First generation fitness consequences of hatchery-origin strays in Prince William Sound

Erika M. King*, Kyle R. Shedd, Kristen M. Gruenthal, Milo D. Adkison, Lorna I. Wilson, Bobby Hsu, Peter A.H. Westley, Samuel A. May, Alex Wertheimer, Peter S. Rand

AMSS 1/28/2026

Outline

1. AHRP background
2. Previous studies
3. F1 reproductive success
4. Hurdle model
5. Questions

Introduction

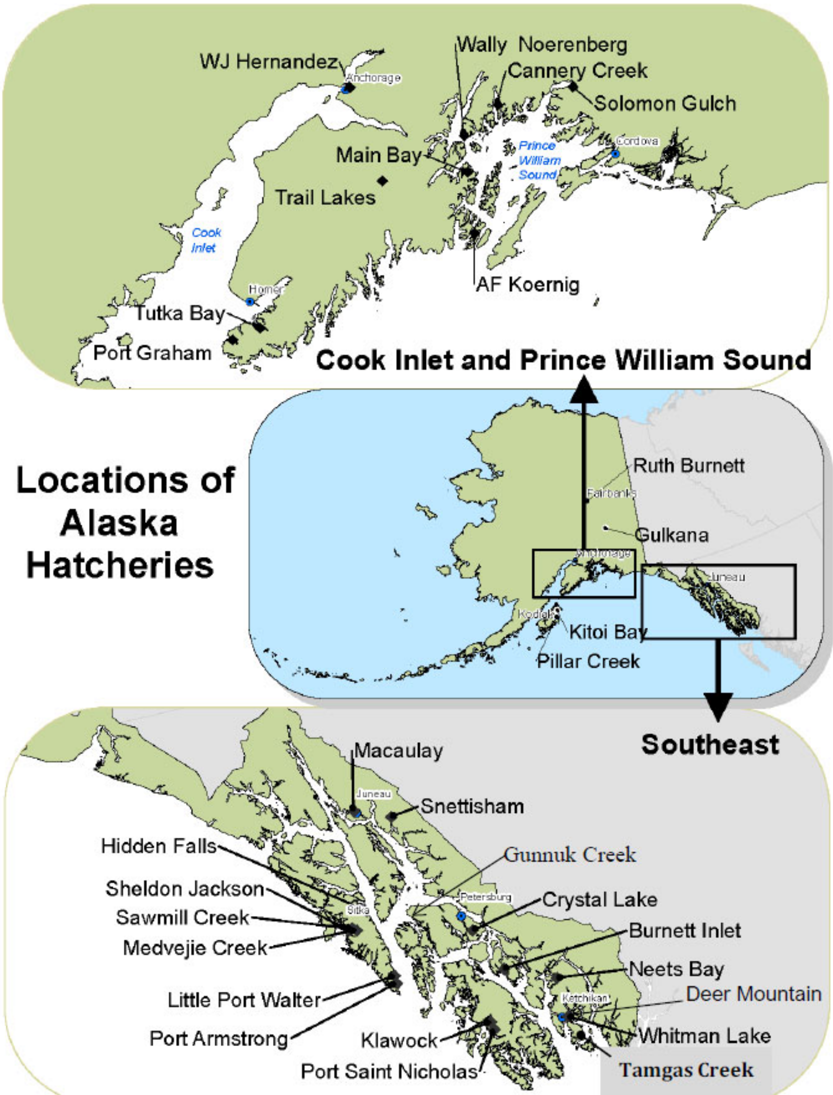
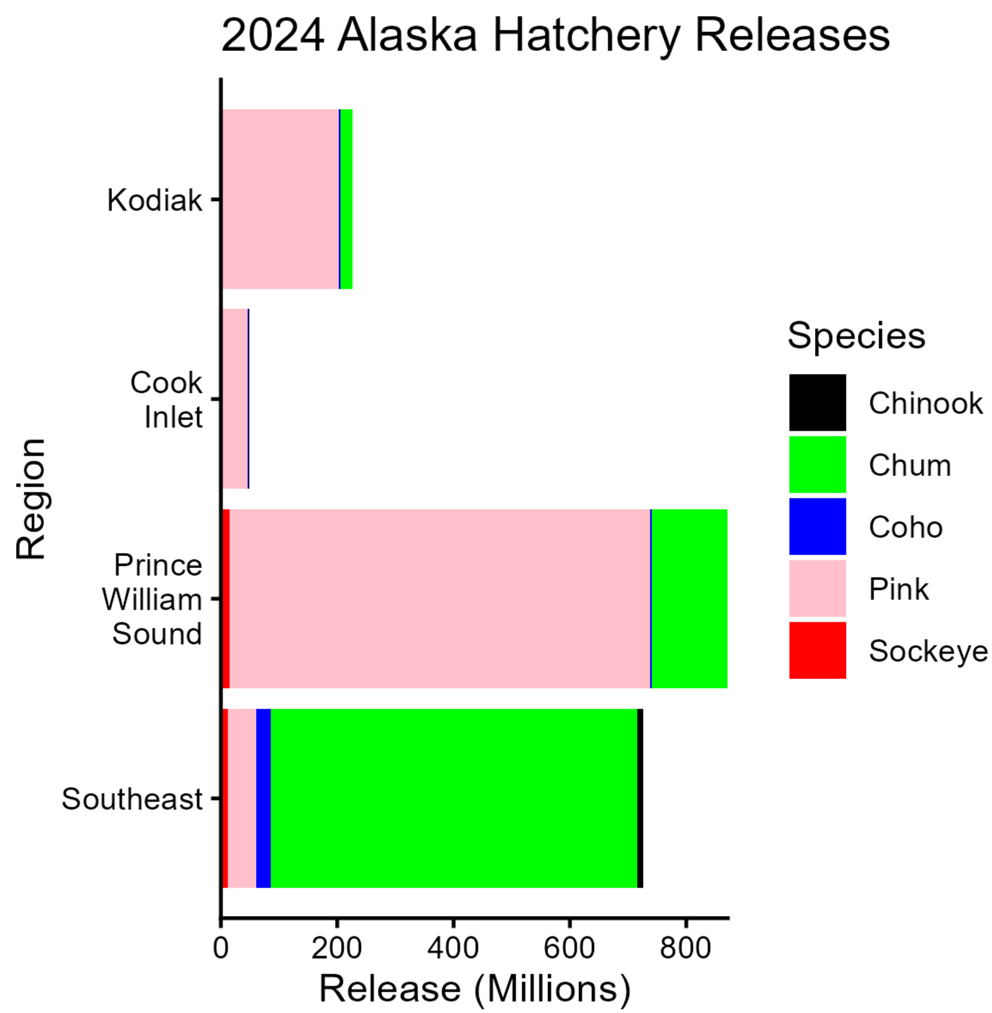
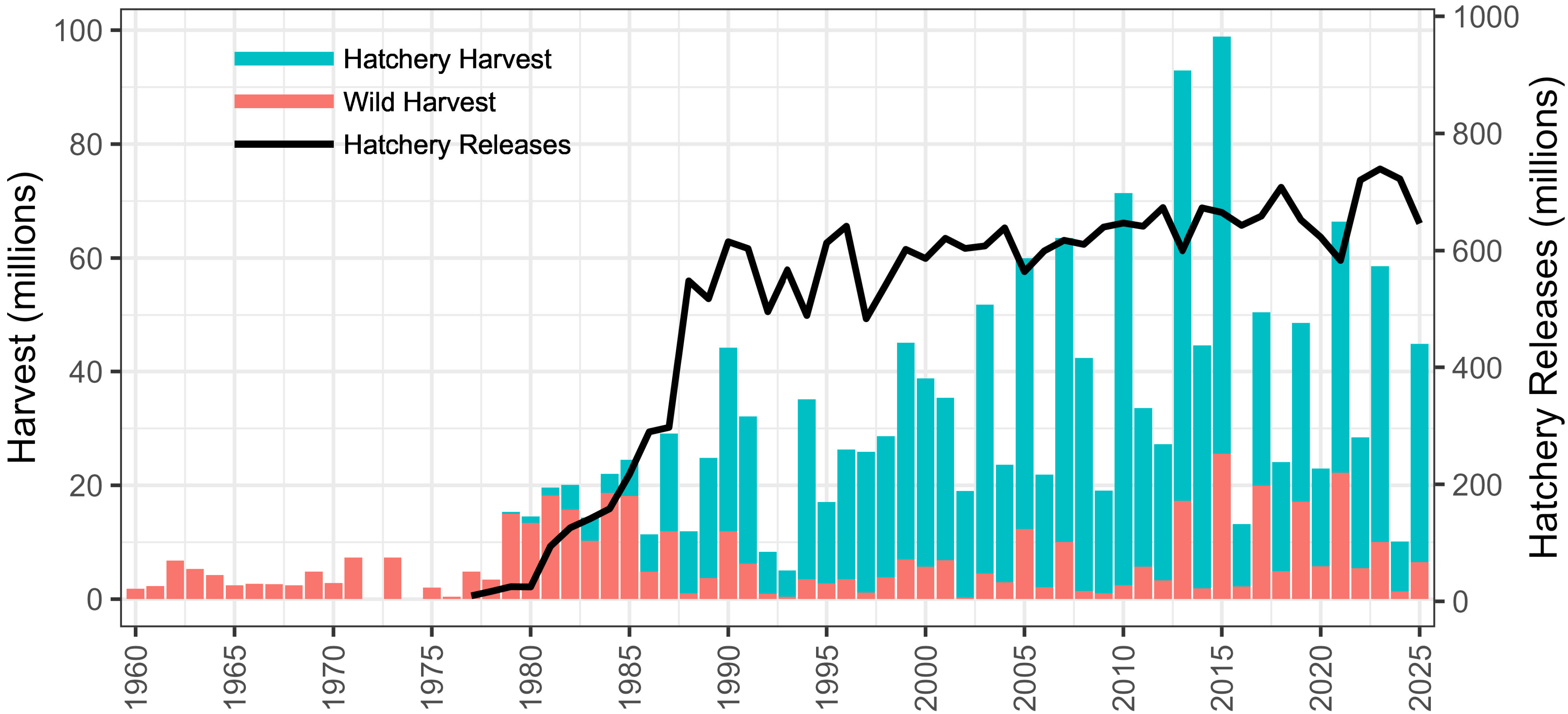


Figure 5 – Wilson 2025 ADF&G



Data from Table 4 – Wilson 2025 ADF&G

Prince William Sound Pink Salmon



Potential Hatchery Concerns – straying

- Ecological
- Genetic

Steelhead

Differential reproductive success of sympatric, naturally spawning hatchery and wild steelhead trout (*Oncorhynchus mykiss*) through the adult stage

Jennifer E. McLean, Paul Bentzen, and Thomas P. Quinn

MOLECULAR ECOLOGY

Reduced reproductive success of hatchery coho salmon in the wild: insights into most likely mechanisms

Genetic Effects of Captive Breeding Cause a Rapid, Cumulative Fitness Decline in the Wild

Hitoshi Araki, Becky Cooper, Michael S. Blouin

Effective population size of steelhead trout: influence of variance in reproductive success, hatchery programs, and genetic compensation between life-history forms

HITOSHI ARAKI, ROBIN S. WAPLES, WILLIAM R. ARDREN, BECKY COOPER and MICHAEL S. BLOUIN

biology letters

Conservation biology

Carry-over effect of captive breeding reduces reproductive fitness of wild-born descendants in the wild

Hitoshi Araki, Becky Cooper and Michael S. Blouin

Transactions of the American Fisheries Society

Diminished Reproductive Success of Steelhead from a Hatchery Supplementation Program (Little Sheep Creek, Imnaha Basin, Oregon)

Genetic adaptation to captivity can occur in a single generation

PNAS

Chinook

Use of Parentage Analysis to Determine Reproductive Success of Hatchery-Origin Spring Chinook Salmon Outplanted into Shitike Creek, Oregon

Factors influencing the relative fitness of hatchery and wild spring Chinook salmon (*Oncorhynchus tshawytscha*) in the Wenatchee River, Washington, USA

Kevin S. Williamson, Andrew R. Murdoch, Todd N. Pearsons, Eric J. Ward, and Michael J. Ford

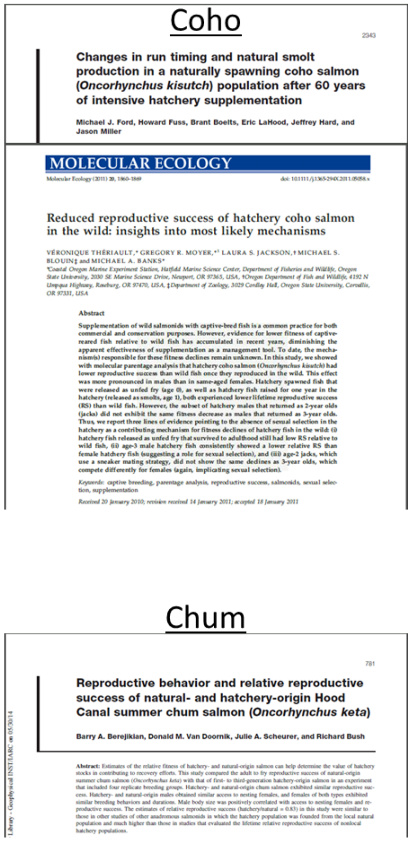
MOLECULAR ECOLOGY

Supportive breeding boosts natural population abundance with minimal negative impacts on fitness of a wild population of Chinook salmon

Evolutionary Applications

ORIGINAL ARTICLE

Reproductive success of captively bred and naturally spawned Chinook salmon colonizing newly accessible habitat



Coho

Changes in run timing and natural smolt production in a naturally spawning coho salmon (*Oncorhynchus kisutch*) population after 60 years of intensive hatchery supplementation

Michael J. Ford, Howard Fuss, Brant Boelts, Eric LaHood, Jeffrey Hard, and Jason Miller

MOLECULAR ECOLOGY

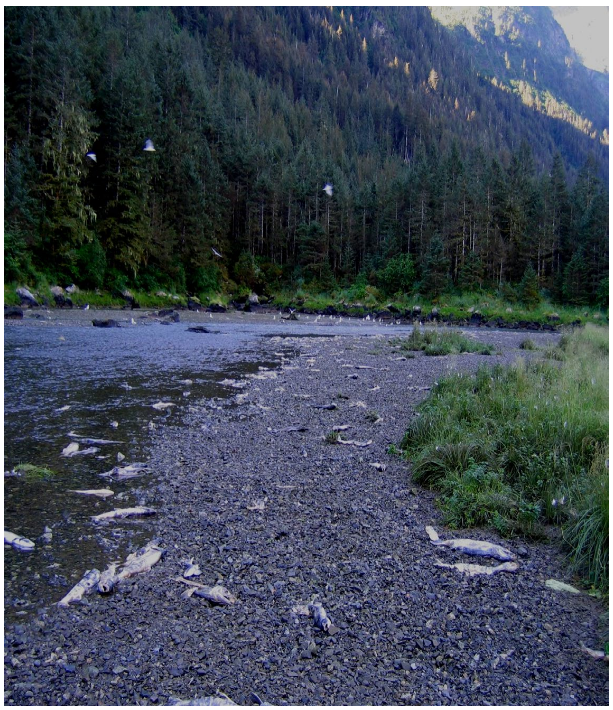
Reduced reproductive success of hatchery coho salmon in the wild: insights into most likely mechanisms

Chum

Reproductive behavior and relative reproductive success of natural- and hatchery-origin Hood Canal summer chum salmon (*Oncorhynchus keta*)

Barry A. Berejikian, Donald M. Van Doornik, Julie A. Scheurer, and Richard Bush

Alaska Hatchery Research Project (AHRP)



1) What is the genetic stock structure of pink and chum in PWS and SEAK?

2) What is the extent and annual variability of straying?

3) What is the impact on fitness (*productivity*) of natural pink and chum stocks?

Methods

Measuring Reproductive Success

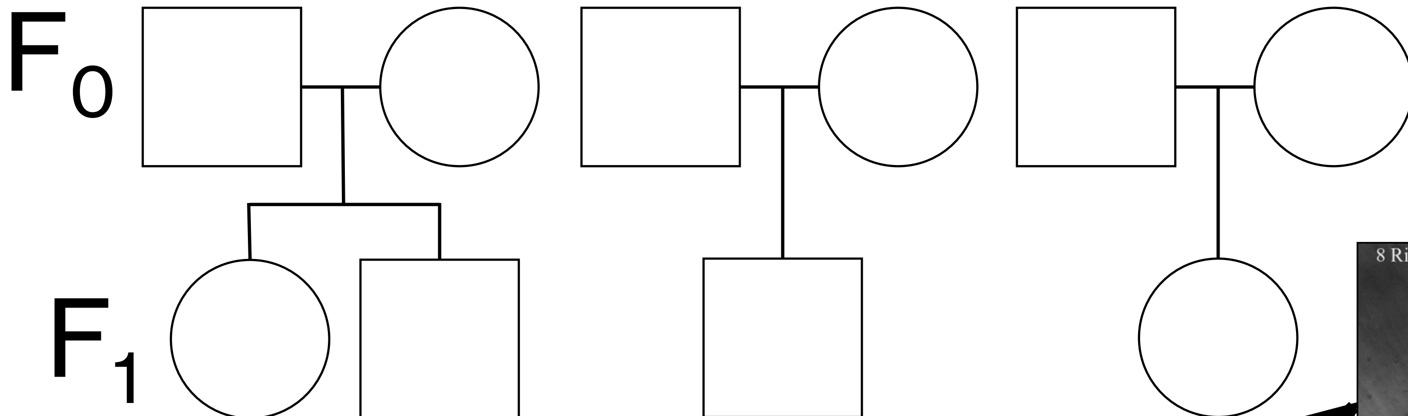
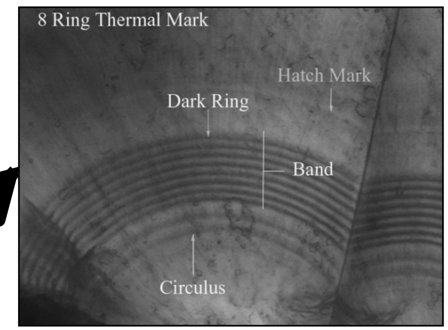


Photo credit: David Janka, PWSSC



Hatchery-origin

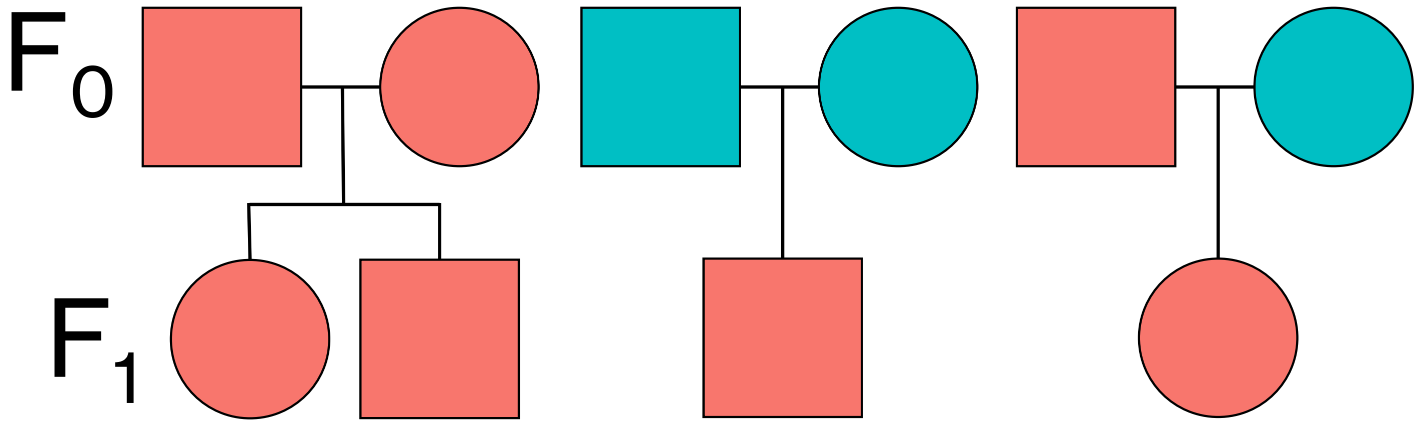
No thermal mark

Natural-origin

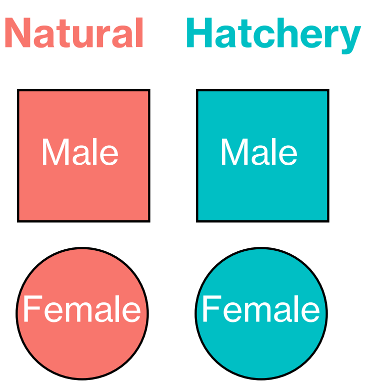
Male

Female

Measuring Reproductive Success



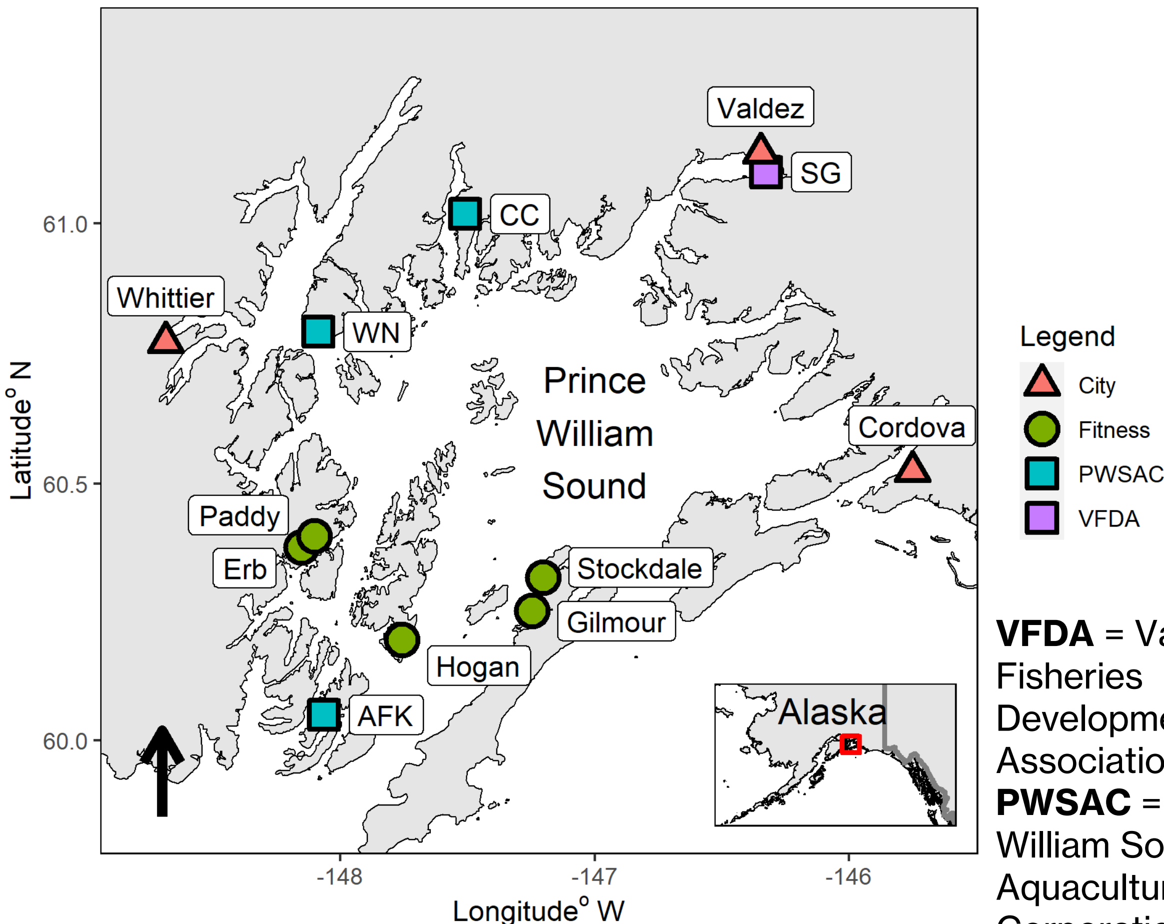
$$RS_{N\ Female} = 2 \qquad RS_{H\ Female} = 1$$



Relative Reproductive Success (RRS)

$$RRS = \frac{1}{2} = 0.5$$

AHRP Streams in PWS



VFDA = Valdez Fisheries Development Association
PWSAC = Prince William Sound Aquaculture Corporation

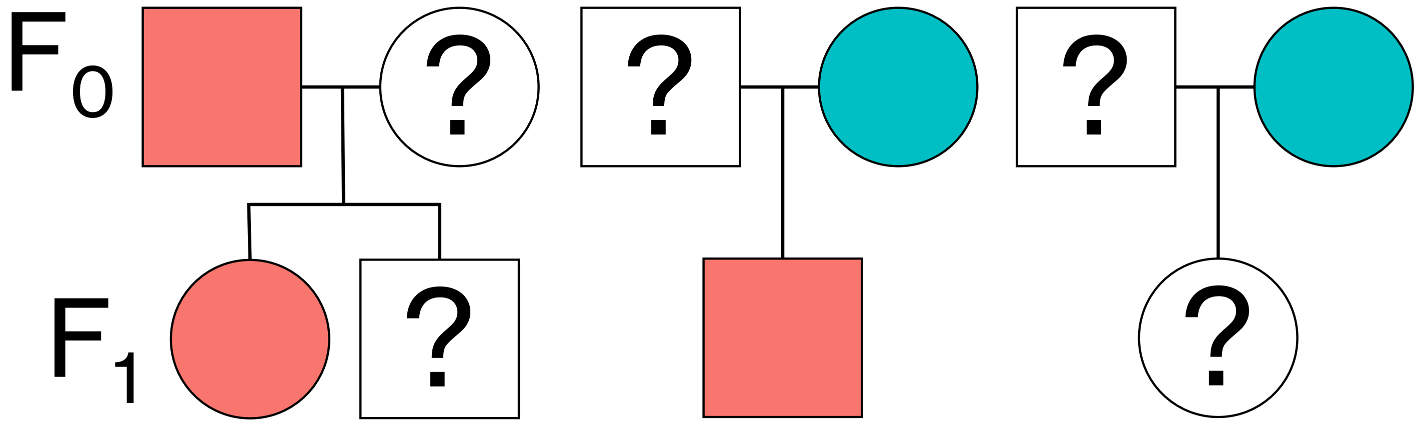
Methods: Field Sampling

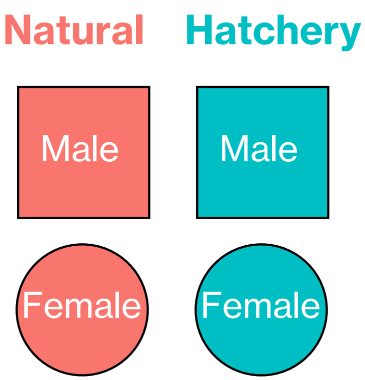
Intensive carcass sampling

- Body length
- Date
- Location
  - Intertidal
  - Upstream
- Otolith
- Tissue

Photo credit: Brad von Wichman (PWSSC)

Measuring Reproductive Success





Relative Reproductive Success (RRS)

$$\mathbf{RRS} = \frac{\overline{RS}_{Hatchery}}{\overline{RS}_{Natural}}$$

Phase I & II

Phase I (Shedd 2022)

- Two streams
- One odd (2013) and even (2014) brood year

Phase II

- Three additional streams
- Four additional brood years (2015-2018)
- Explored stream:covariate interactions
- AIC model-selection

Modeling Approach

- Most individuals produced 0 offspring:
  - Negative binomial GLM w/ logit link
  - Hurdle model
- Separate models for even and odd lineages
- Variables
  - Origin
  - Sex
  - Length
  - Sample date (proxy for run timing)
  - Spawning location

Zero

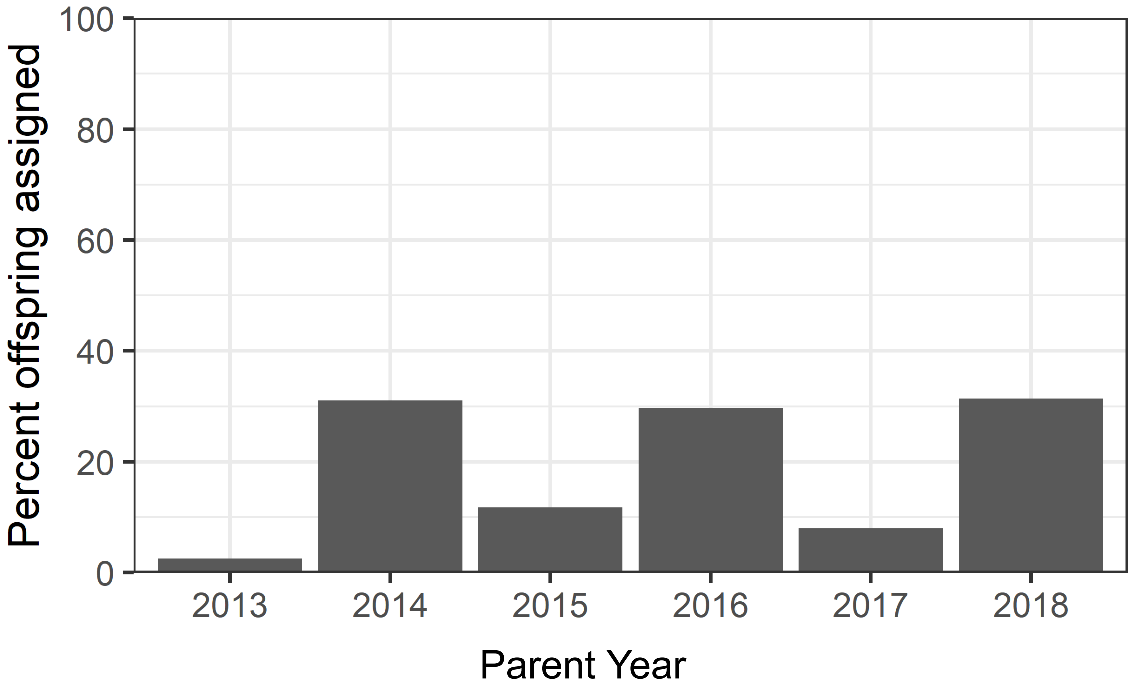
probability of not producing offspring

Conditional

expected number of offspring given success

Disclaimer

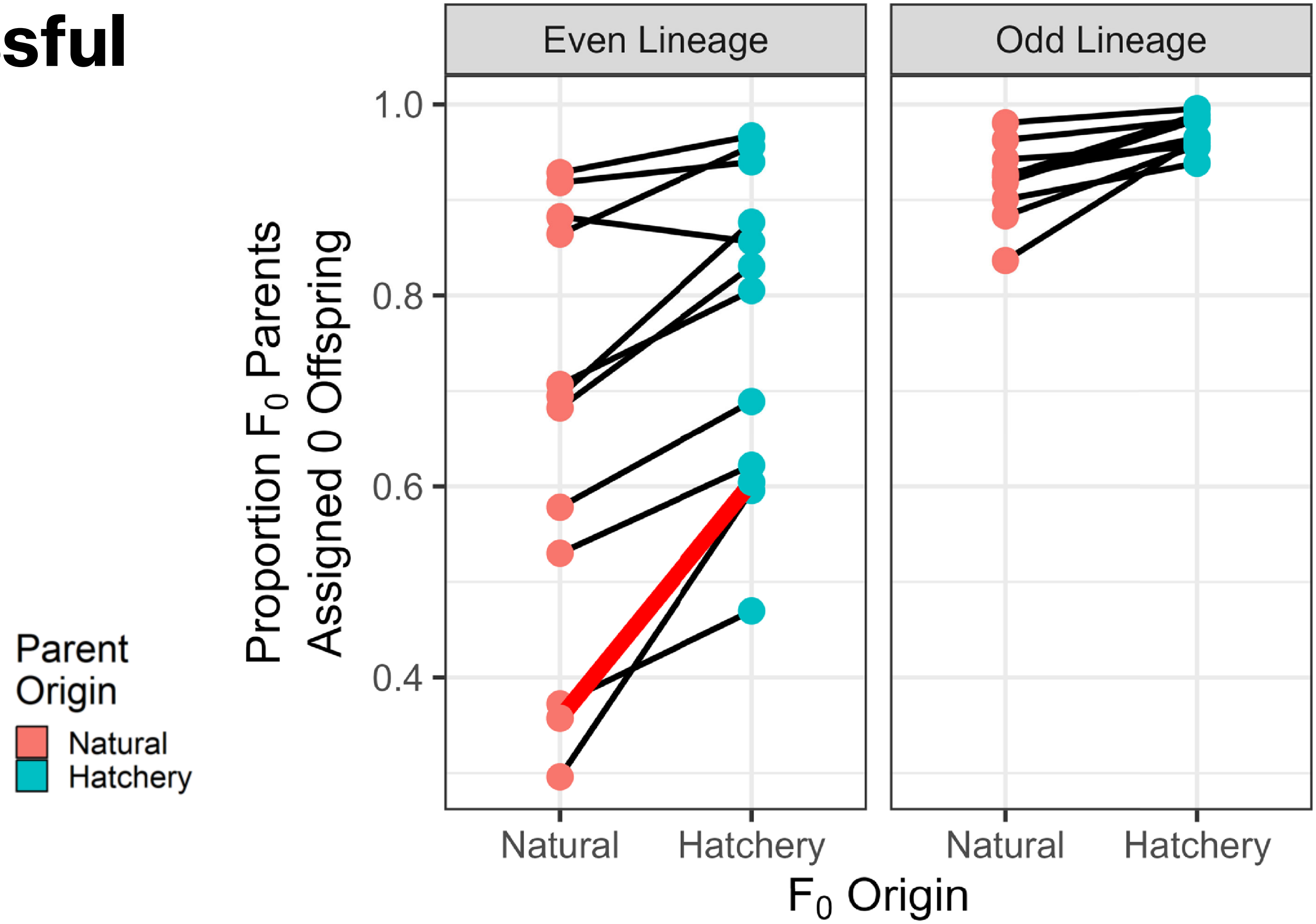
Number of offspring produced ~ assigned



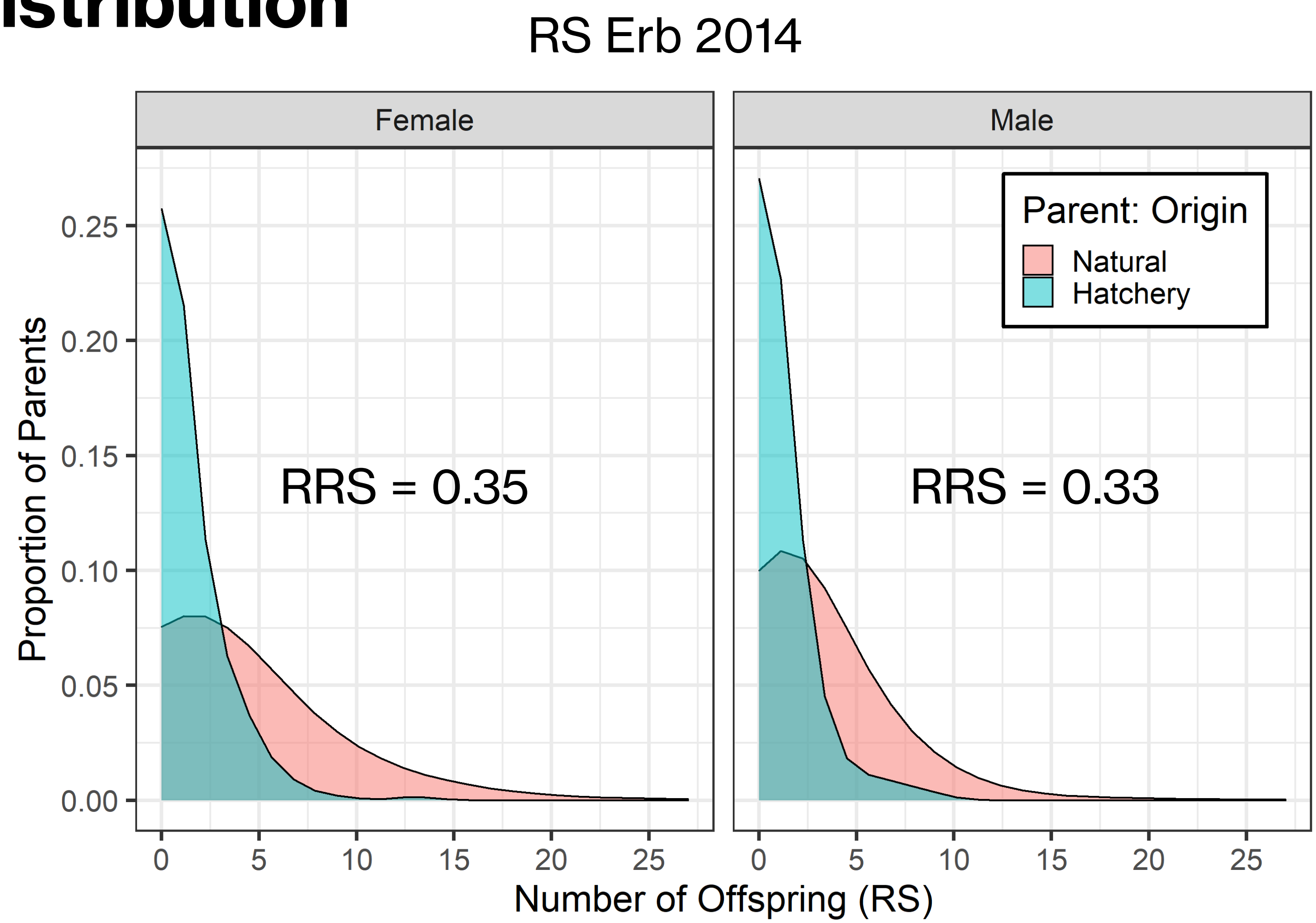
Percent of offspring assigned to parents:
13% odd lineage
40% even lineage

Results

Unsuccessful Parents

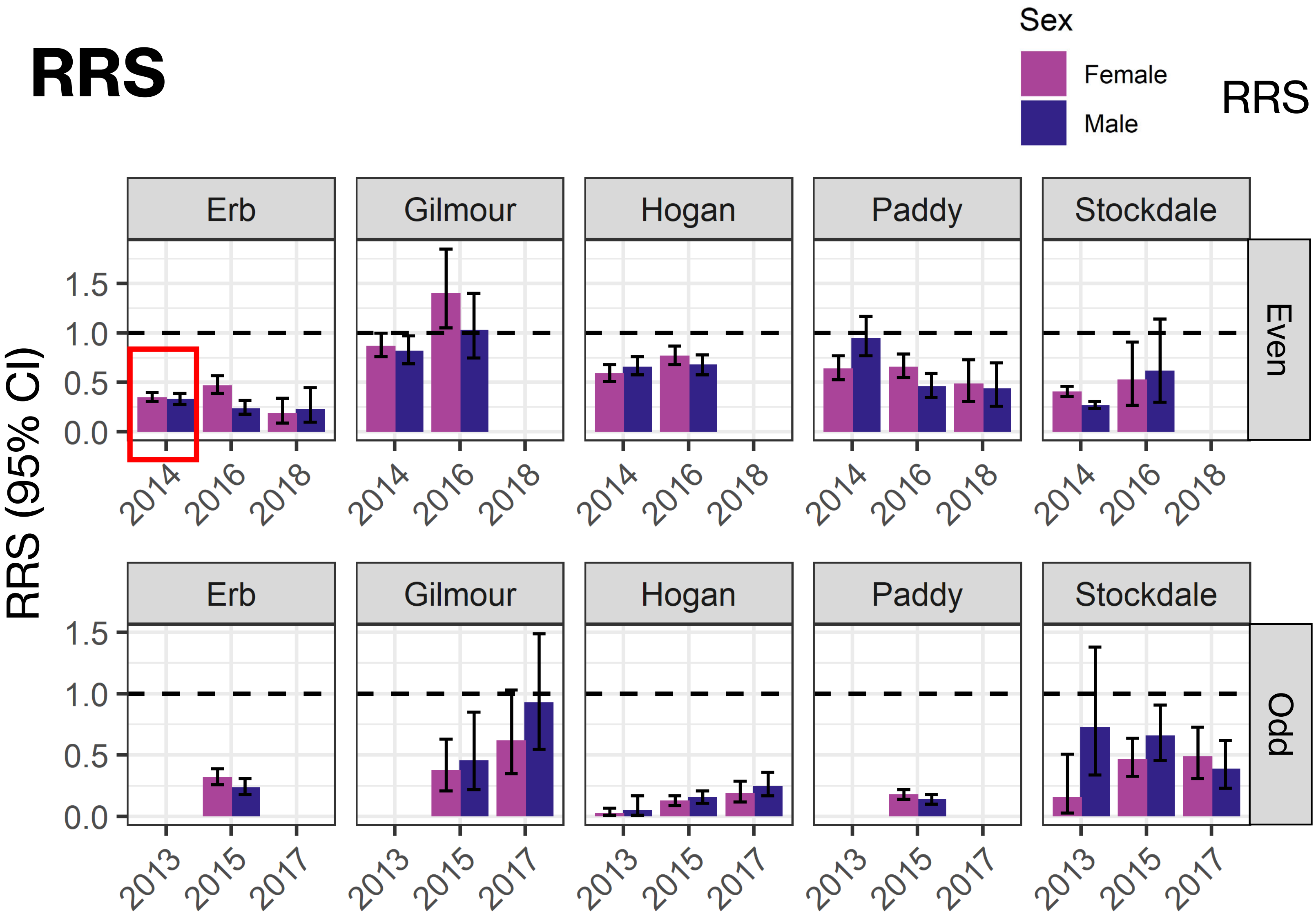


RS Distribution



RRS

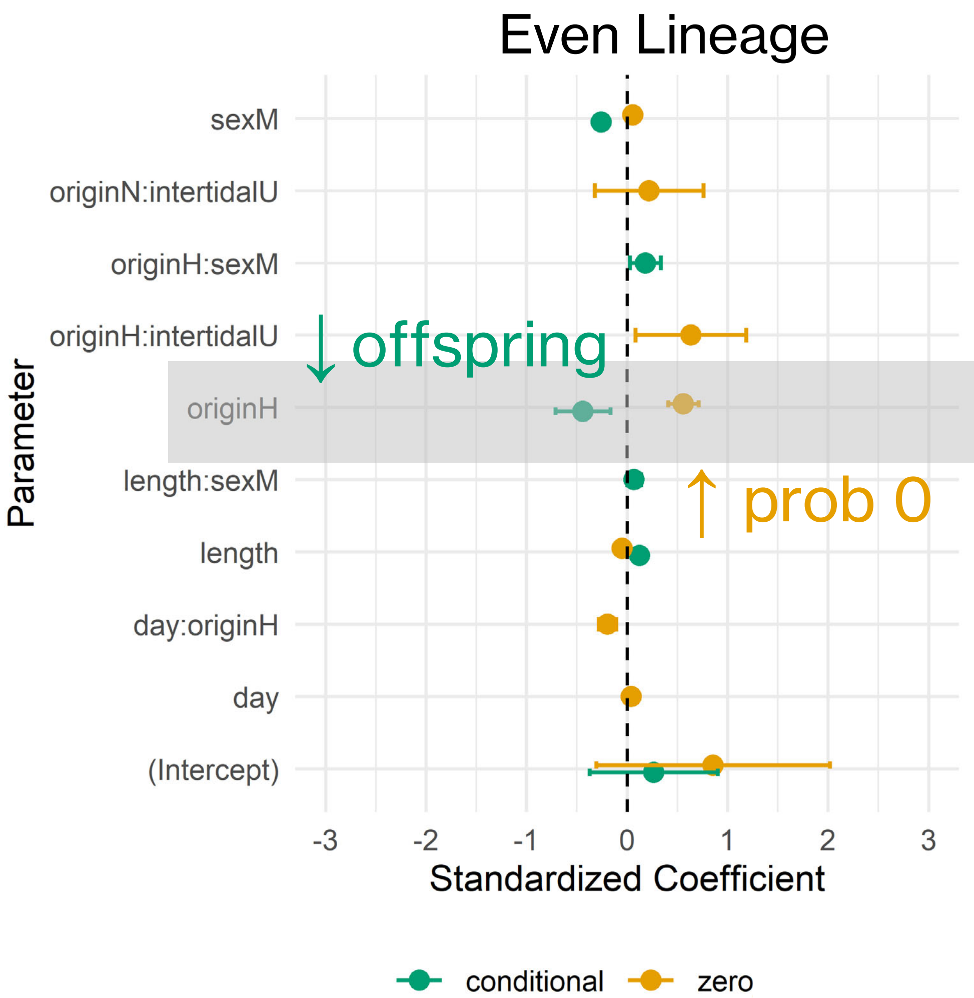
$$RRS = \frac{\overline{RS}_{Hatchery}}{\overline{RS}_{Natural}}$$

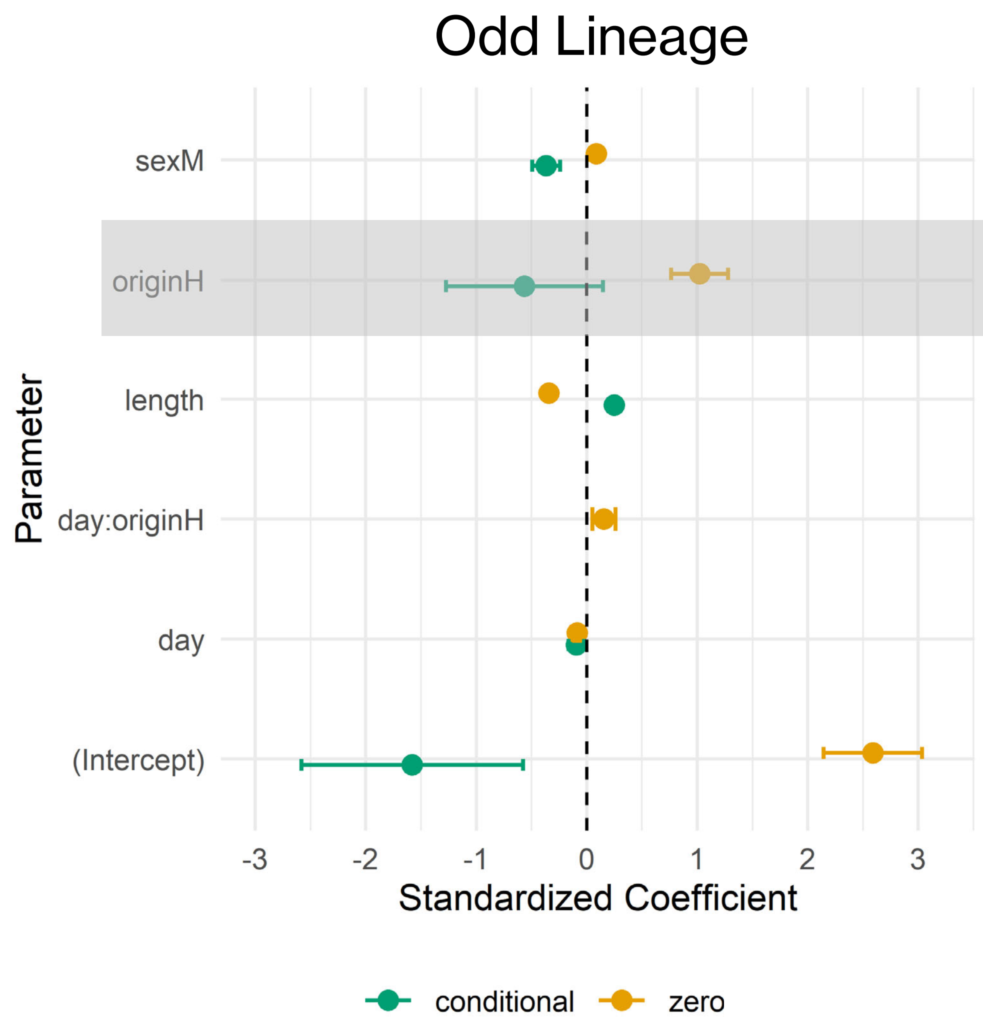


Average
0.481

Average
0.279

Hurdle Models: coefficients





Hurdle Models: origin

		Estimate	exp(Estimate)		Std. Error	Pr(>|z|)
Even lineage	Zero	1.30	3.66		0.19	4.21e-12 ***
	Conditional	-0.44	0.65 0.78	**Female** **Male**	0.14	0.002 **
Odd lineage	Zero	0.51	1.66		0.23	0.027 *
	Conditional	-0.56	0.57		0.36	0.121

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Conclusion

Conclusion

- Hatchery fitness < Natural fitness
- Similar to previous results
- Origin influences:
  - Probability of zero offspring
  - Number of offspring produced
- Potential mechanisms for ↓ fitness
  - Run timing ~ stream temperature

Photo credit: Kharis Schrage PWSSC

Potential Mechanisms

Phenotype–environment mismatch

- Most hatchery strays (late run) vs study streams (early run)
- Stream temperature selects development rate/emergence timing
- Offspring from late-run strays emerge at suboptimal time for survival

Other

- Other hatchery ancestry or founding “stock” effects
- Domestication selection
- Epigenetic modifications

Diving deeper

Second-generation offspring of hatchery strays show reduced fitness, but the decline is much less severe than in the first generation, particularly in the odd lineage.

Relative Reproductive Success

	$F_0 \rightarrow F_1$	$F_1 \rightarrow F_2$
Even lineage	0.481	0.727
Odd lineage	0.279	0.848

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- Alaska Hatchery Research Program
  - State of Alaska
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- Prince William Sound Science Center
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- University of Washington - Seeb Lab
- ADF&G Gene Conservation Laboratory

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Questions?

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Reduced relative fitness in hatchery-origin Pink Salmon in two streams in Prince William Sound, Alaska

Kyle R. Shedd, Emily A. Lescak, Christopher Habicht, E. Eric Knudsen, Tyler H. Dann, Heather A. Hoyt, Daniel J. Prince, William D. Templin

Marine and Coastal Fisheries
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Hatchery-Origin Stray Rates and Total Run Characteristics for Pink Salmon and Chum Salmon Returning to Prince William Sound, Alaska, in 2013–2015

E. Eric Knudsen, Peter S. Rand, Kristen B. Gorman, David R. Bernard, William D. Templin

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North American Journal of Fisheries Management

Article | Open Access

Proportions of Hatchery Fish in Escapements of Summer-Run Chum Salmon in Southeast Alaska, 2013–2015

Ronald Josephson, Alex Wertheimer, David Gaudet, E. Eric Knudsen, Benjamin Adams, David R. Bernard, Steven C. Heinl, Andrew W. Piston, William D. Templin

Salmon hatchery strays can demographically boost wild populations at the cost of diversity: quantitative genetic modelling of Alaska pink salmon

Samuel A. May; Kyle R. Shedd; Kristen M. Gruenthal; Jeffrey J. Hard; William D. Templin; Charles D. Waters; Milo D. Adkison; Eric J. Ward; Christopher Habicht; Lorna I. Wilson; Alex C. Wertheimer; Peter A. H. Westley

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Hatcheries Research
Overview

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In 1971, the State of Alaska initiated its modern salmon fishery enhancement

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