

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

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AMSS 1/28/2026



Outline

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



Introduction

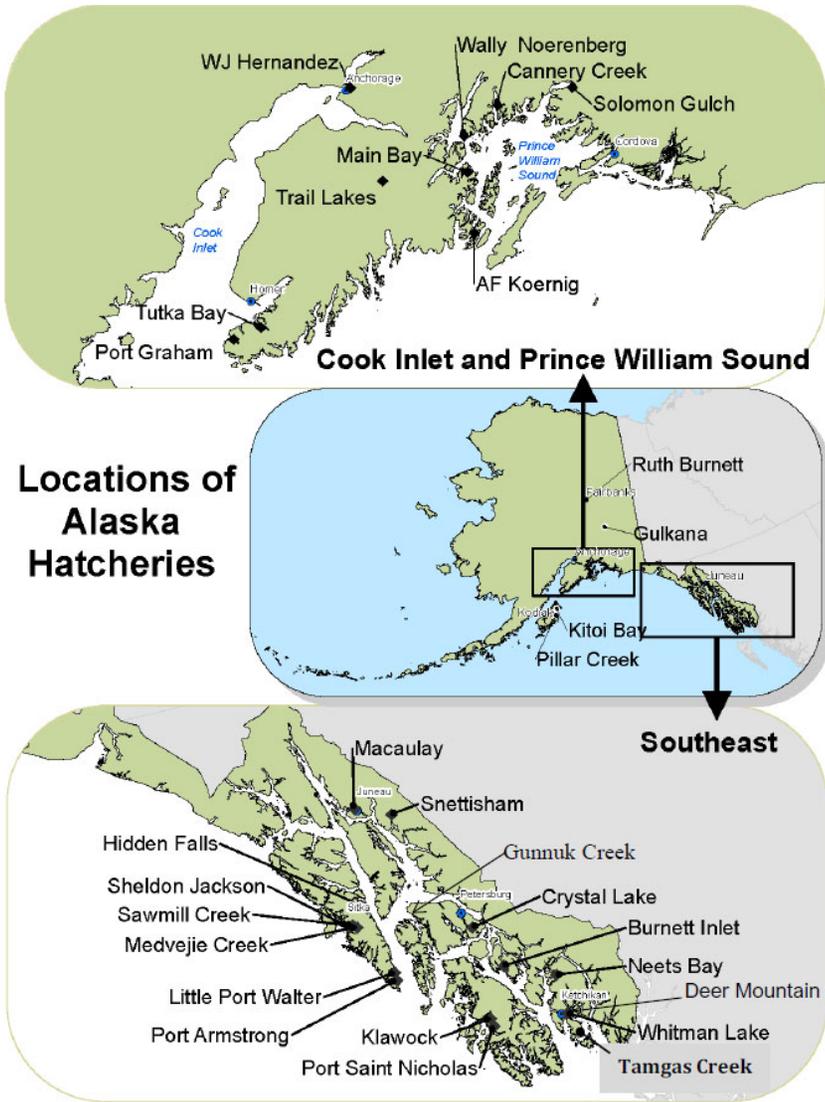
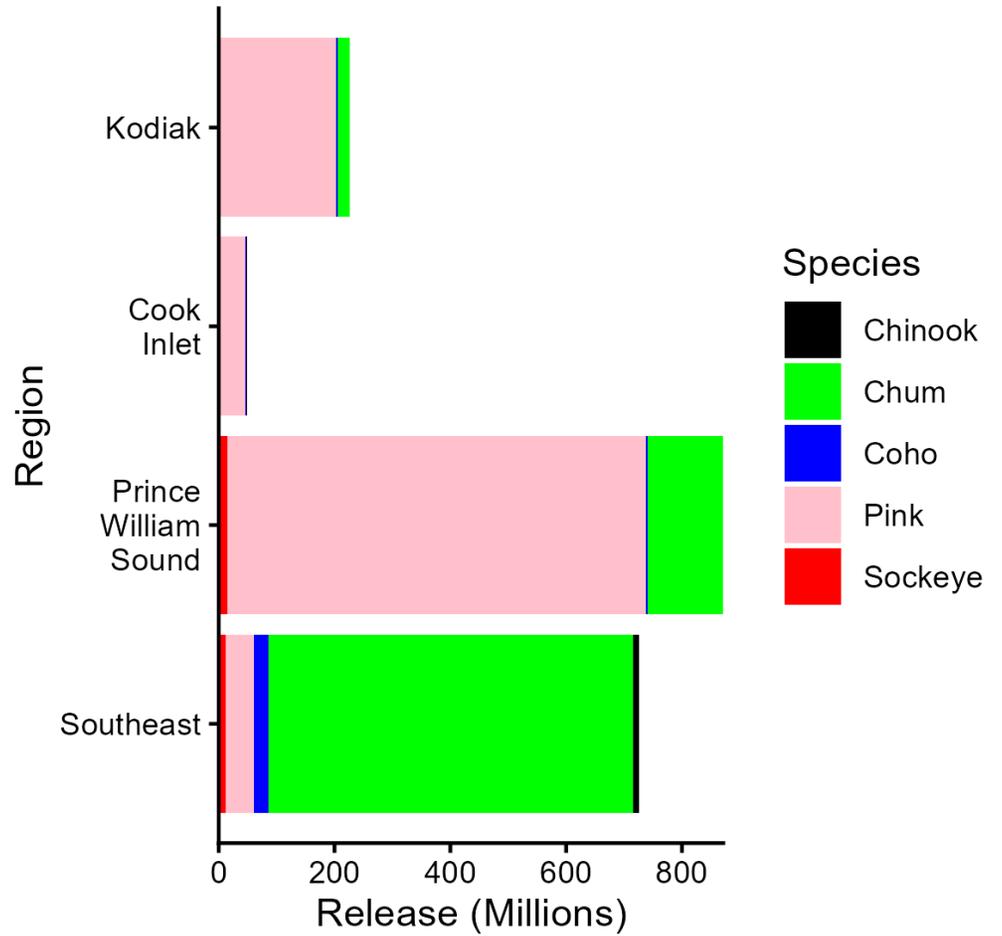


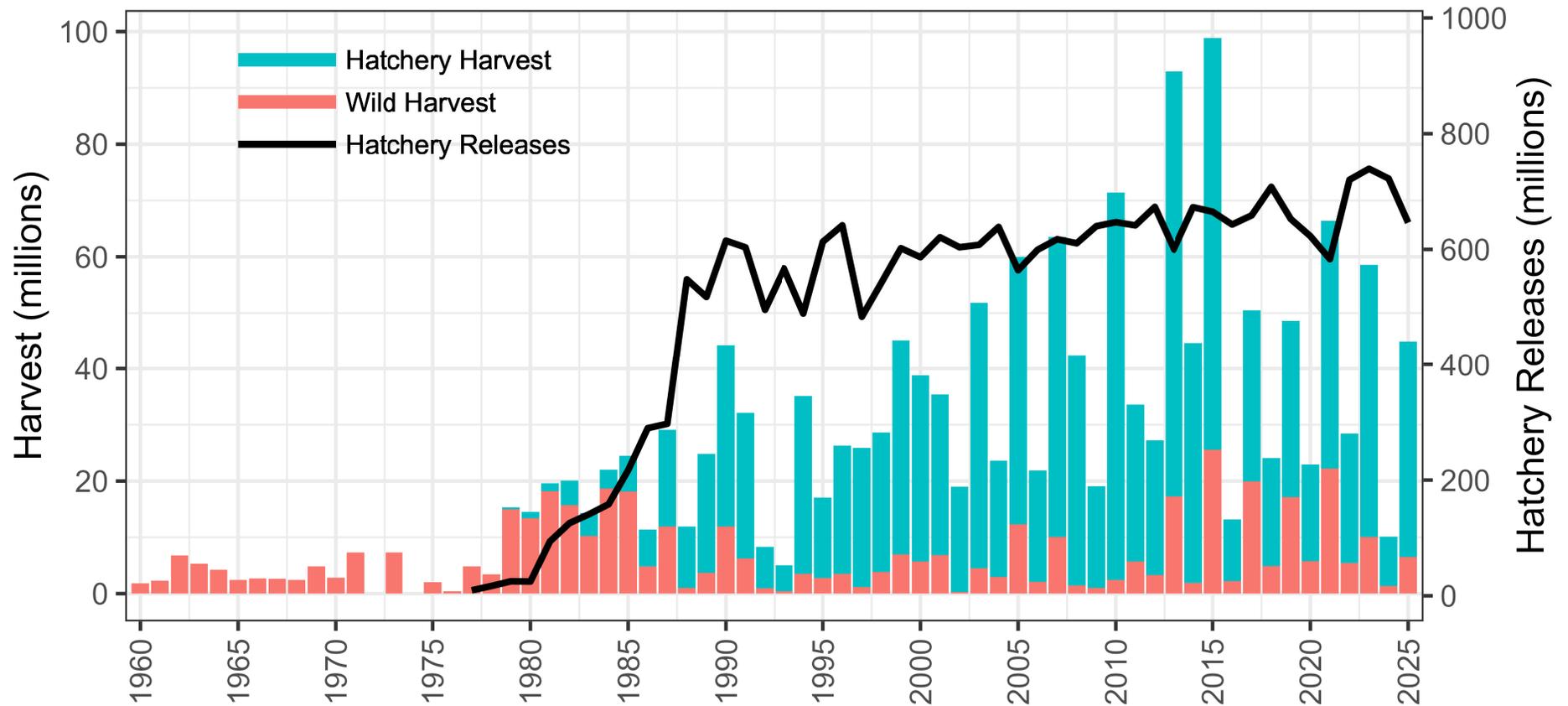
Figure 5 – Wilson 2025 ADF&G

2024 Alaska Hatchery Releases



Data from Table 4 – Wilson 2025 ADF&G

Prince William Sound Pink Salmon



Potential Hatchery Concerns – straying

- Ecological
- Genetic

Steelhead 433

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
Molecular Biology (2011) 36, 433–443 doi: 10.1111/j.1365-3113.2011.00584.x

Reduced reproductive success of hatchery coho salmon in the wild: insights into most likely mechanisms
VERONIQUE THERIAULT,* GREGORY R. MOYER,¹ LAURA S. JACKSON,* MICHAEL S. ROUNQ,* and MICHAEL A. BASKS²

Genetic Effects of Captive Breeding Cause a Rapid, Cumulative Fitness Decline in the Wild
Hiroshi Araki,¹ 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
HETOSHI AKARI,* ROBIN S. WAFERS,* WILLIAM R. ARDEN,* BECKY COOPER,* and MICHAEL S. BLOUIN¹

biology letters
with captive-bred organisms (supplementations) are not clear yet... their negative effects of captive breeding are especially relevant for substantial species because of the worldwide decline of native subnational populations and the large scale of hatchery programs to compensate for those losses. First, there is now evidence that adding captive-bred organisms has boosted the lifetime productivity of wild subnational populations (Foster 2008). Secondly, supplementation of declining wild populations entails risks such as disease introduction, increased competition for resources, and genetic changes in the supplemented population (Oppliger & Dohle 2010). The genetic risk results because artificial environments can select for reproductive individuals that are maladapted to the natural environment (Bridwell '86 wild'). For example, artificially-bred

Transactions of the American Fisheries Society
Diminished Reproductive Success of Steelhead from a Hatchery Supplementation Program (Little Sheep Creek, Imnaha Basin, Oregon)
Ernest A. Bertozzi¹, Richard W. Carmichael², Michael W. Fleisher³, Eric J. Ward⁴ & Paul Hagan⁵

Genetic adaptation to captivity can occur in a single generation
Mark A. Crease¹, Matthew C. Moore¹, Rod A. Fensholt¹ and Michael S. Blouin²

PNAS

Chinook [Article]

Use of Parentage Analysis to Determine Reproductive Success of Hatchery-Origin Spring Chinook Salmon Outplanted into Shilike Creek, Oregon
JASON BAUMSTEKER¹
U.S. Fish and Wildlife Service, 1440 Abernathy Creek Road, Longview, Washington 98022, USA

DAVID M. HANSEN² and DOUGLAS E. OLSON³
U.S. Fish and Wildlife Service, Columbia River Fisheries Program (OES-122) Southeast Coastal Center, Suite 300, Vancouver, Washington 98665, USA

ROBERT SPATHEBEL² and GARY FIEBIGER³
Columbia River Fisheries Program, Department of Natural Resources, Warm Springs, Oregon 97131, USA

WILLIAM R. ARDEN⁴
U.S. Fish and Wildlife Service, Laboratory Fish Pathology Center, 1440 Abernathy Creek Road, Longview, Washington 98022, USA

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. Pearson, Eric J. Ward, and Michael J. Ford

MOLECULAR ECOLOGY
Molecular Biology (2012) 37, 1636–1650 doi: 10.1111/j.1365-3113.2011.00584.x

Supportive breeding boosts natural population abundance with minimal negative impacts on fitness of a wild population of Chinook salmon
MAUREEN A. HESS,* CRAIG D. RARE,¹ JASON L. VOGEL,¹ JEFF J. STEPHENSON,* DOUG D. NELSON² and SHAWN R. NARUM³

Evolutionary Applications
Evolutionary Applications (2012) 5, 1651–1661

ORIGINAL ARTICLE
Reproductive success of captively bred and naturally spawned Chinook salmon colonizing newly accessible habitat
Joseph H. Anderson,^{1,2} Paul L. Fausch,¹ William L. Attala³ and Thomas P. Quinn¹

Keywords
captive breeding, natural selection, population, genetic drift, genetic diversity, genetic structure, genetic differentiation, genetic adaptation

Abstract
Captively reared animals can provide an immediate demographic boost in reintroduction programs, but may also reduce the fitness of colonizing populations. Conservation of a fish passage for Elly at Lambing Division Dam on the Collier River, WA, USA, provided a unique opportunity to explore this risk-off. We thoroughly sampled adult Chinook salmon (*Oncorhynchus tshawytscha*) at the onset of colonisation (2005–2007), constructed a pedigree from genotypes at 10 microsatellite loci, and calculated reproductive success (RS) in the total number of surviving adult offspring. Hatchery males were consistently but not significantly less productive than naturally spawned males (range in relative RS 0.25–2.05), but the pattern for females varied between years. The one male not newly bred toward male offspring, inclusion of the hatchery males increased the risk of genetic drift and with RS between 0.5 and 1.0. Measurements of natural selection indicated that larger salmon had higher RS than smaller fish. Fish that strayed early in the spawning period tended to have more production than later fish, although in some years, RS was maximised at intermediate dates. Our results underscore the importance of natural and natural selection to preserving adaptive

Coho 2540

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, Brent Boeltis, Eric LaHood, Jeffrey Hard, and Jason Miller

MOLECULAR ECOLOGY
Molecular Biology (2011) 36, 444–456 doi: 10.1111/j.1365-3113.2011.00584.x

Reduced reproductive success of hatchery coho salmon in the wild: insights into most likely mechanisms
VERONIQUE THERIAULT,* GREGORY R. MOYER,¹ LAURA S. JACKSON,* MICHAEL S. ROUNQ,* and MICHAEL A. BASKS²

Abstract
Supplementation of wild salmonids with captive-bred fish is a common practice for both commercial and conservation programs. However, evidence for lower fitness of captive-reared fish relative to wild fish has accumulated in recent years, diminishing the apparent effectiveness of supplementation as a management tool. To date, the molecular mechanisms responsible for these fitness declines remain unknown. In this study, we showed with molecular parentage analysis that hatchery coho salmon (*Oncorhynchus kisutch*) had lower reproductive success than wild fish since they reproduced in the wild. This effect was more pronounced in males than in some aged females. Hatchery spawned fish that were released as adults by age 0, as well as hatchery fish raised for one year in the hatchery tank and as smolts, age 0, both experienced lower lifetime reproductive success (RS) than wild fish. However, the subset of hatchery males that returned as 2-year olds (aged) did not exhibit the same fitness decrease as males that returned as 1-year olds. Thus, we report three lines of evidence pointing to the absence of sexual selection in the hatchery as a contributing mechanism for fitness decline of hatchery fish in the wild: 1) hatchery fish released as adults fry that survived to adulthood still had low RS relative to wild fish; 2) aged male hatchery fish consistently showed a lower relative RS than female hatchery fish (suggesting a male for sexual selection), and 3) aged jacks, which use a male-like mating strategy, did not show the same decline as 2-year olds, which compete differently for females (ages, implying sexual selection).

Keywords
captive breeding, parentage analysis, reproductive success, natural selection, sexual selection, supplementation

Received 20 January 2010; revision received 16 November 2010; accepted 19 January 2011

Chum 781

Reproductive behavior and relative reproductive success of natural- and hatchery-origin Hood Canal salmon (*Oncorhynchus keta*)
Barry A. Bierlik, Donald M. Van Dornick, Julie A. Scherzer, and Richard Bush

Abstract
Estimates of the relative fitness of hatchery- and natural-origin salmon can help determine the value of hatchery stocks in contributing to recovery efforts. This study compared the ability for reproductive success of natural-origin Hood Canal salmon (age 0) with that of first-generation hatchery-origin salmon in an experimentally controlled environment. In this study, we used a pedigree-based approach to estimate relative reproductive success. Hatchery- and natural-origin males obtained similar success in mating females, and females of both types exhibited similar breeding behavior and duration. Male body size was positively correlated with success in mating females and reproductive success. The estimate of relative reproductive success (hatchery:natural = 0.85) in this study was similar to those in other studies of other salmonids in which the hatchery population was founded from the local natural population and much higher than those in studies that evaluated the lifetime relative reproductive success of natural hatchery populations.

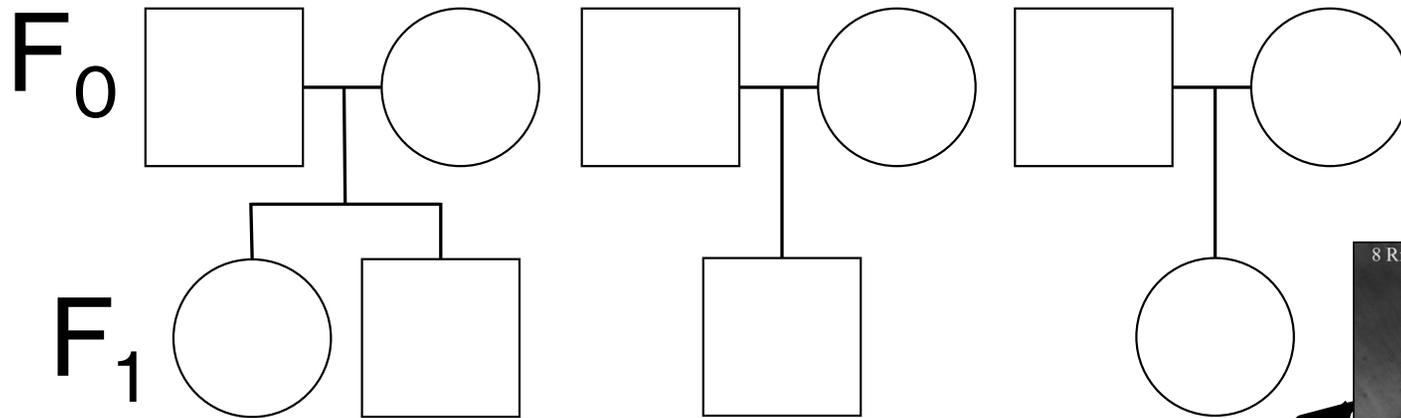
Alaska Hatchery Research Project (AHRP)



- 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

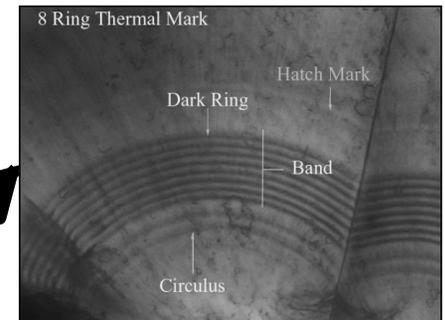


Male

Female



Photo credit: David Janka, PWSSC

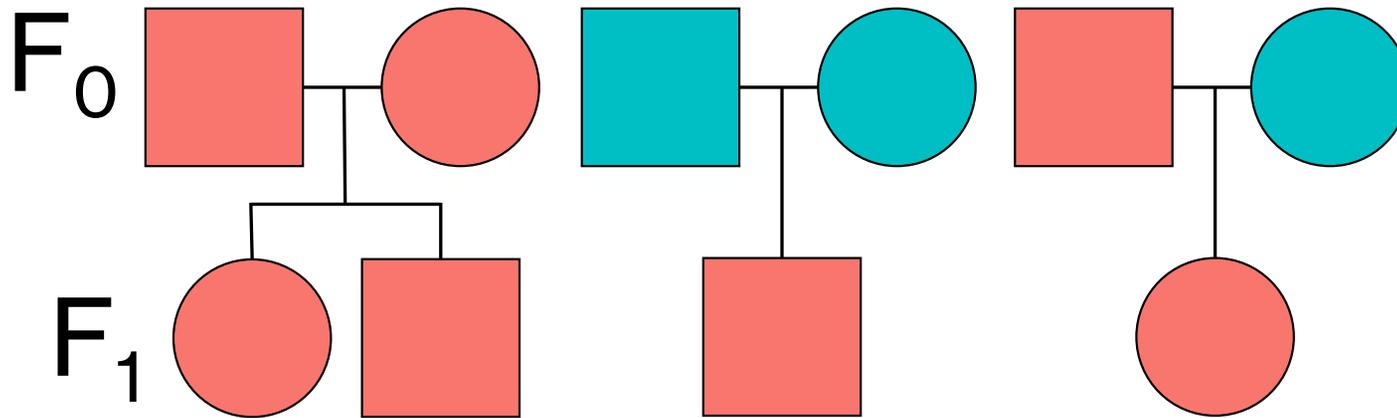


Hatchery-origin

No thermal mark

Natural-origin

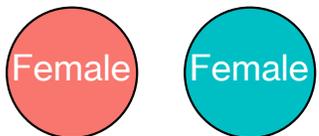
Measuring Reproductive Success



$$RS_{N \text{ Female}} = 2$$

$$RS_{H \text{ Female}} = 1$$

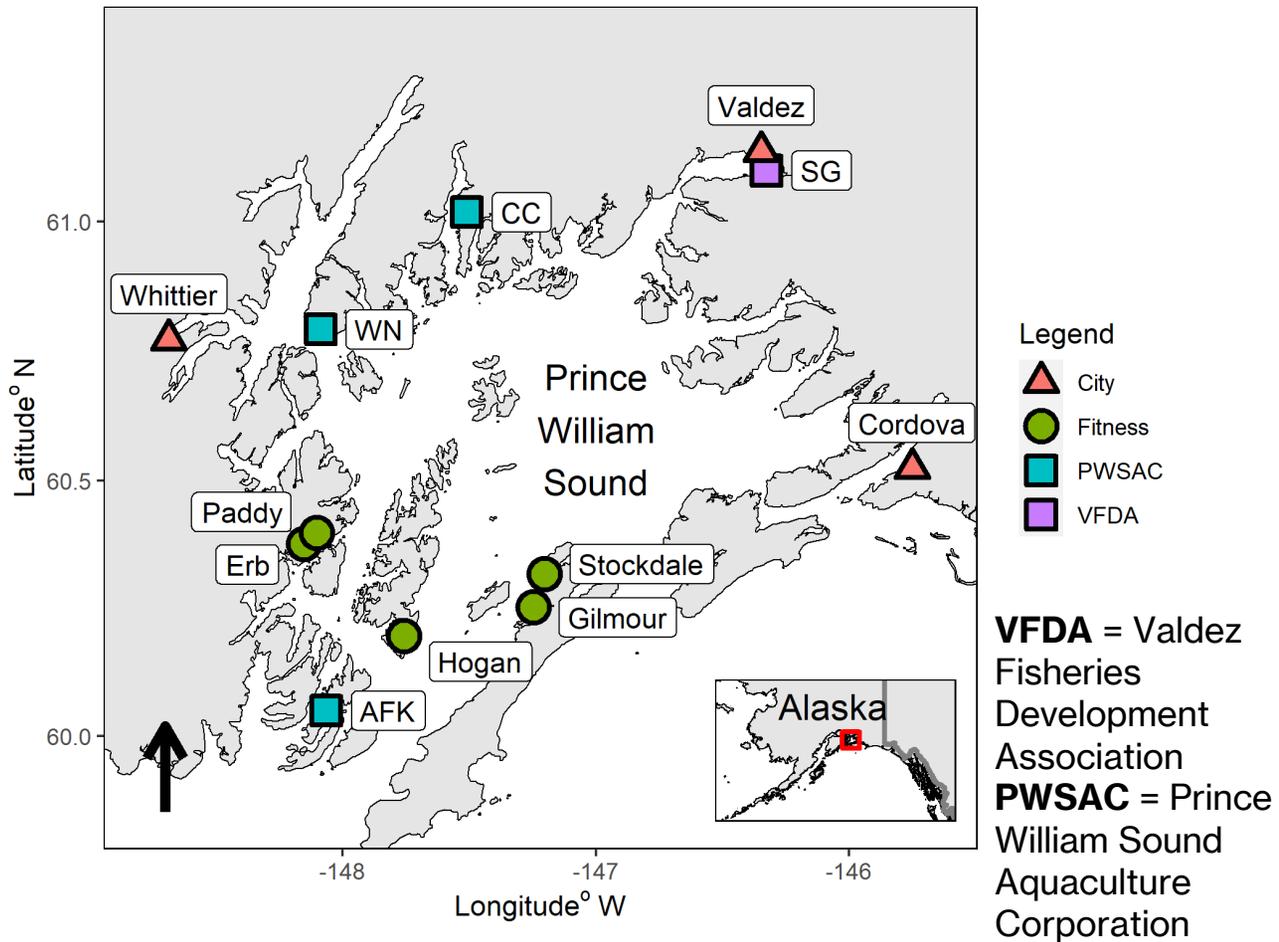
Natural Hatchery



Relative
Reproductive
Success
(RRS)

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

AHRP Streams in PWS





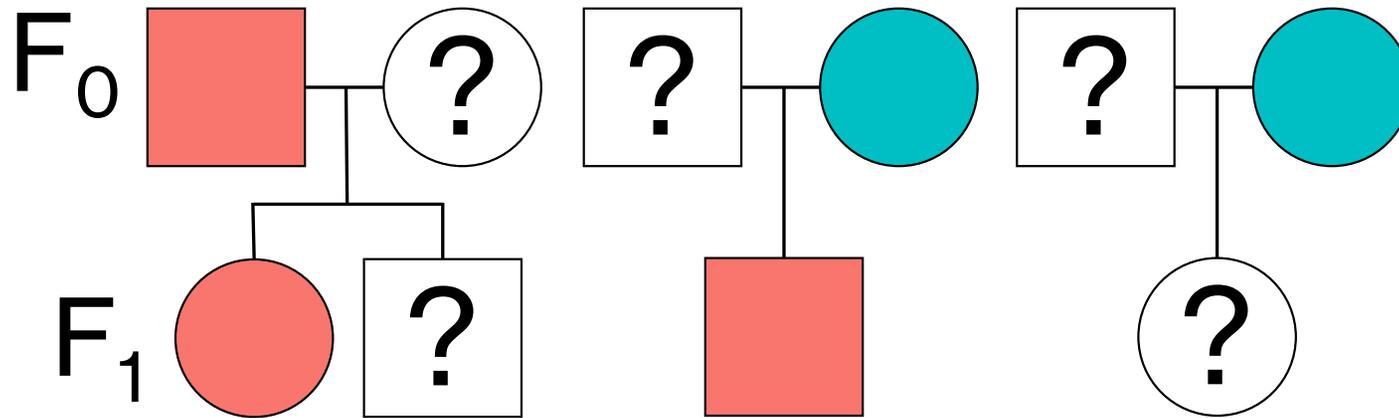
Methods: Field Sampling

Intensive carcass sampling

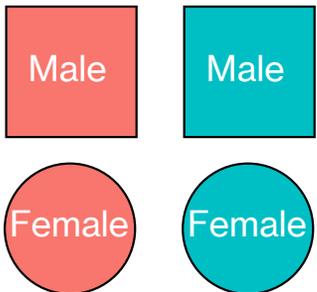
- Body length
- Date
- Location
 - Intertidal
 - Upstream
- Otolith
- Tissue

Photo credit: Brad von Wichman (PWSSC)

Measuring Reproductive Success



Natural Hatchery



Relative
Reproductive
Success
(RRS)

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

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

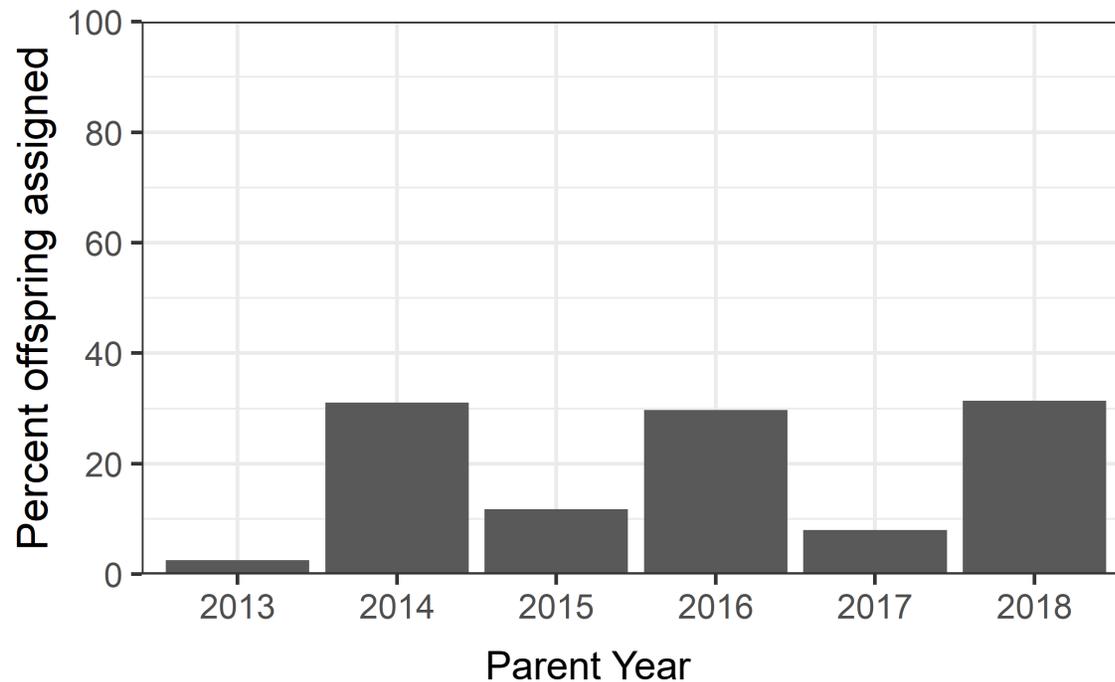
probability of not
producing offspring

Conditional

expected number
of offspring given
success

Disclaimer

Number of offspring produced ~ assigned

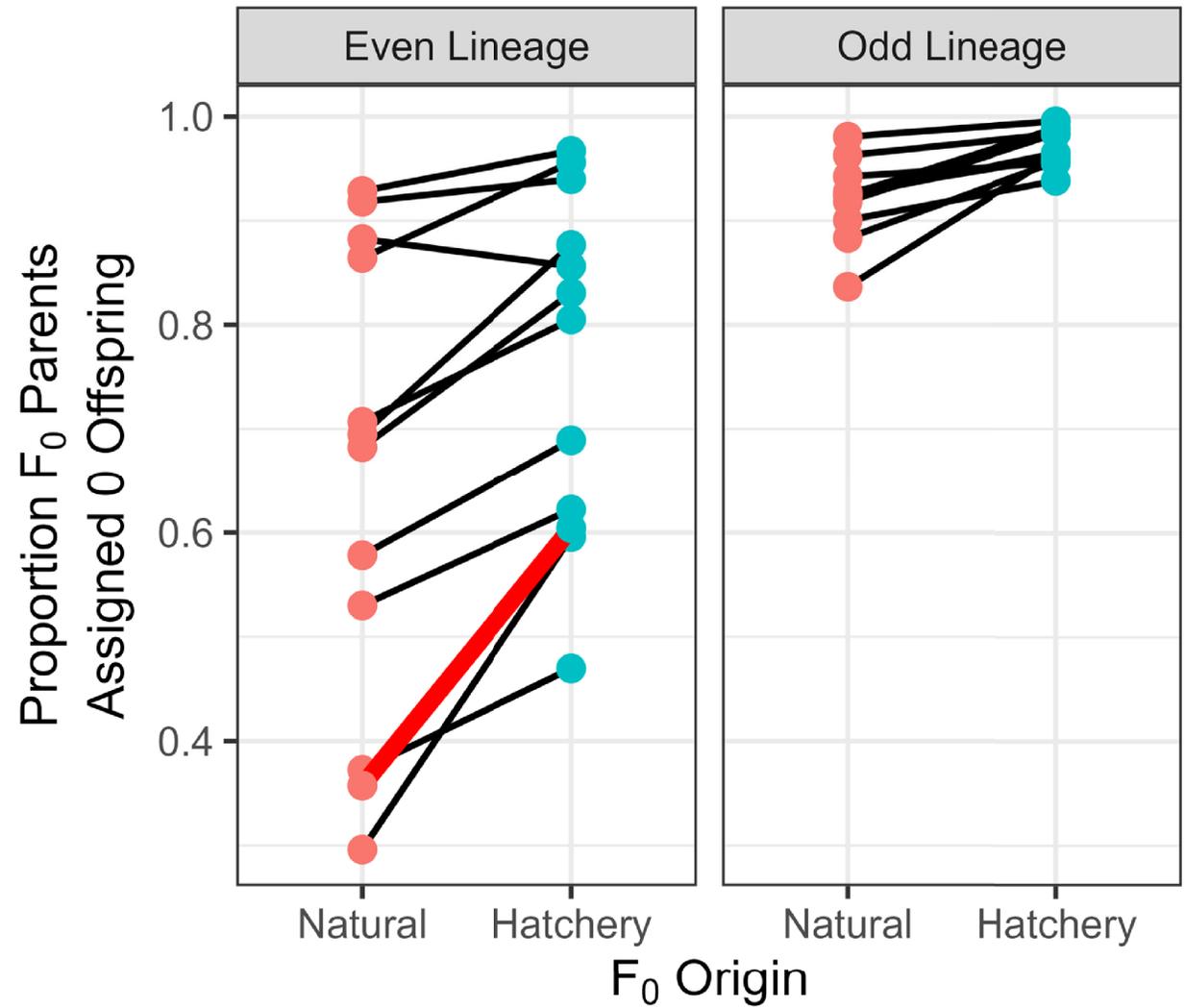


Percent of offspring assigned to parents:
13% odd lineage
40% even lineage

Results

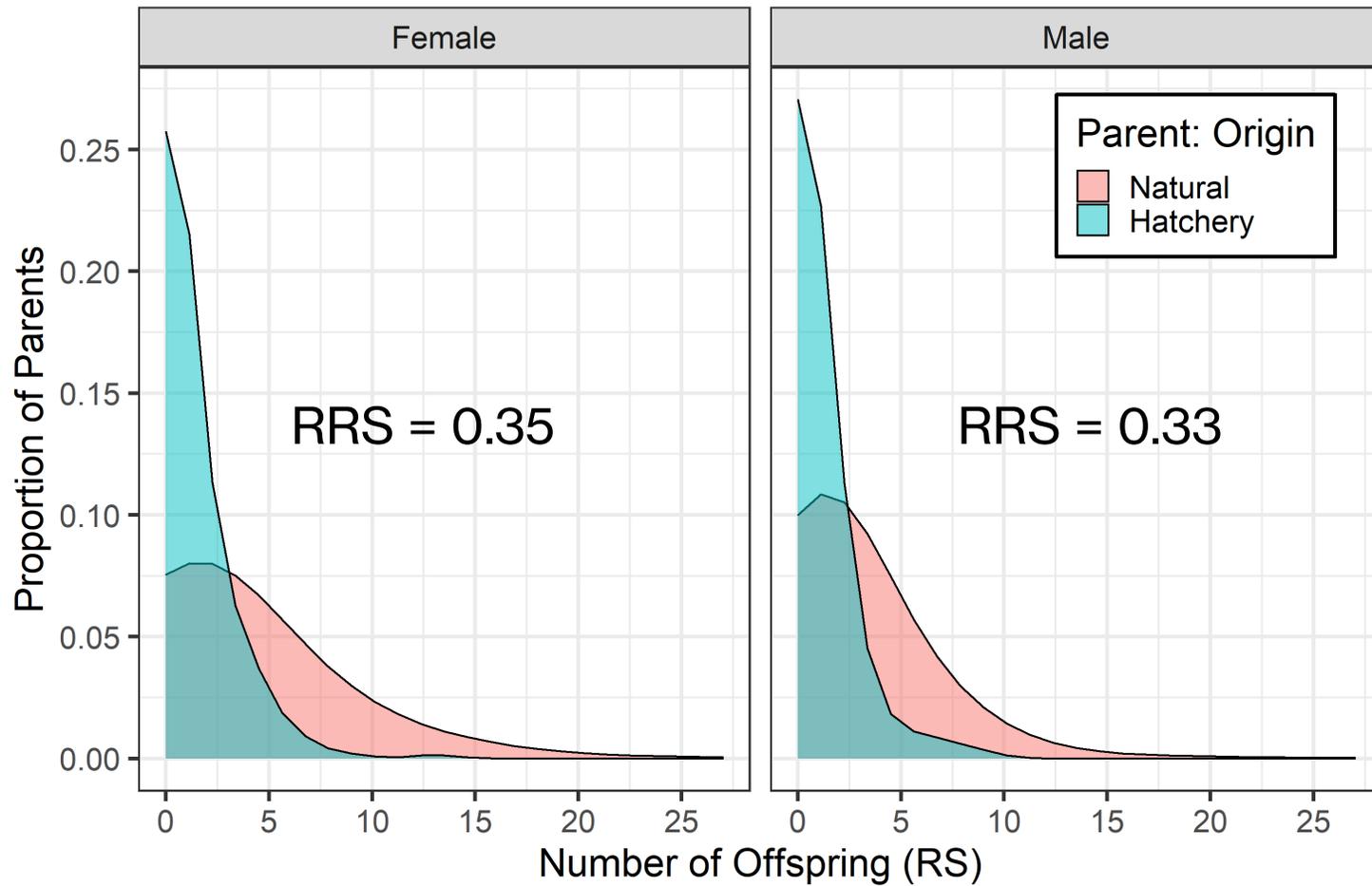
Unsuccessful Parents

Parent Origin
Natural
Hatchery



RS Distribution

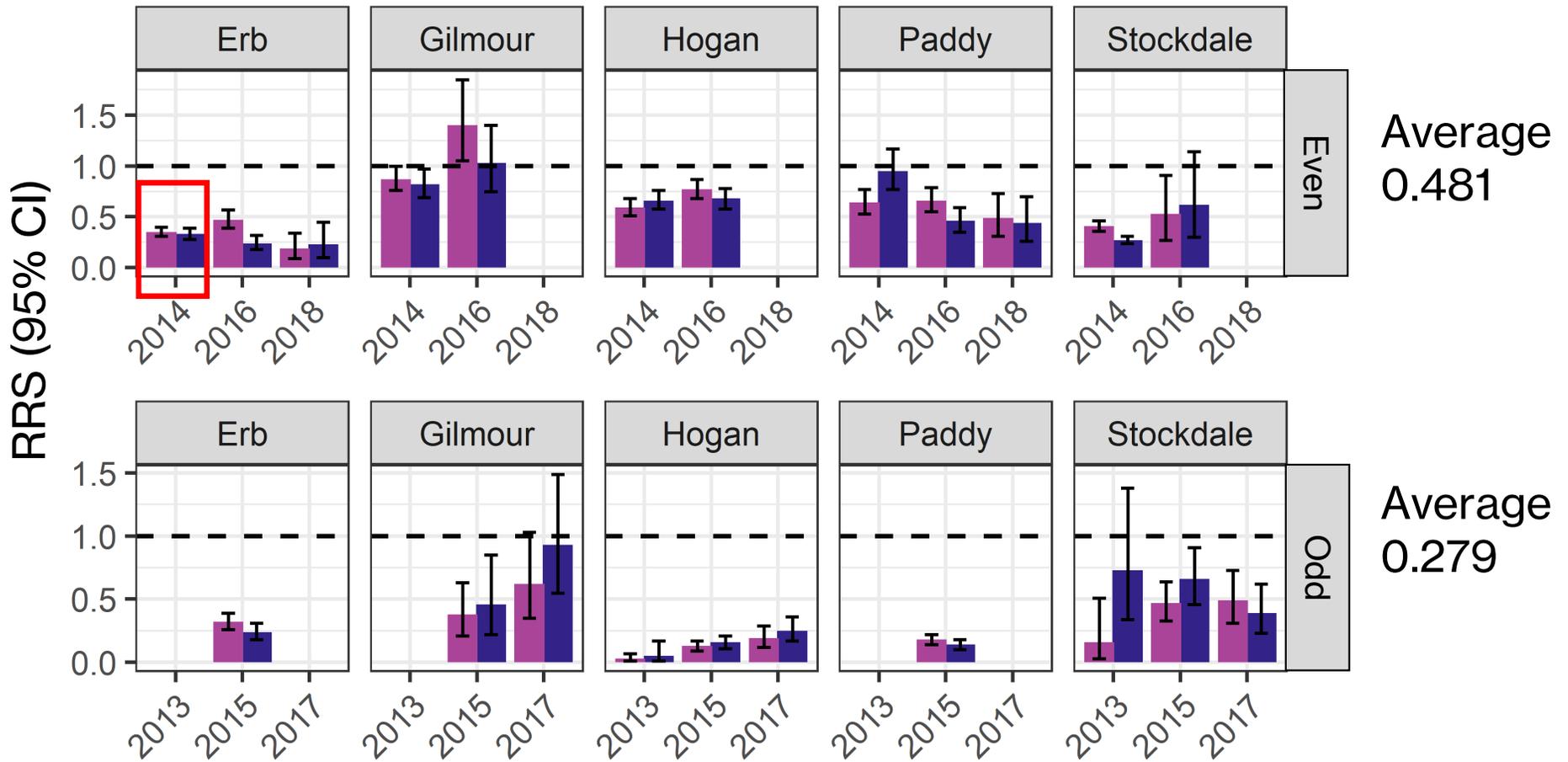
RS Erb 2014



RRS

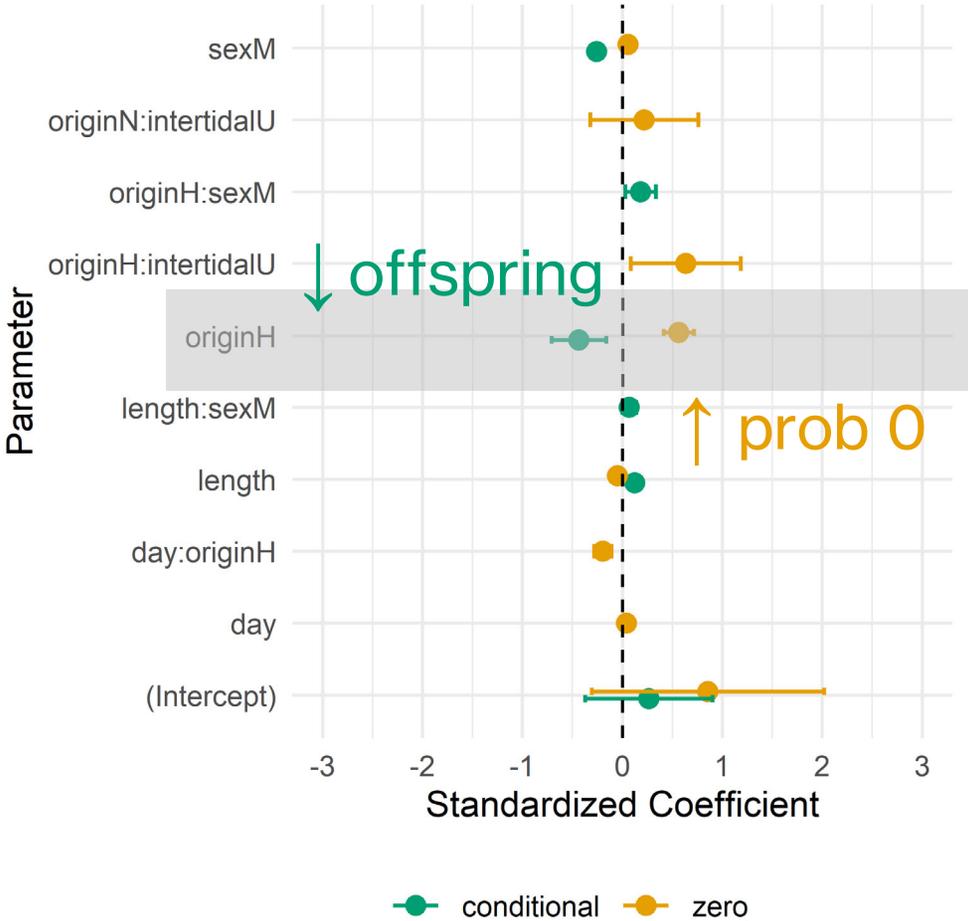
Sex
■ Female
■ Male

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

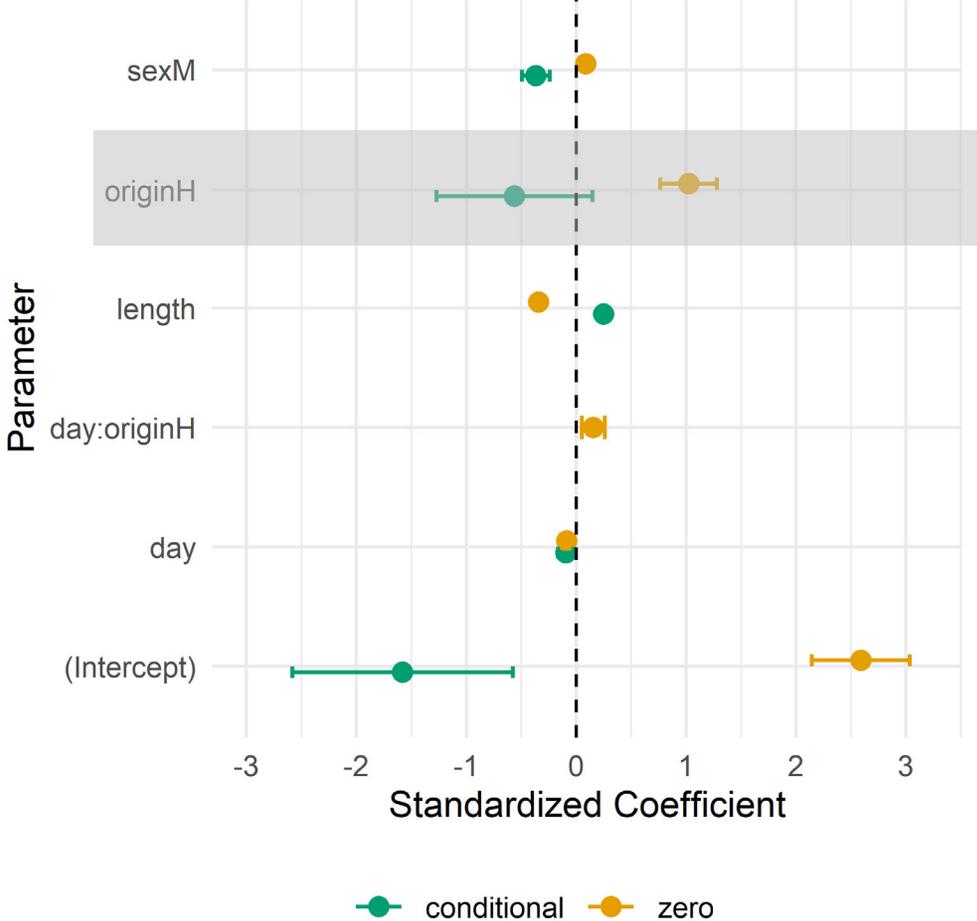


Hurdle Models: coefficients

Even Lineage



Odd Lineage



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	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
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 - Seafood industry
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- North Pacific Research Board (Project #1619)
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 - Funding for Stockdale analyses (2014/2016)
- Prince William Sound Science Center
 - Field collection
- ADF&G Cordova Otolith Lab
- University of Washington - Seeb Lab
- ADF&G Gene Conservation Laboratory



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Questions?

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AHRP Communications

Evolutionary Applications

Evolutionary approaches to environmental, biomedical and socio-economic issues

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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

Dynamics, Management, and Ecosystem Science

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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

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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

+ Author & article information

R Soc Open Sci. (2024) 11 (7): 240455 .

The screenshot shows the Alaska Department of Fish and Game website. The main navigation bar includes Home, Fishing, Hunting, Subsistence, Viewing, Education, Species, Habitat, and Regulations. Below this, there are sub-navigations for Licenses & Permits, Commercial, Sport, Subsistence, Personal Use, Aquatic Farming, Hatcheries, and Research. The current page is 'Hatcheries Research Overview'. The breadcrumb trail is 'ADF&G Home > Fishing > Hatcheries > FishingHatcheriesResearch'. The page title is 'Hatcheries Research Overview'. There are tabs for 'Overview', 'Current Research Project', 'Findings', and 'Meetings'. The main content area starts with the text: 'In 1971, the State of Alaska initiated its modern salmon fishery enhancement'.

<https://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesResearch.main>