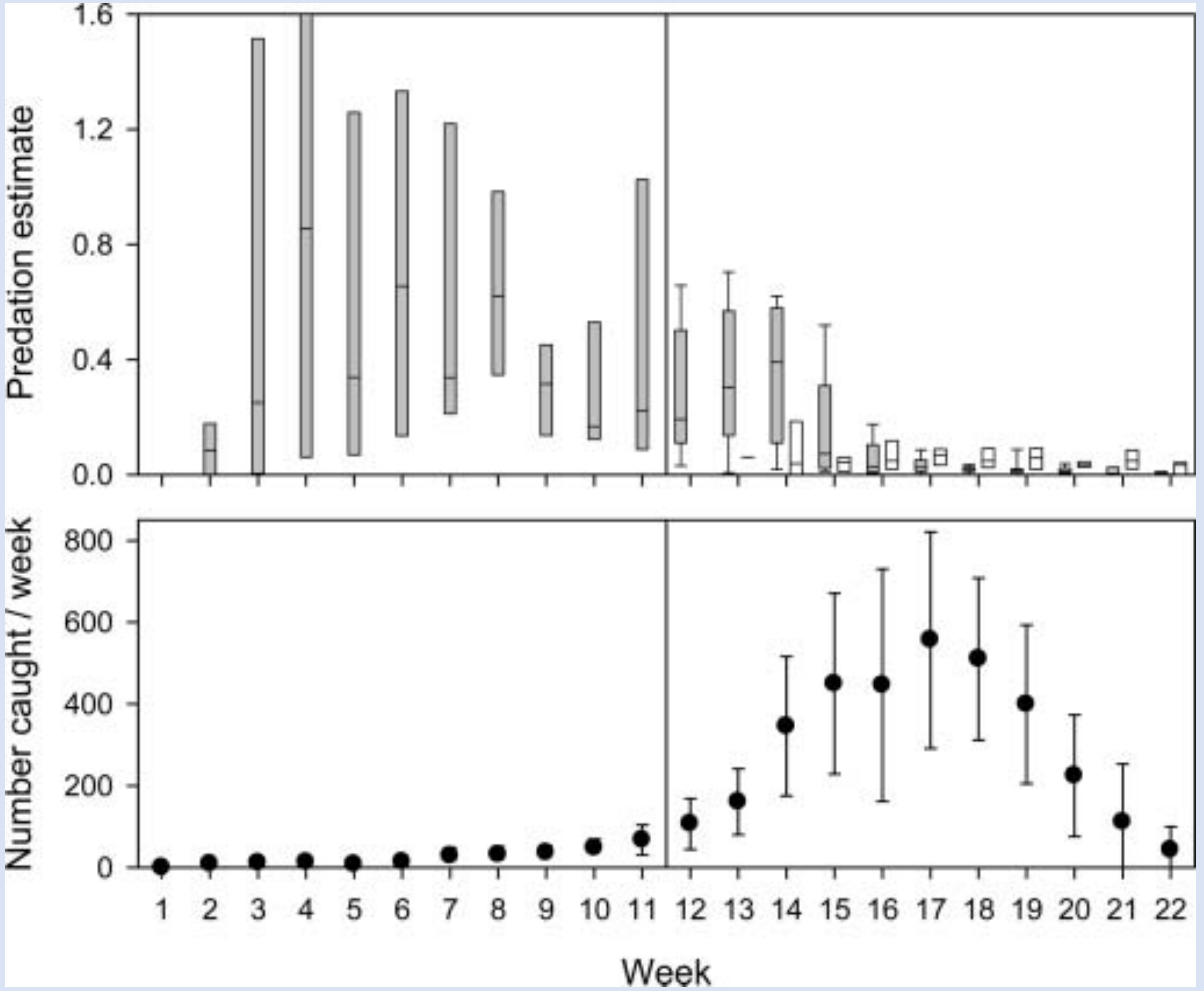
- Sea lions feeding below dams have been a particular problem
  - Herschel and friends at Ballard Locks
  - Bonneville Dam and Willamette Falls

Photo: Seattle Post Intelligencer

Photo: L.E. Baskow

Sea lion predation of spring Chinook in the Bonneville Dam tailrace

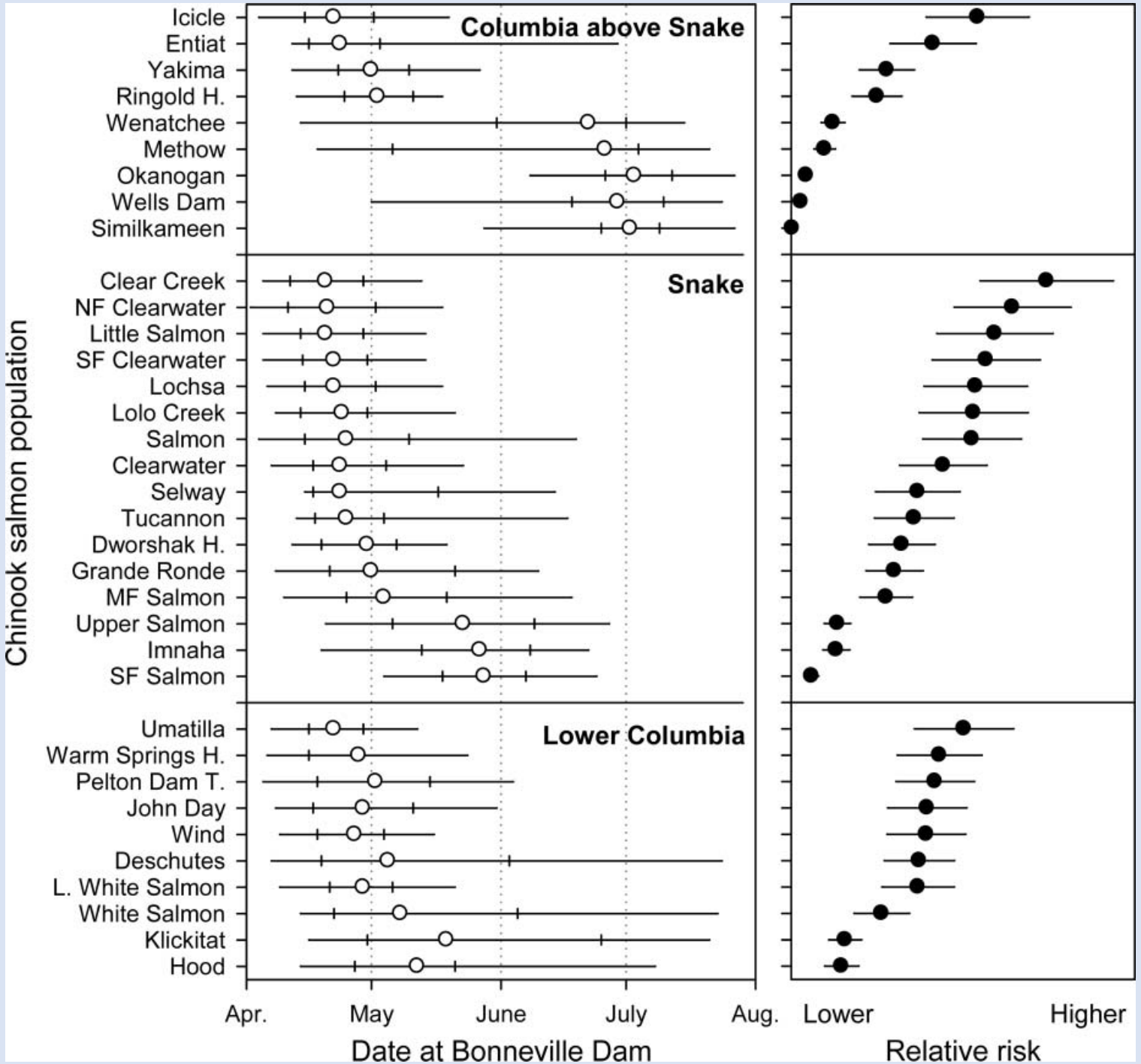
- Predation mortality was higher earlier in the spring Chinook run



Keefer et al. 2012, Trans Am Fish Soc

Population-specific risk

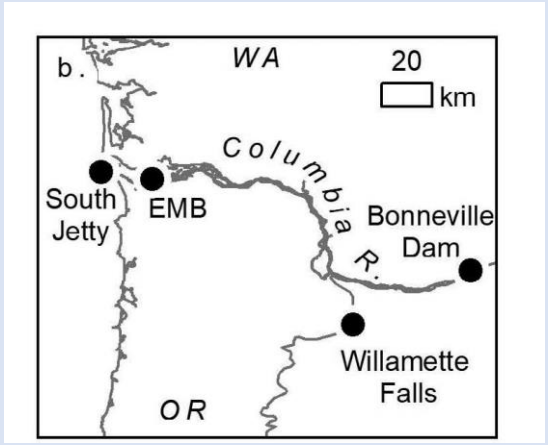
- Earlier-migrating populations experienced higher predation risk below Bonneville Dam

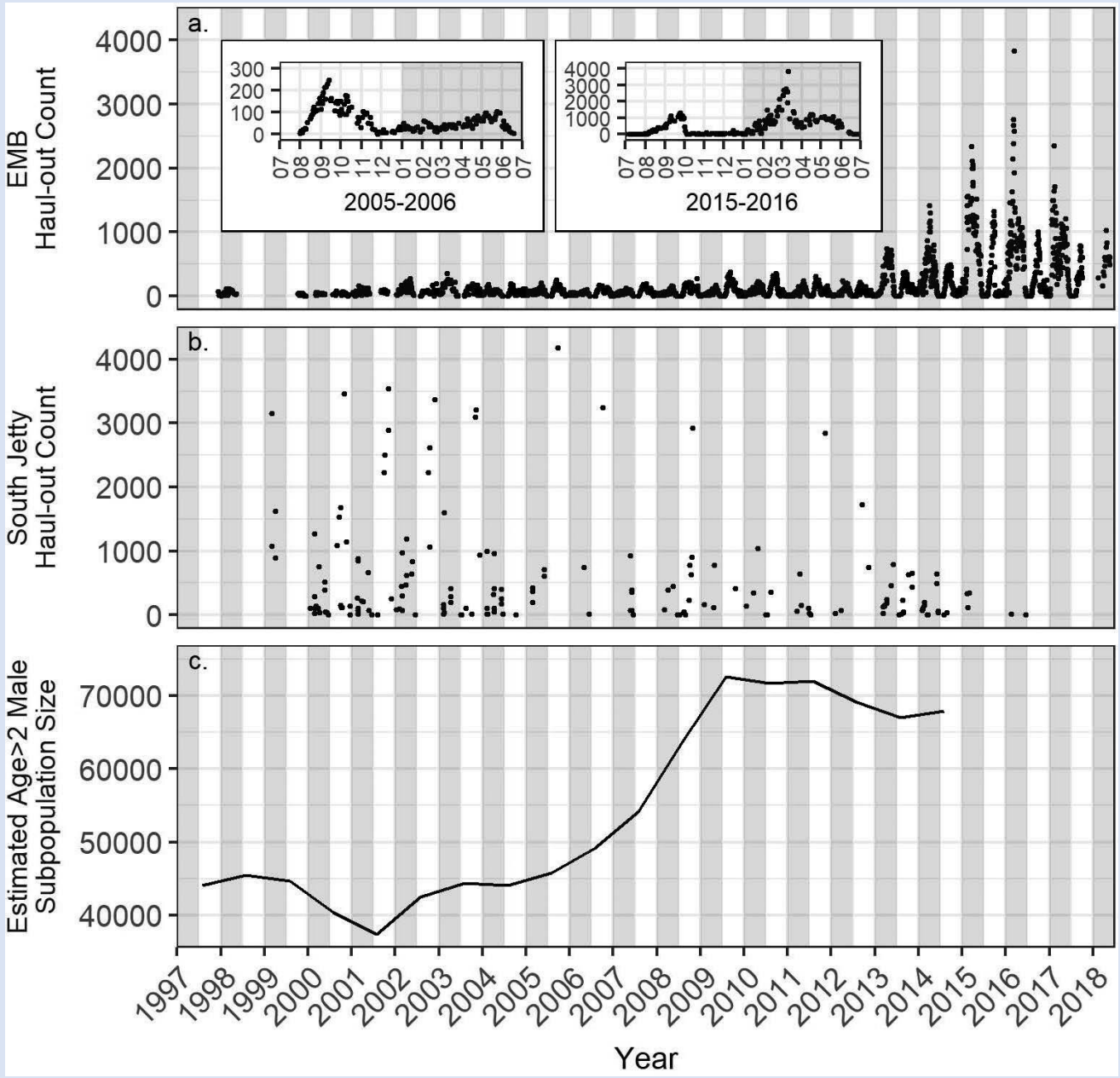


Keefer et al. 2012, Trans Am Fish Soc

River mouth haul out counts

- Sea lions haul out in Astoria (EMB) and South Jetty
  - ~200 km from Bonneville
- Many more animals than below Bonneville Dam
- EMB count increased precipitously from 2013 to 2016

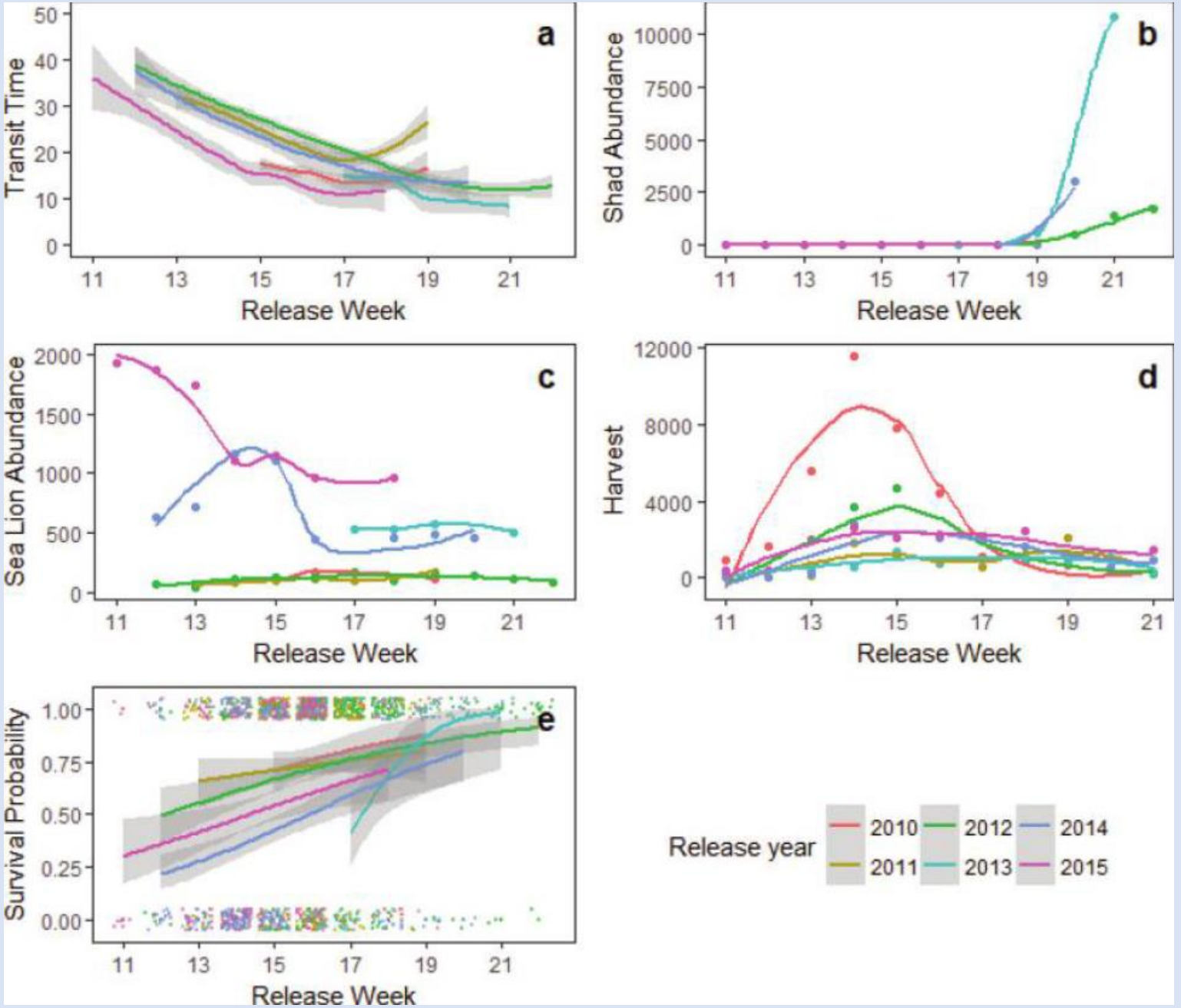




Brown et al. 2020, Northwest Naturalist

Survival from Astoria to Bonneville Dam

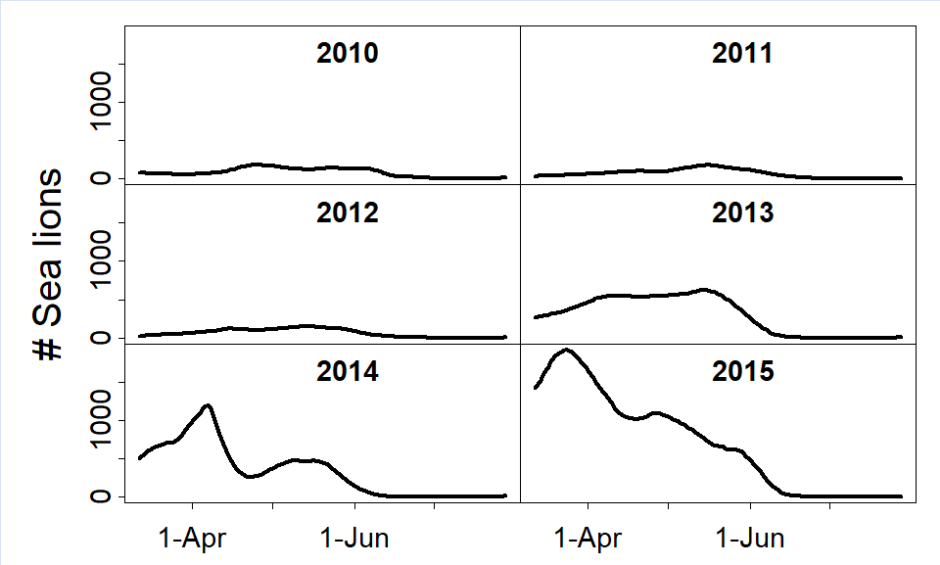
- Survival was negatively associated with EMB sea lion counts
- Survival was lower earlier in spring
  - Suggests earlier populations experienced higher mortality



Wargo Rub et al. 2019, CJFAS

Objectives

- Estimate mortality for individual populations as a function of migration timing and EMB sea lions
- Estimate additional mortality associated with increased sea lion abundance in 2013-2015 relative to 2010-2012



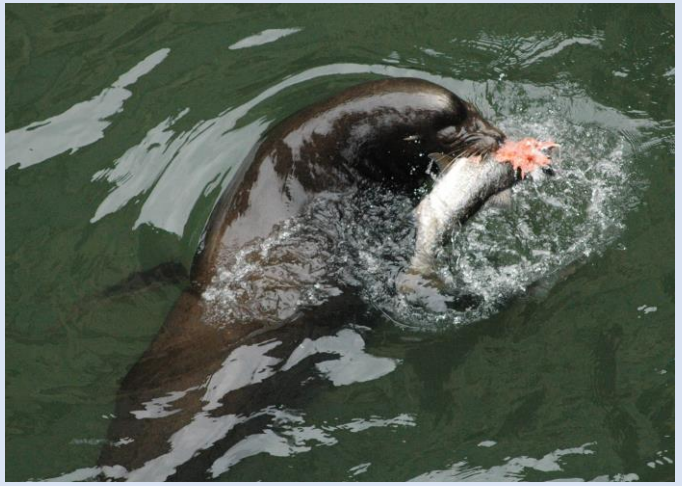


Photo credit: B. Wright, ODFW

Methods: Multistate model (process)

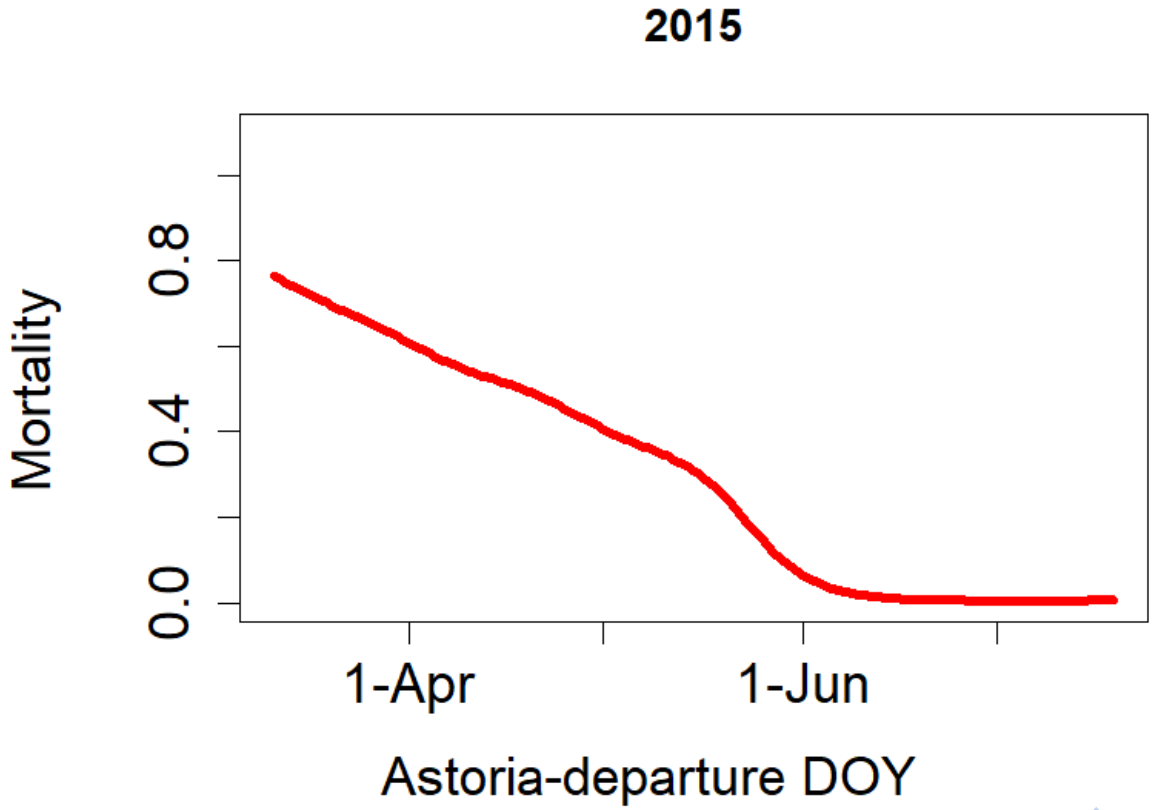
- $\phi_{i,t,y}$ = **Daily survival** of individual i on day t in year y
  - Modeled as function of sea lions, temperature, and hatchery/wild status (clip)
  - $logit(\phi_{i,t,y}) = \beta_{t,y}^{Sea\ lion} * Sea\ lion_{t,y} + \beta_{t,y}^{Temp} * Temp_{t,y} + \beta_{i}^{Clip} * Clip_{i}$
- **Daily probability of passing Bonneville Dam** if alive and downstream
  - Function of day of year at Astoria, river discharge, and spill at Bonneville Dam
  - Parametric time-to-event modeling framework

Methods: Multistate model (data)

- Data
  - Capture histories: release date and Bonneville Dam passage day (or never detected)
    - Assumed perfect detection at Bonneville Dam
    - Assumed no straying
  - Covariates: Daily sea lion counts at EMB (Astoria), river environment at Bonneville
- Likelihood
  - Hidden Markov model likelihood using forward algorithm

Methods: Population-specific migration timing

- Multistate model gave us mortality rates depending on Astoria departure day and year
- Need information on population-specific arrival timing to estimate population-specific mortality



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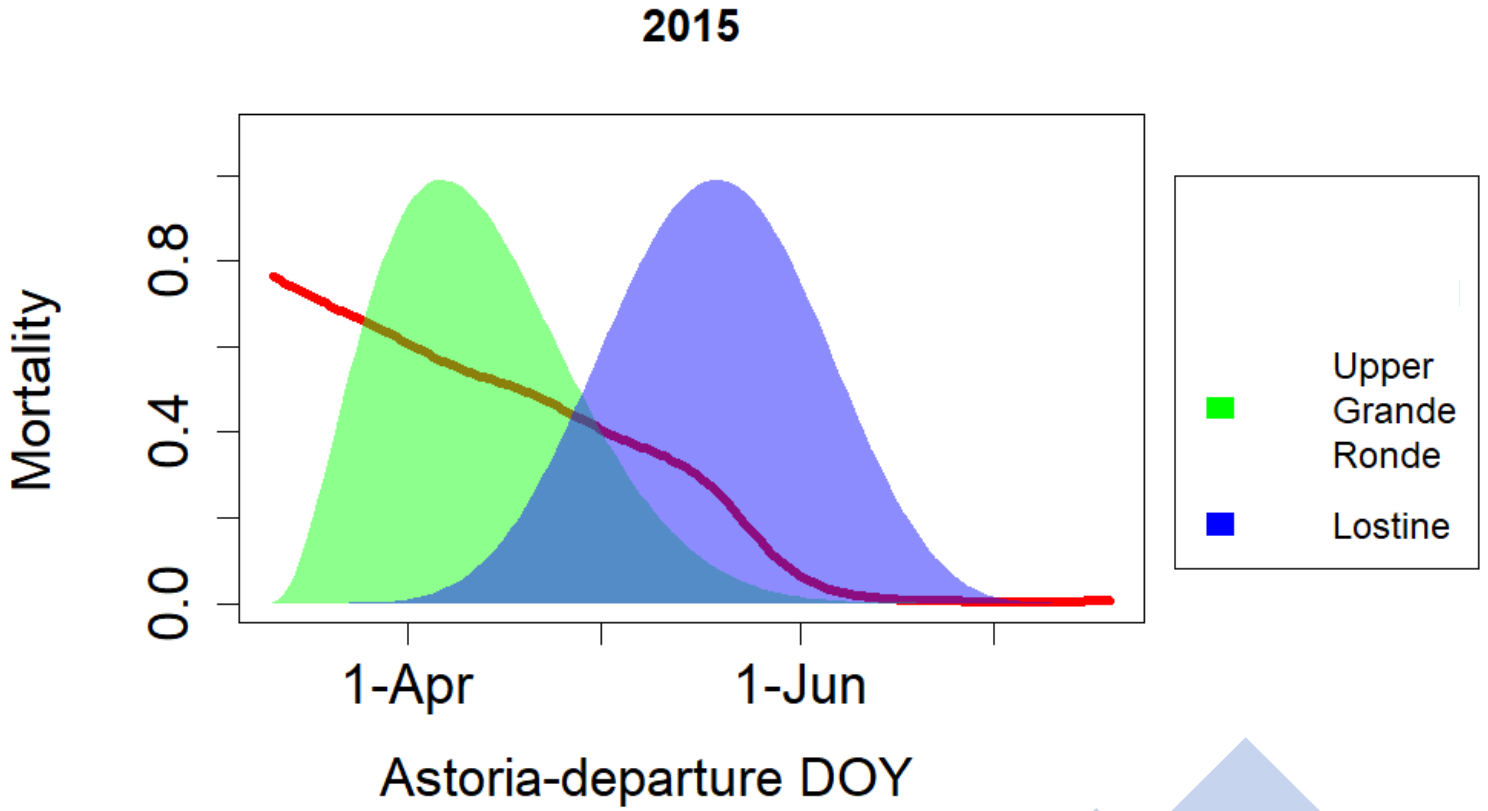
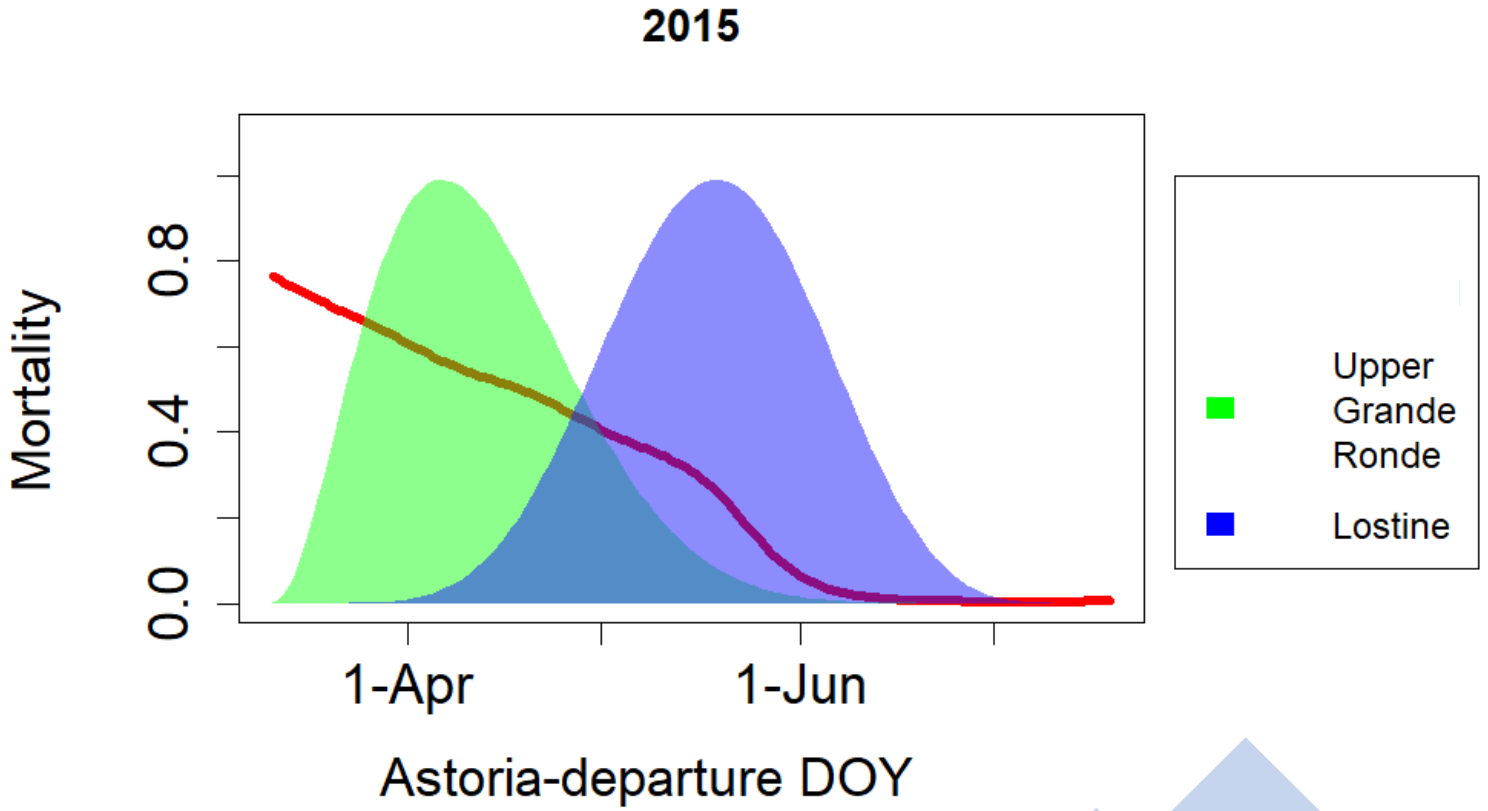


Methods: Population specific migration timing

- $p(A_{p,t,y})$ = Probability of arriving at Astoria on day t in year y for fish from population p
  - $p\left(A_{p,\frac{t}{n\ days},y}\right) \sim Beta(\alpha_{p,y}, \beta_{p,y})$
- Data
  - Detection dates of known-population fish at Bonneville Dam
    - PIT-tagged as juveniles in natal stream
- Likelihood
  - Daily probabilities of Astoria arrival translated to Bonneville Dam arrival based on the travel time and survival model
  - Used daily probabilities of Bonneville Dam arrival to calculate data likelihood

Methods: Population-specific mortality

- To calculate annual population-specific mortality
  - Calculated weighted averages based on the proportion of each population arriving on each day



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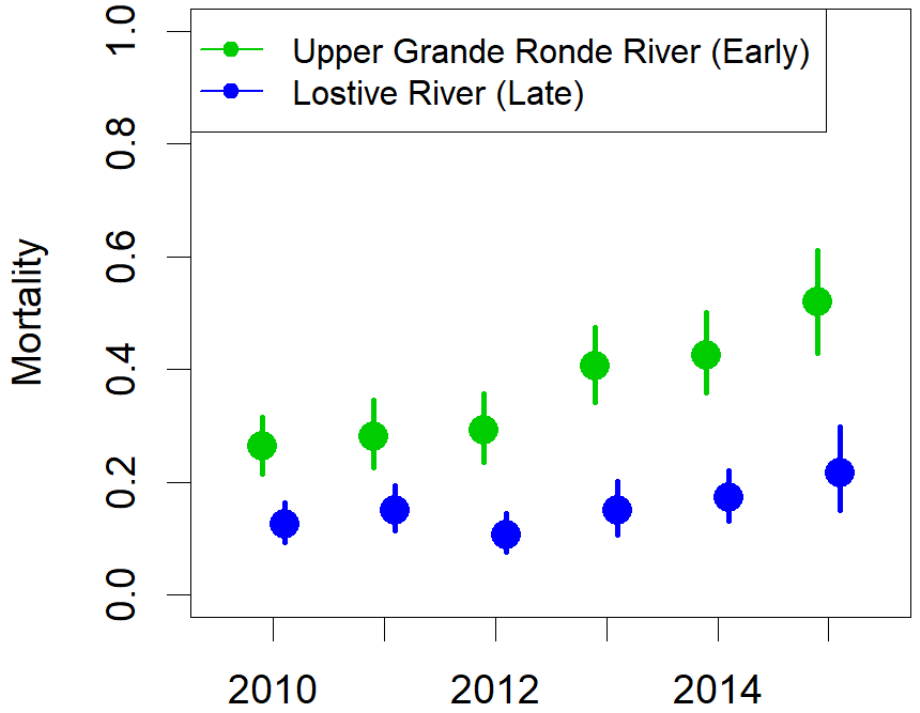


Methods: Population-specific mortality

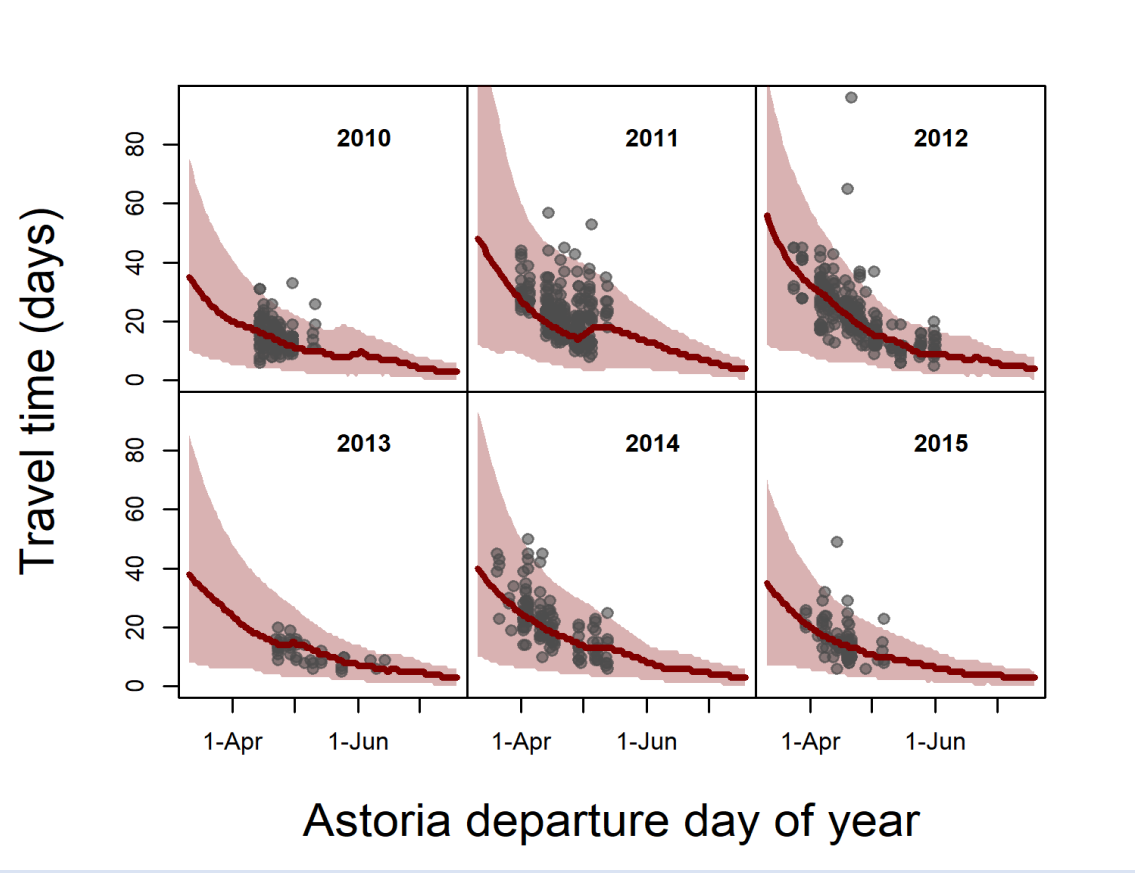
- Population- and year-specific mortality ($M_{p,y}$) is the average mortality of fish with different Astoria departure days t, weighted by $p(A_{p,t,y})$
  - $M_{p,y} = \sum_t M_{t,y} p(A_{p,t,y})$

Methods: Population-specific mortality

- Population- and year-specific mortality $(M_{p,y})$ is the average mortality of fish with different Astoria departure days t, weighted by $p(A_{p,t,y})$
  - $M_{p,y} = \sum_t M_{t,y} p(A_{p,t,y})$
- Calculated the change in mortality (ΔM) between 2010-2012 (baseline sea lions) and 2013-2015 (high sea lions)
  - $\Delta M_p = M_{p,2013-2015} - M_{p,2010-2012}$
  - Useful for assessing potential impact on populations

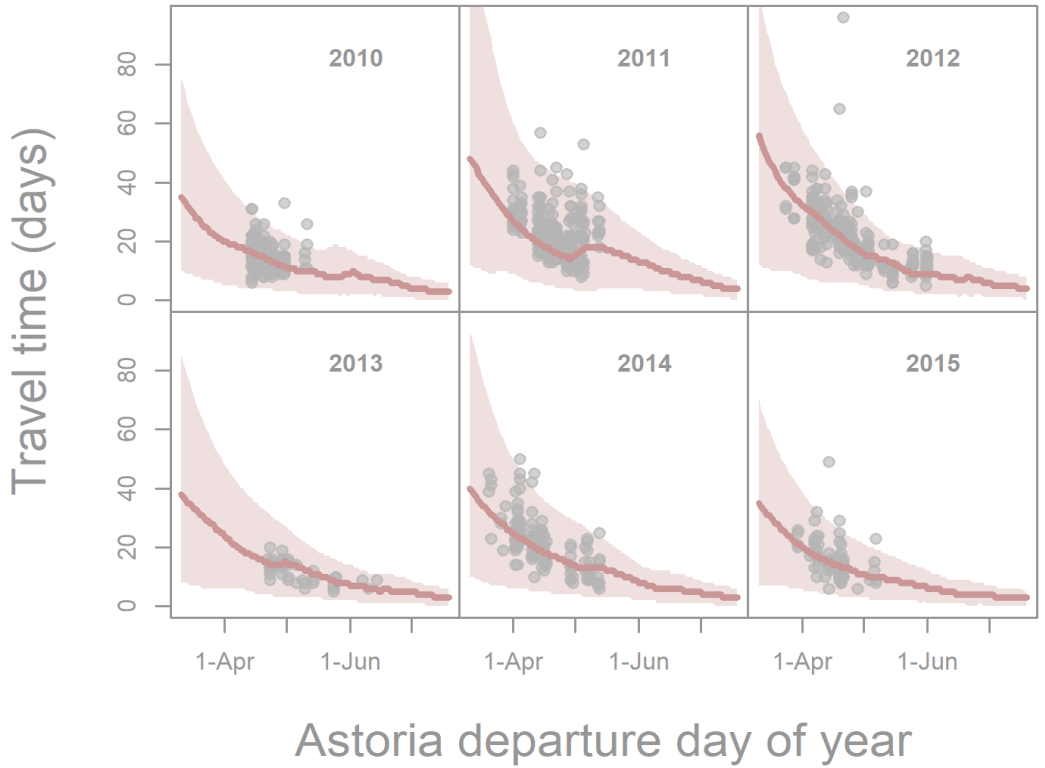
Results: Travel time

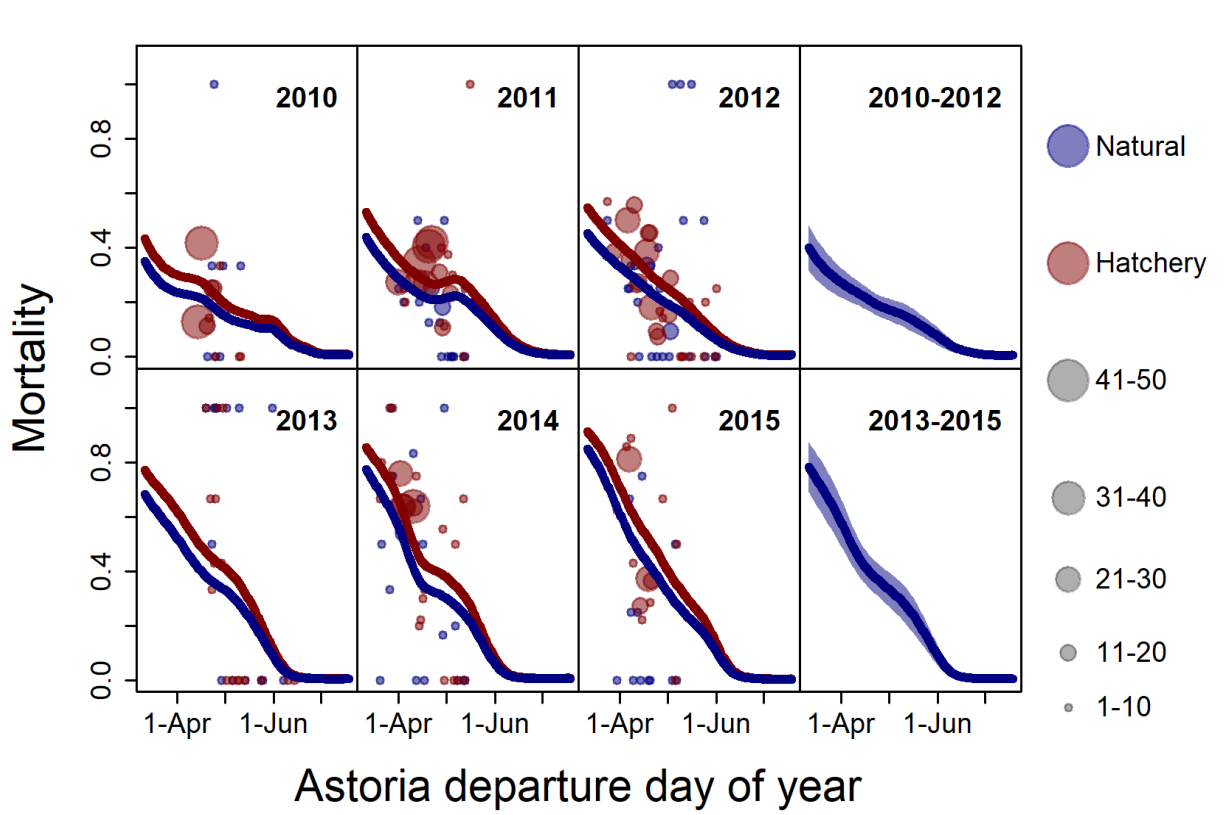
- Longer travel time for early-arriving fish



Results: Travel time and mortality

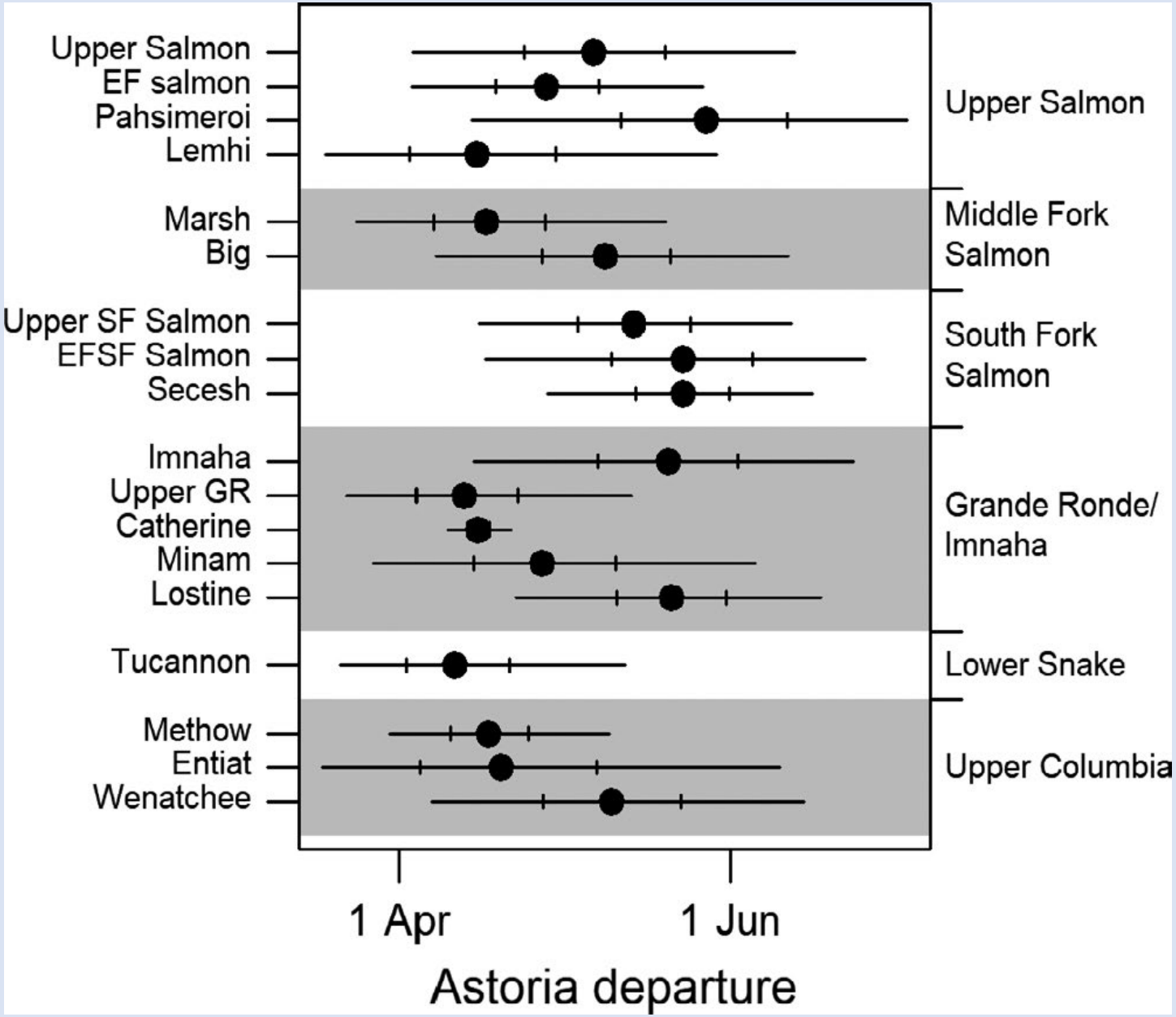
- Longer travel time for early-arriving fish
- Higher mortality for early-arriving fish
- Higher mortality in years with greater sea lions (2013-2015), particularly for earlier arriving fish





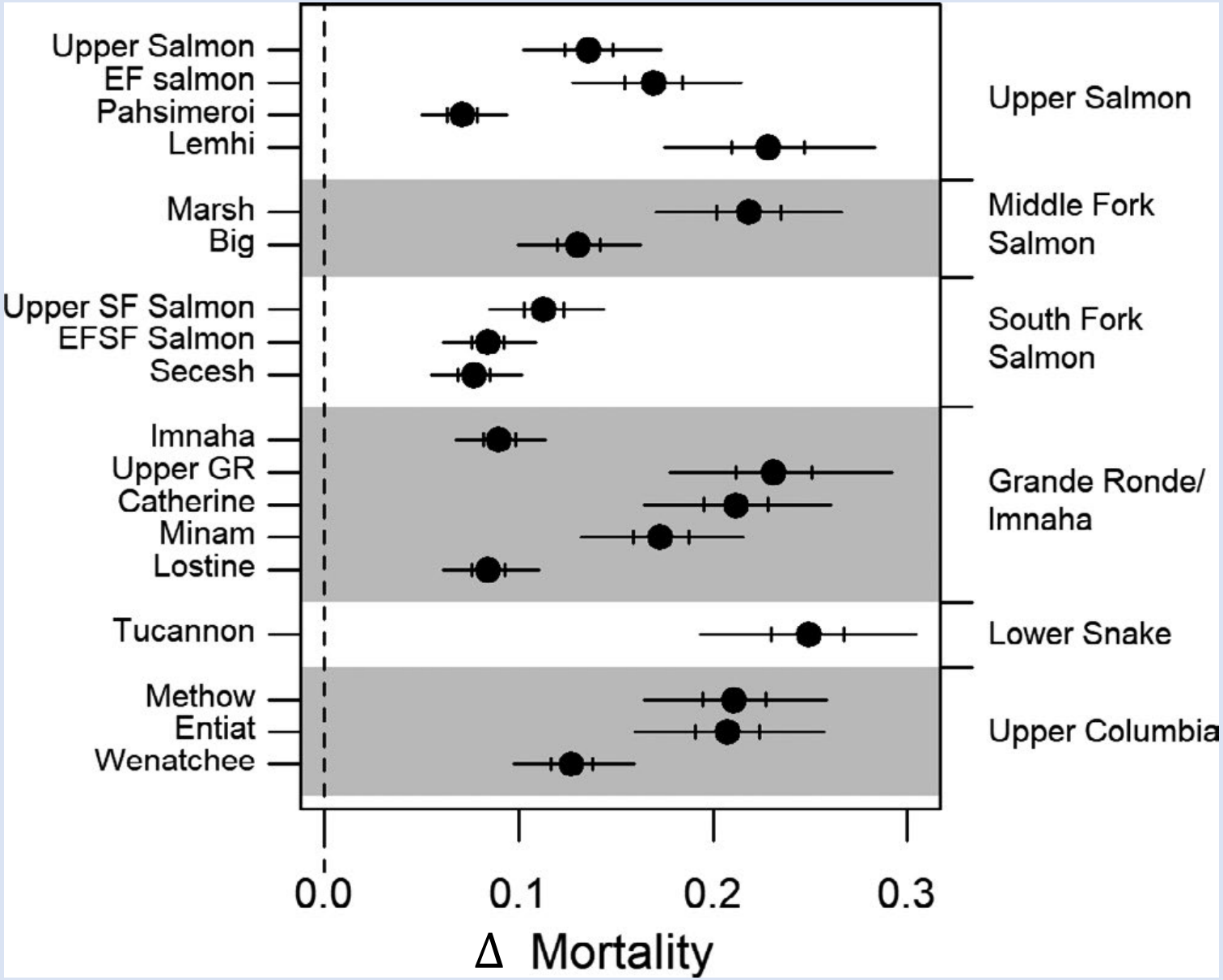
Results: Population-specific migration timing

- Considerable diversity among populations
  - Diversity within Major Population Groups



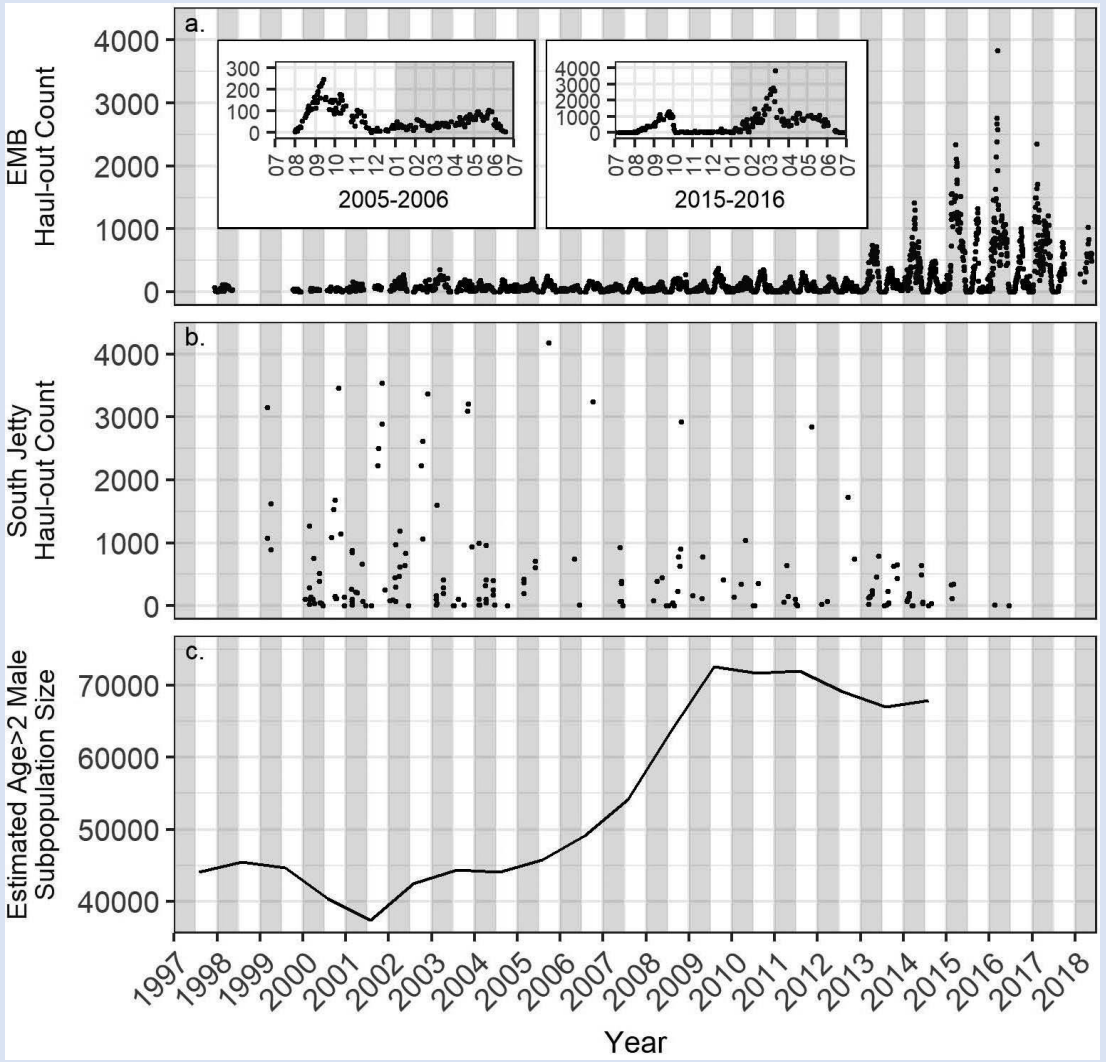
Results: Population specific change in mortality

- 9 earliest-arriving populations experienced an additional ~20% mortality in 2013-2015
- 9 latest-arriving populations experienced an additional ~10% mortality



Discussion

- Increased spring sea lion counts after 2012 were associated with increased Chinook salmon mortality
  - Appears to have greatest impact on early migrating populations
    - Unless travel times of earlier populations were faster
- Increased mortality may increase extinction risk, especially for early-migrating populations



Brown et al. 2020, Northwest Naturalist

Discussion

- Loss of early-migrating fish could reduce stability and adaptive capacity of Evolutionarily Significant Units
- Hatchery populations also affected
  - Many migrate early
- Future sea lions counts…TBD

Photo credit: R. Stansell, ACOE

Discussion

- Increased removal of California and Steller sea lions was recently authorized under the Endangered Salmon Predation Prevention Act
- Continued monitoring is needed to determine both sea lion and salmon responses to management

Photo credit: B. Wright, ODFW

Photo credit: S. Jeffries, WDFW

Thank you!

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RESEARCH ARTICLE

Estimating population-specific predation effects on Chinook salmon via data integration

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