Density-dependent marine survival of hatchery-origin Chinook salmon may be associated with pink salmon

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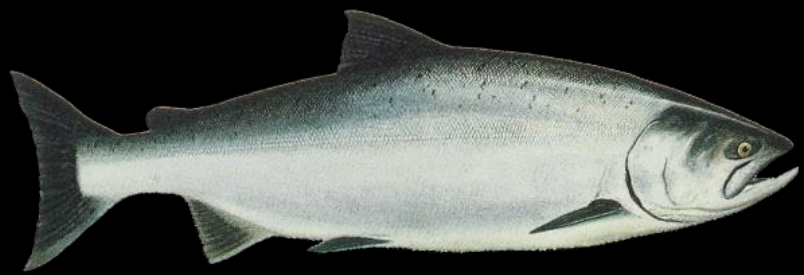


Challenges in the Salish Sea

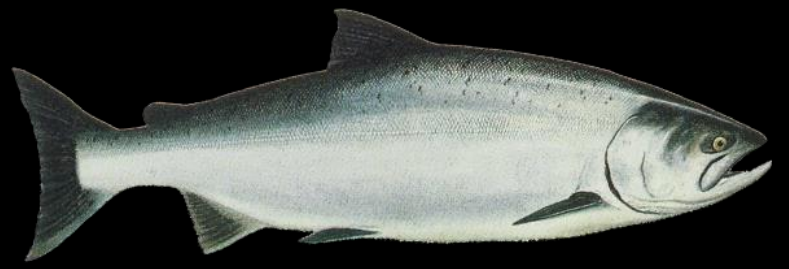
- Chinook salmon are crucial prey of endangered southern resident orcas; increased releases of hatchery Chinook salmon proposed to support whales
- When more hatchery Chinook juveniles are released, do more survive in the ocean to return to feed orcas?
- Consider ecosystem-based management


AP Photo/Elaine Thompson

Research question

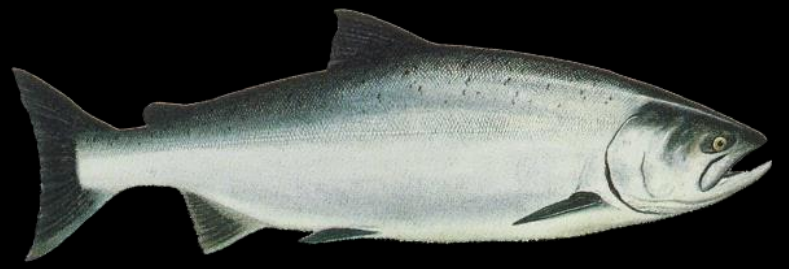
- When more hatchery Chinook salmon have been released, have more hatchery Chinook salmon survived their migration in the ocean and returned as adults?

Initial analysis



- Develop a model to predict Chinook marine survival based on:
  - hatchery Chinook juvenile release numbers
  - year
  - region
  - emigrating juvenile pink salmon presence
  - harbor seal abundance

Initial analysis



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- Consider presence of emigrating juvenile pink salmon

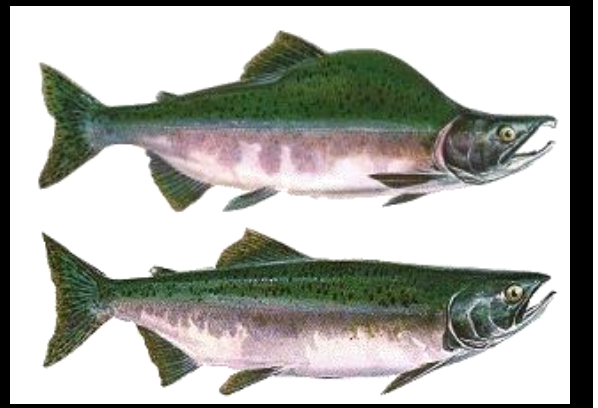
→ Evaluate hatchery Chinook survival rates vs. release numbers and juvenile pink salmon presence

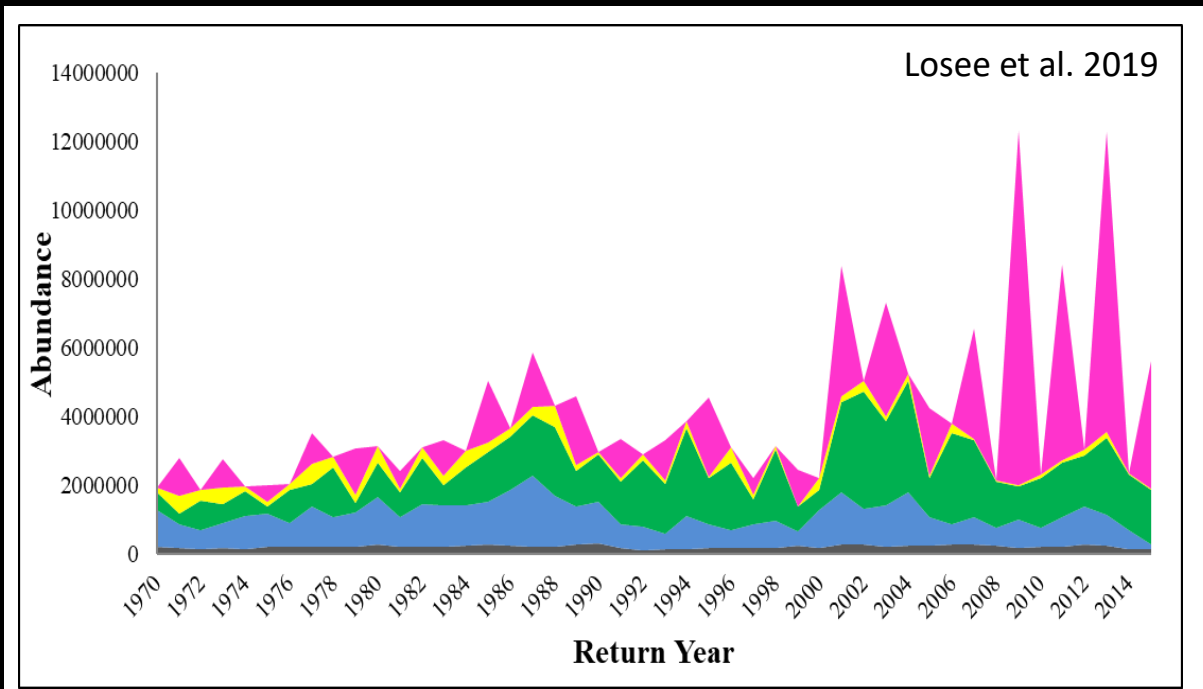
Pink salmon

- 2-year life cycle (1 year in ocean)
- Locations often have predominantly even- or odd-year spawners; more odd-year pink spawners throughout the Pacific Rim
- Have dominated adult abundance and biomass of all salmon in North Pacific Ocean since 1990 (Ruggerone and Irvine 2018)
- Numerous studies have documented: pink salmon alter growth and survival of other salmon, potentially through prey availability (Shiomoto et al. 1997, Batten et al. 2018, Kaga et al. 2013, Springer et al. 2018)

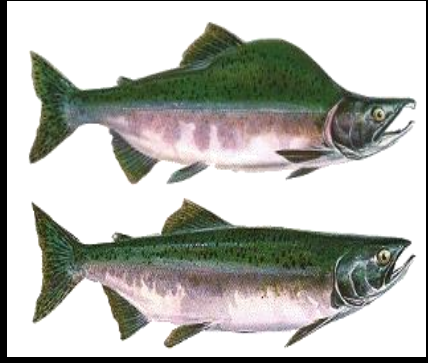
Pink salmon in the Salish Sea

- Have become dominant salmonid species
- Most pinks are wild; very few hatchery releases
- Almost all spawn in odd years, so juveniles outmigrate in even years





Pink salmon in the Salish Sea



- Density-dependent interactions examined previously (Ruggerone and Goetz 2004, Ruggerone et al. 2019, Claiborne et al. 2020):

1) lower juvenile Chinook growth rates and survival in their first ocean year when many juvenile pink salmon are present

2) when juvenile Chinook salmon emigration cohorts experienced above-average growth, lower numbers of emigrating juvenile pink salmon

- Mechanism not fully understood: direct vs. indirect (Wells et al. 2017, Holt and Bonsall 2017, Rhodes et al. 2017)

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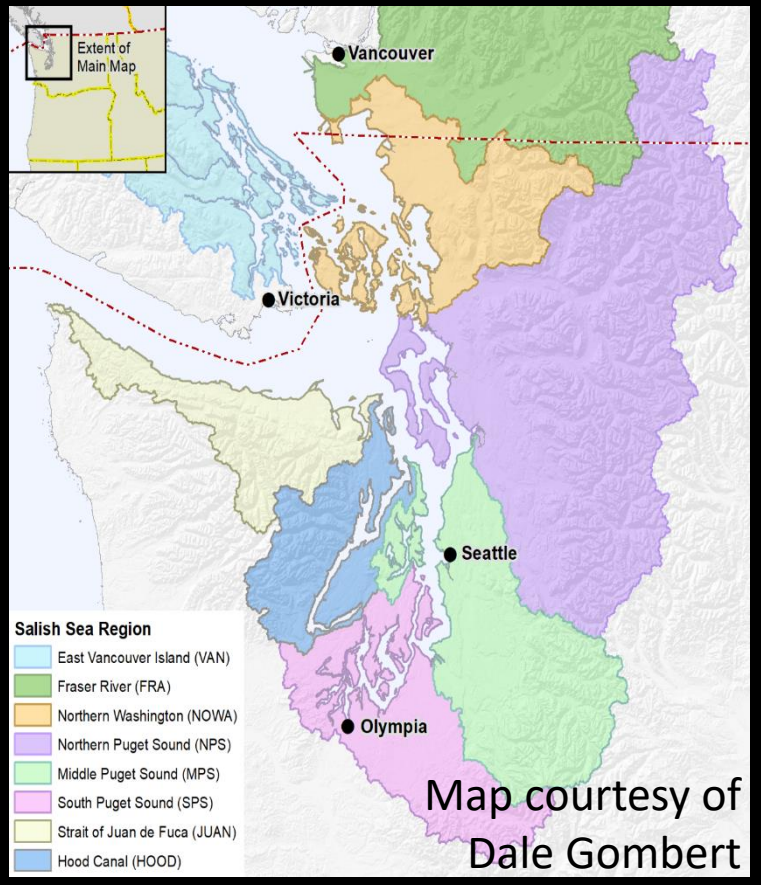
Data utilized

1. Number of Chinook salmon juveniles released from a given hatchery
2. Survival in first year in ocean
3. Pink salmon presence/absence

- 33 stocks released into 8 regions of Puget Sound, Strait of Georgia, Strait of Juan de Fuca
  - Ocean entry years 1983-2012



Map courtesy of Dale Gombert

Analysis—Bayesian hierarchical regression models


Photo by Morgan Bond

- Best-fit model to predict Chinook marine survival rate included indicator variables:
  - hatchery juvenile release numbers
  - juvenile pink salmon presence (even vs. odd year)
  - interaction term between hatchery release numbers and juvenile pink salmon presence

Interaction between presence of juvenile pink salmon and juvenile hatchery Chinook release numbers was significant

- **Higher** Chinook marine survival when more hatchery fish released *when juvenile pink salmon were **absent***
- **Lower** Chinook marine survival when more hatchery fish released *when juvenile pink salmon were **present***

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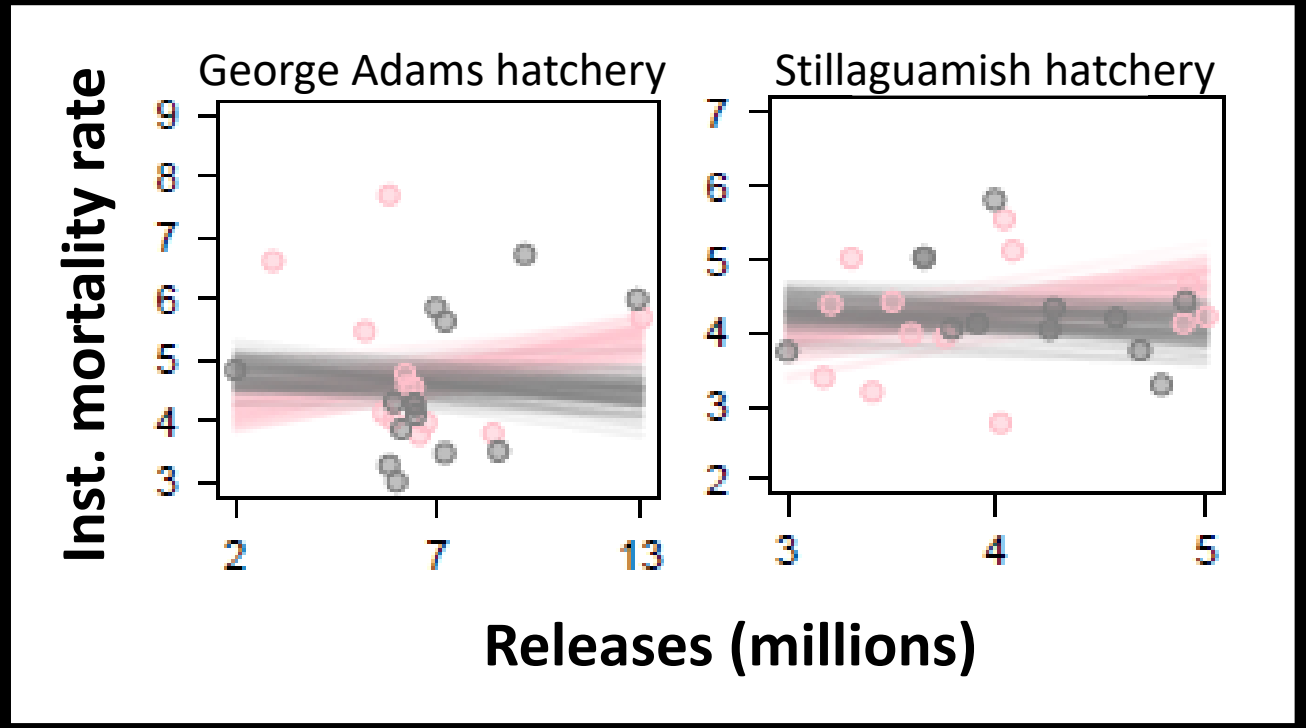
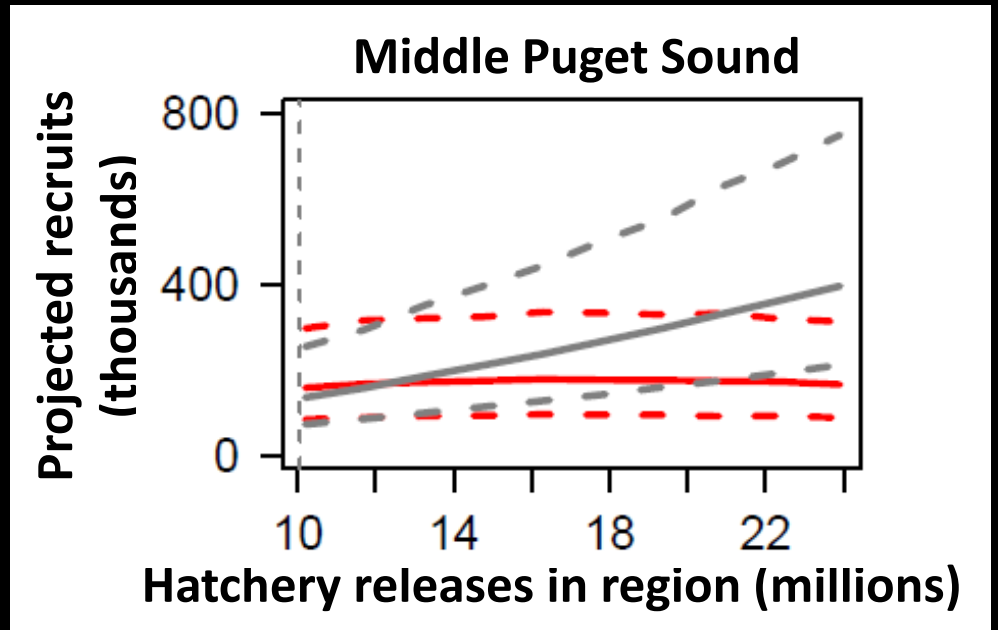
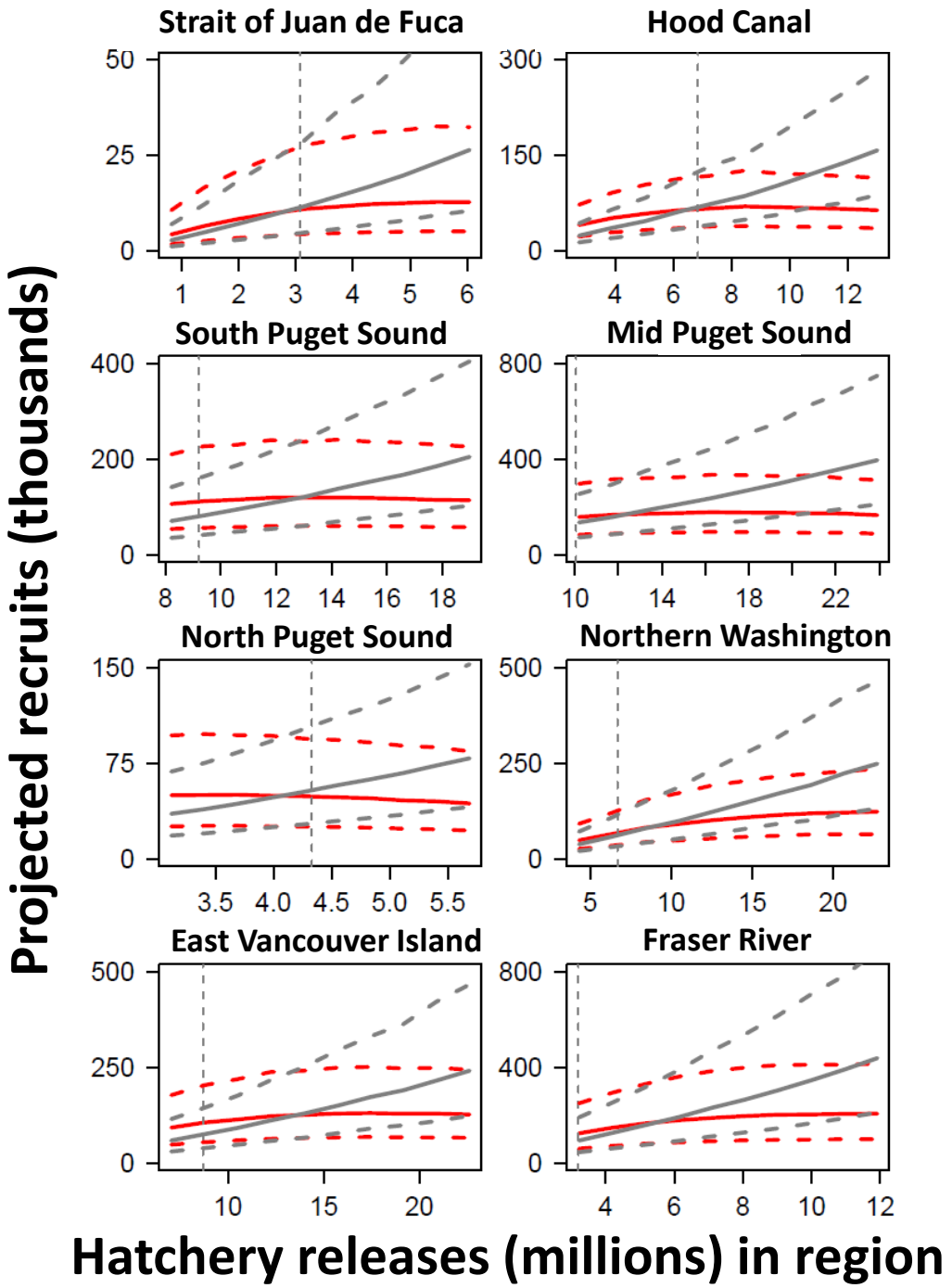


Hatchery Chinook releases vs. projected *numbers* of Chinook in pink vs. non-pink outmigration years

- In non-pink (odd-numbered) emigration years, increases in hatchery Chinook production associated with linear increases in recruits
- In pink years, increases in Chinook hatchery production associated with leveling off of numbers of "recruits," suggesting density-dependent survival




Strait of Juan de Fuca
Hood Canal
South Puget Sound
Mid Puget Sound
North Puget Sound
Northern Washington
East Vancouver Island
Fraser River
Projected recruits (thousands)
Hatchery releases (millions) in region

Key finding, some remaining questions

- Salish Sea hatchery Chinook experienced density-dependent marine survival when they emigrated in pink salmon emigration years (even-numbered) since early 1980s. Density-dependent marine survival not observed in non-pink emigrating years.

- How and where are juvenile pink and Chinook salmon interacting in Salish Sea?
- What is mechanism for Chinook salmon density-dependent mortality during first year in Salish Sea associated with presence of many juvenile pink salmon?
- What about outside of the Salish Sea? What about for coho salmon?

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Questions?