Alaska Hatchery Research Program: Study Question 3: Relative Reproductive Success Update

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Alaska Department of Fish and Game

BOF Hatchery Committee Meeting

March 23, 2022



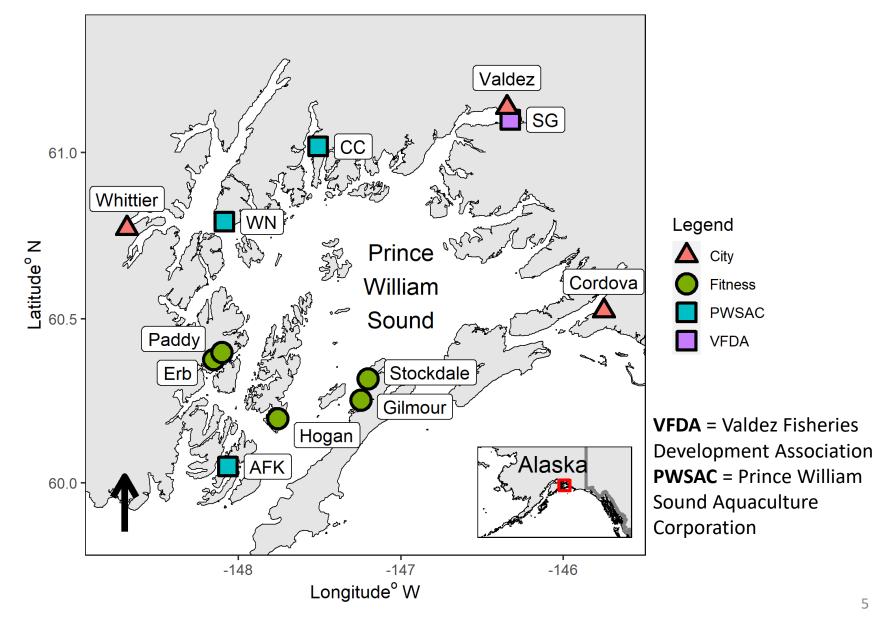
Alaska Hatchery Research Program

- 1) What is the genetic 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 <u>fitness</u> (productivity) of natural pink and chum stocks due to straying hatchery pink and chum salmon?

Hatchery/Natural Fitness

Steelhead	Chinook	Coho
Differential reproductive success of sympatric, naturally spawning hatchery and wild steelhead trout (<i>Oncorhynchus mykiss</i>) through the adult stage Jennifer E. McLean, Paul Bentzen, and Thomas P. Quinn	Stort harrise for of of blocks througene 25 SC2-16E, 208 [Article] OC 10.2776441 (H.) Use of Parentage Analysis to Determine Reproductive Success of Hatchery-Origin Spring Chinook Salmon Outplanted into Shitike Creek, Oregon Joon Businstructs ¹	Changes in run timing and natural smolt production in a naturally spawning coho salmon (<i>Oncorhynchus kisutch</i>) population after 60 years of intensive hatchery supplementation Michael J. Ford, Howard Fuss, Brant Boelts, Eric LaHood, Jeffrey Hard, and
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Effective population size of steelhead trout: influence of variance in reproductive success, hatchery programs, and genetic compensation between life-history forms Introduit ARANT: POINTS WAPLESS WILLIAM R. ARDEN: YECKY COOPER* and MICHAELS REQUINY Therefore a control of the state of the st	MOLECULAR ECOLOGY Mercel # Rodge 2010 R. KSok 420 Supportive breeding boosts natural population abundance with minimal negative impacts on fitness of a wild population of Chinook salmon MARKEN A. HISS.* CRAIC D. RABE, LASON L. VOCEL, LIKE J. STEPHENSON.* DOUG D.	was more promounced in makes than in same-aged femades. Hathery spowred field that were released as world for fug off, was well as hathery field first order for any system in the hathery trokkand as annules, age 30, both experimental wave Hifelinian exproduction more (RD) takes with first. Moreover, the model of hathery models in the released as 3 years also the state of the there is a state of the state of the state of the release of the state of the hathery as a controlling modelsmain first first first state of the state of the state of the state with Rds. (Gli age) make hathering this constitution between a state of the state of the hathery as a controlling modelsmain the first state direct on all the state RS than form is the shorts of the stage models are interested as a state of the state of the state of the state of the state compete all direct states for first state states and states and the states which does any states of the states states and states and the states of the states are states and the states of the states and states and states and the states which compete all direct states for first states granting analysis, reproductive states which with the states are states and states and states and the states and states and does any states and the states the states and states and the states and compete all direct and the states and states and the states and states and the states are states and the states and the states and the states and the states are states and the states and the states and the states and the states and the states and the states are states and the states and the states and the states are states and the states are states and the states and the states and the states are states and the states are states and the states are states and the states and the states are states and the states are states and the states are states and the states are states are states a
Carry-over effect of captive breeding reduces reproductive fitness of wild-born descendants in the wild Histak Ackir', Besky Cooper and Michael S. Brown Tansactions of the American Fisheries Society	NELSONT and SHARWNE. NARCEM* Evolutionary Applications Beindunary Applications <td< td=""><td>Chum</td></td<>	Chum
Publication details, including instructions for authors and subscription information: http://www.authors.auth	 Scalar JA Agazia end Reina Sciences, Sciences Sci 1994 AU USL 100 Scalar JA Agazia, Scalar AG, Ad. 200 Paper address Marcha, Mala. There address Science address Science Reina Science Address Marcha, Mala USL 100 Terrywonia, marchanichta and Science Address Marcha, Mala Mala Mala Mala Mala Mala Mala Ma	Reproductive behavior and relative reproductive success of natural- and hatchery-origin Hood Canal summer chum salmon (<i>Oncorhynchus keta</i>) Barry A. Berejikian, Denald M. Van Doornik, Julie A. Scheurer, and Richard Bush
Genetic adaptation to captivity can occur in a single generation Make K. Christe ^{4*} , Melarie L. Marine ⁴ , Rod A. French ⁴ , and Michael S. Elbuir ⁴ ¹⁰ Sparmer of 2 Julig, Crays: Net Distance, W. and Kando M. S. Elbuir ⁴ ¹⁰ Sparmer of 2 Julig, Crays: Net Distance, W. and Kando M. M. and Michael S. Elbuir ⁴ ¹⁰ Sparmer of 2 Julig, Crays: Net Distance, W. and Kando M. M. and Michael S. Elbuir ⁴ ¹⁰ Sparmer of 2 Julig, Crays: Net Distance, W. and Michael S. Elbuir ⁴ ¹⁰ Sparmer of 2 Julig, Crays: Net Distance, W. and Michael S. Elbuir ⁴ ¹⁰ Sparmer of 2 Julig, Crays: Net Distance, W. and Michael S. Elbuir ⁴ ¹⁰ Sparmer of 2 Julig, Crays: Net Distance, W. and Michael S. Elbuir ⁴ ¹⁰ Sparmer of 2 Julig, Crays: Net Distance, W. and Michael S. Elbuir ⁴ ¹⁰ Sparmer of 2 Julig, Crays: Net Distance, W. and Michael S. Elbuir ⁴ ¹⁰ Sparmer of 2 Julig, Crays: Net Distance, W. and Michael S. Elbuir ⁴ ¹⁰ Sparmer of 2 Julig, Crays: Net Distance, W. and Michael S. Elbuir ⁴ ¹⁰ Sparmer of 2 Julig, Crays: Net Distance, W. and Michael S. Elbuir ⁴ ¹⁰ Sparmer of 2 Julig, Crays: Net Distance, Ne	Insured 13 Advances Settiment Informer, Sense 2725 Senset Marken Settiment Informer, Sense 2726 Senset Marken Senset Informer, Sense 2726 Senset Informer, Senset Info	Advance. Ensistence of the relative fitness of functionsy and matural-origin solitons can help determine the value of handney match in contributing to microwry efficient. This many compared the adult is fit preproductive success of matural-origin summer choice statuses (theoretistus larger with the of fitness to their generation handney arigin admines in an experiment summer choice statuses (theoretistus) larger with the of fitness to their generation handney arigin admines in an experiment summer choice statuses (theoretistus) and the status of the status of the status of the status summer choice status of their summer choice status of the status of the status of the status summer thereing between sum datasetistus. Main help (are status) constitut of while status is noticing from and research productives market and results have its mature to an experimity constitut with screen to noticing from and re- populations and runs. Stagier that these is malates that evaluated the filterse relative reproductive success the choice of noticed hadvery populations.

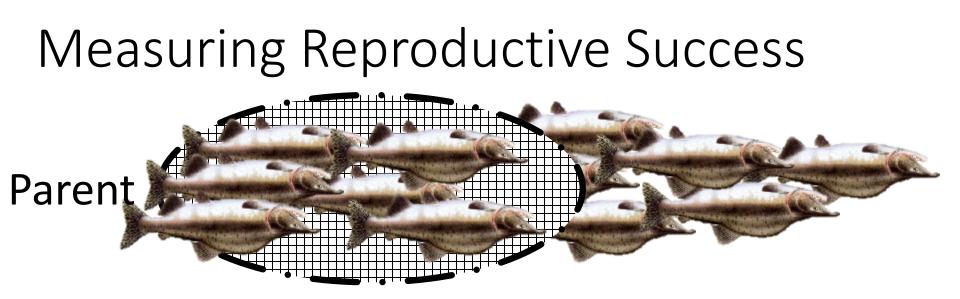
AHRP Fitness Study: PWS Pink Salmon



Fitness = Reproductive Success







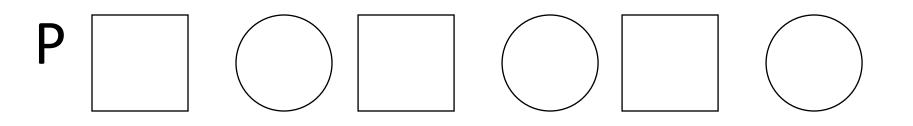
Parent

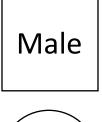


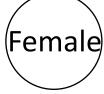
- Carcass sampling
 - Body length
 - Date
 - Location
 - Otolith
 - Tissue

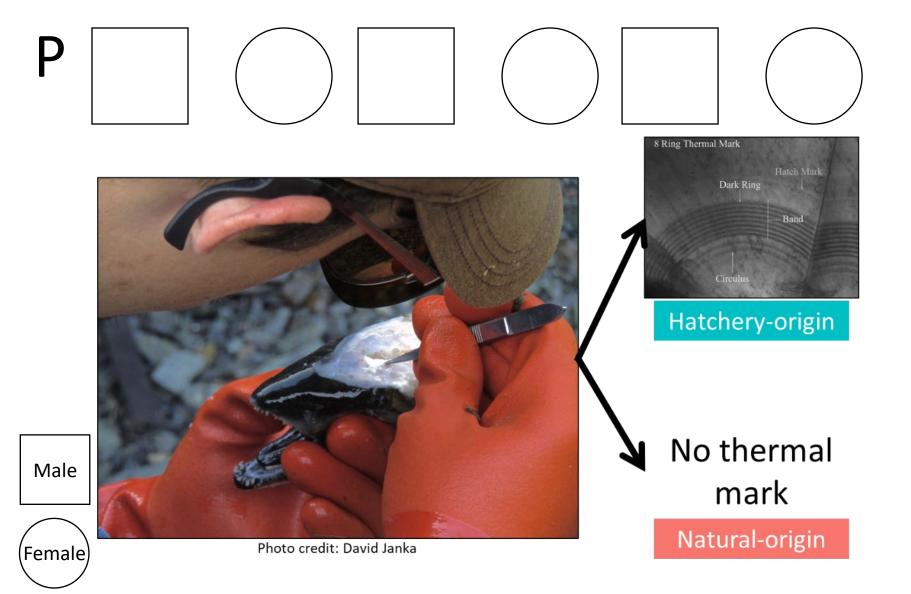


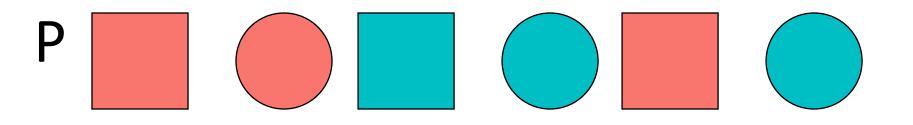
Photo credit: Brad von Wichman

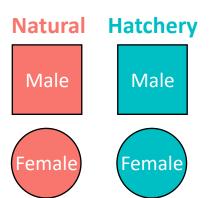


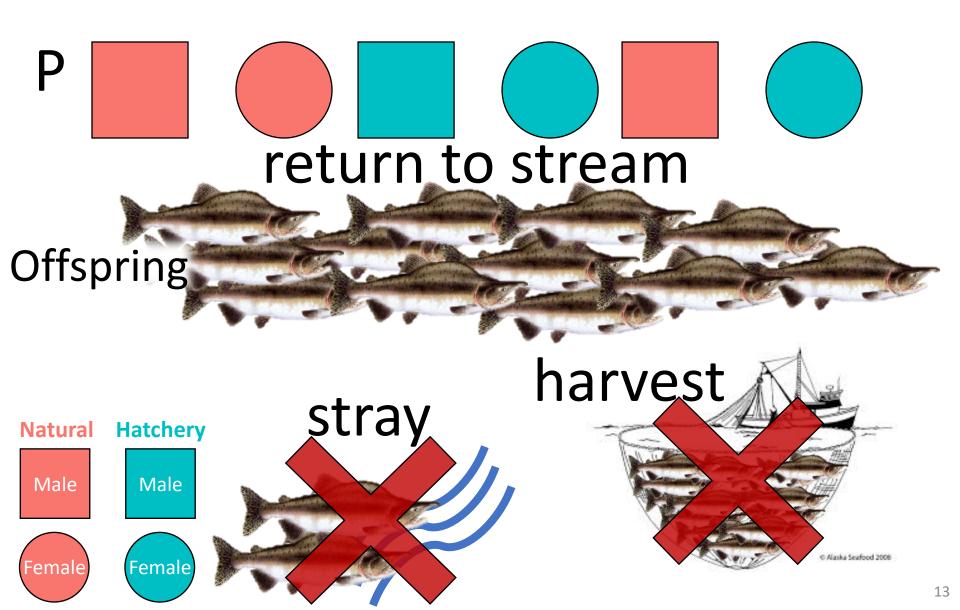


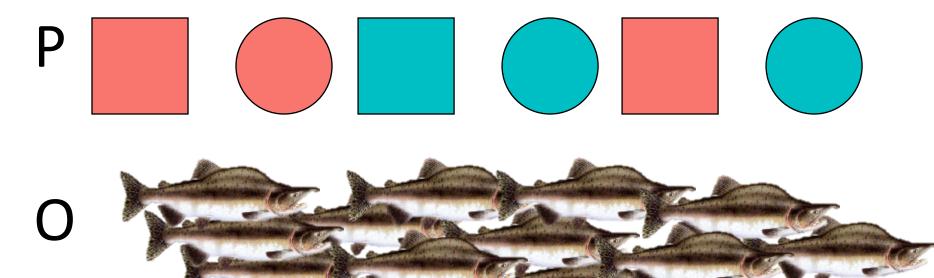


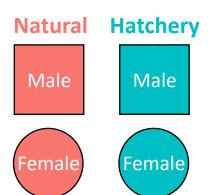


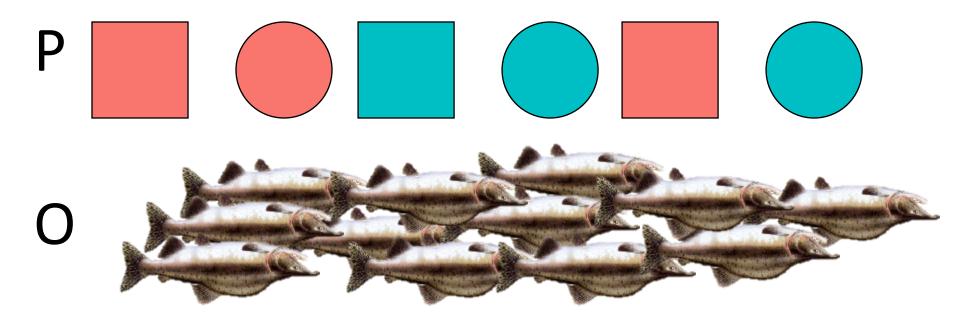


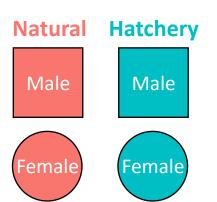


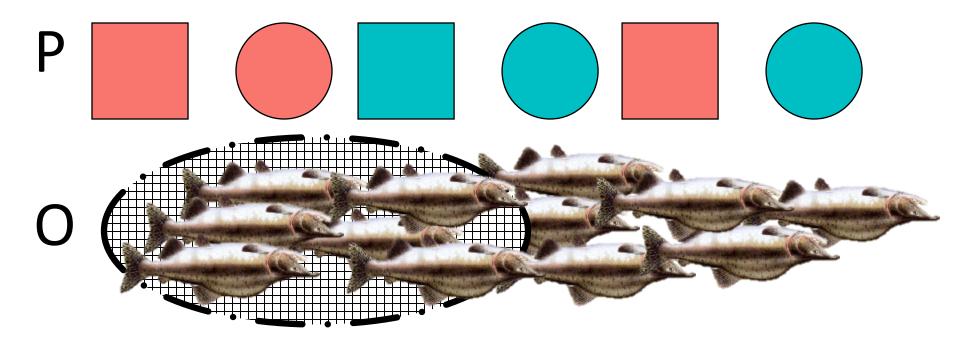


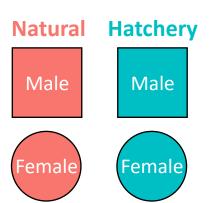


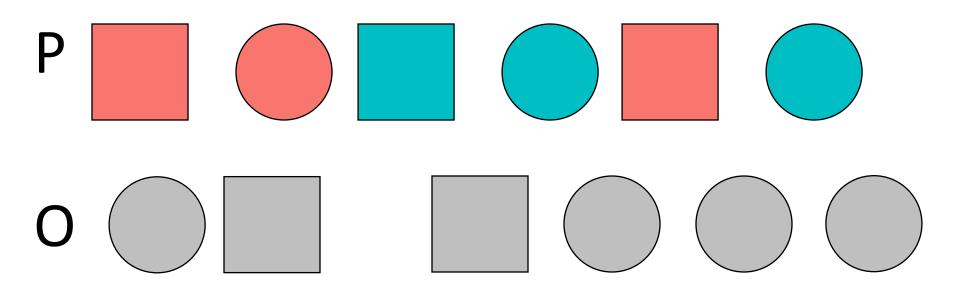


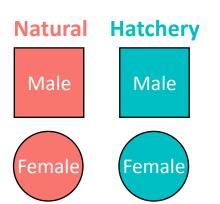


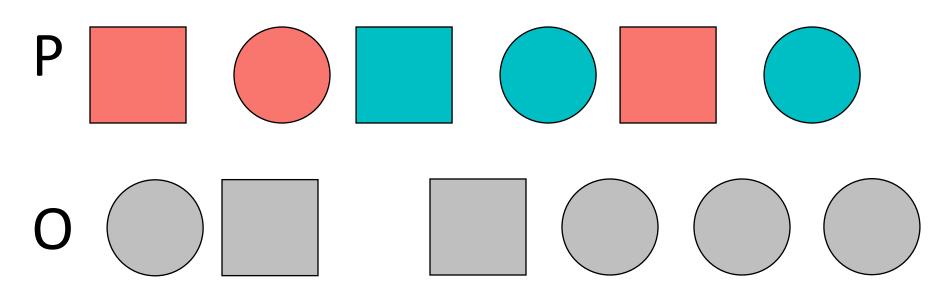


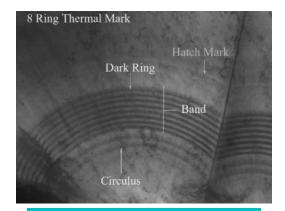




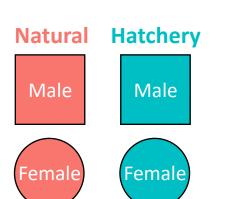


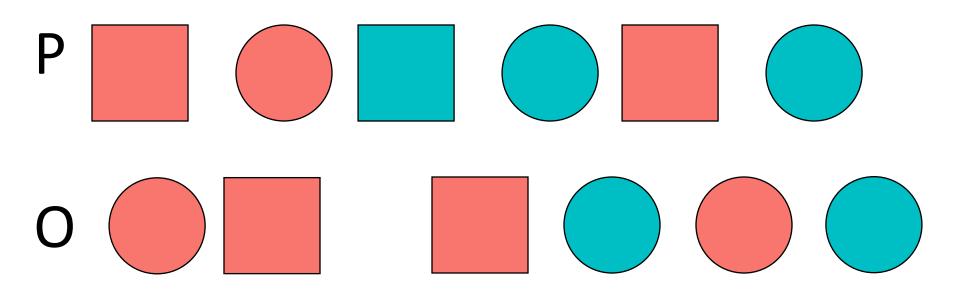


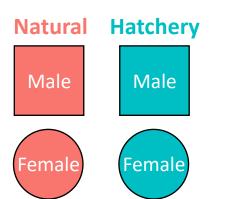


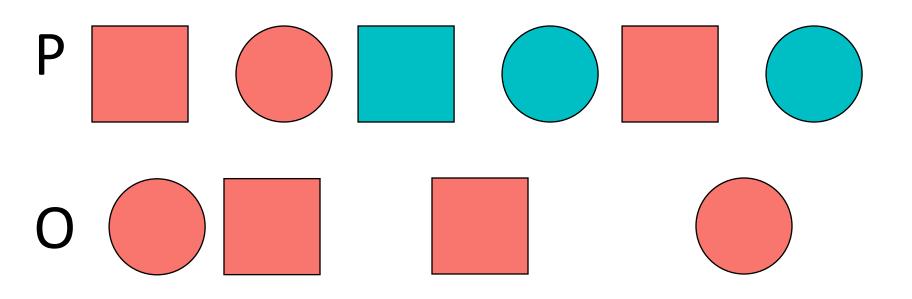


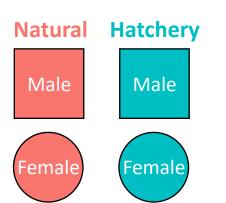
Hatchery-origin



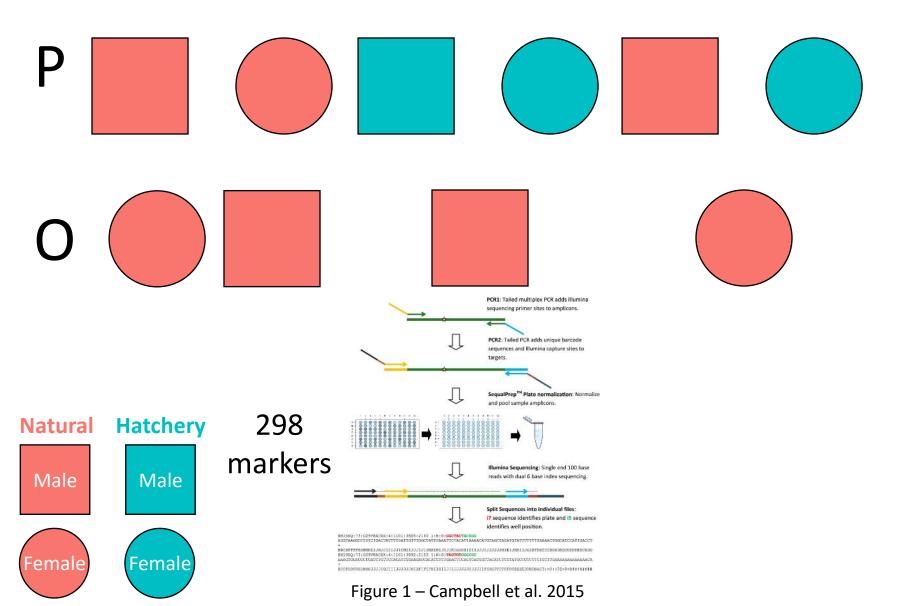


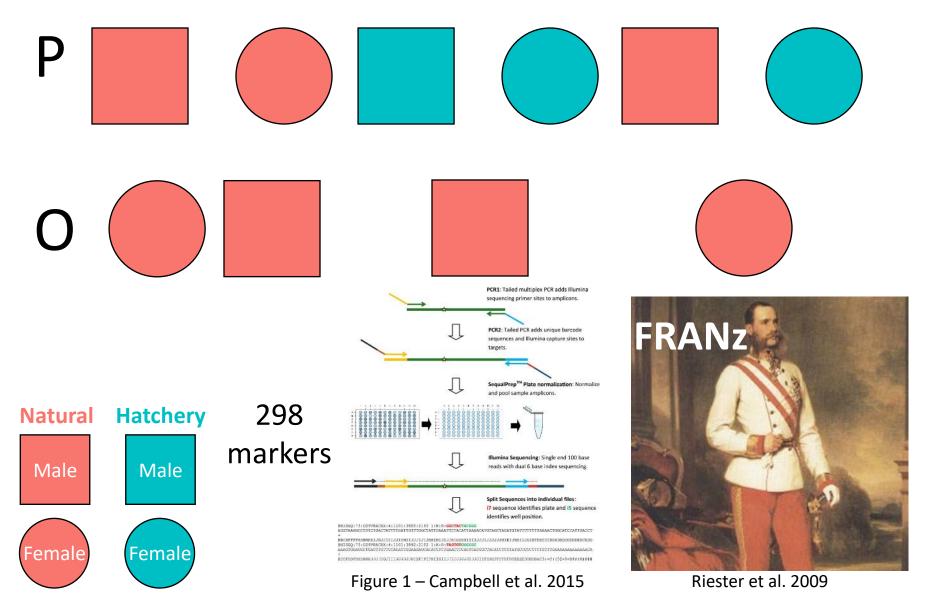


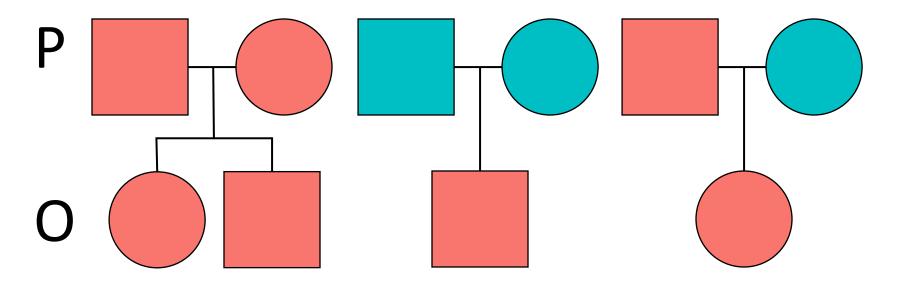


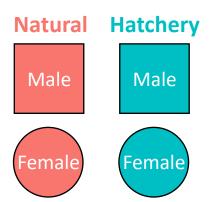


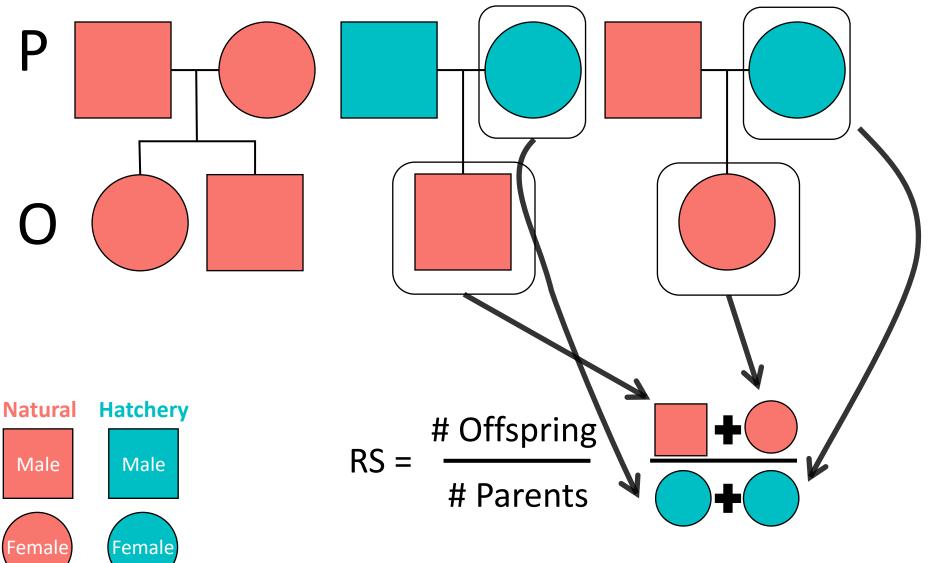
Hatchery-origin fish are not genotyped in the offspring generation because they have a known origin.

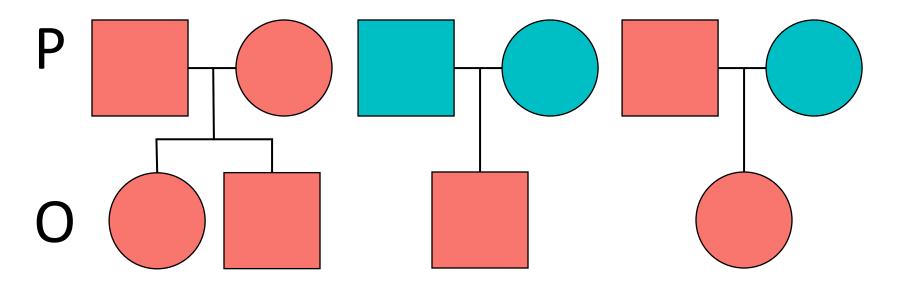




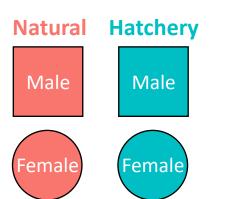


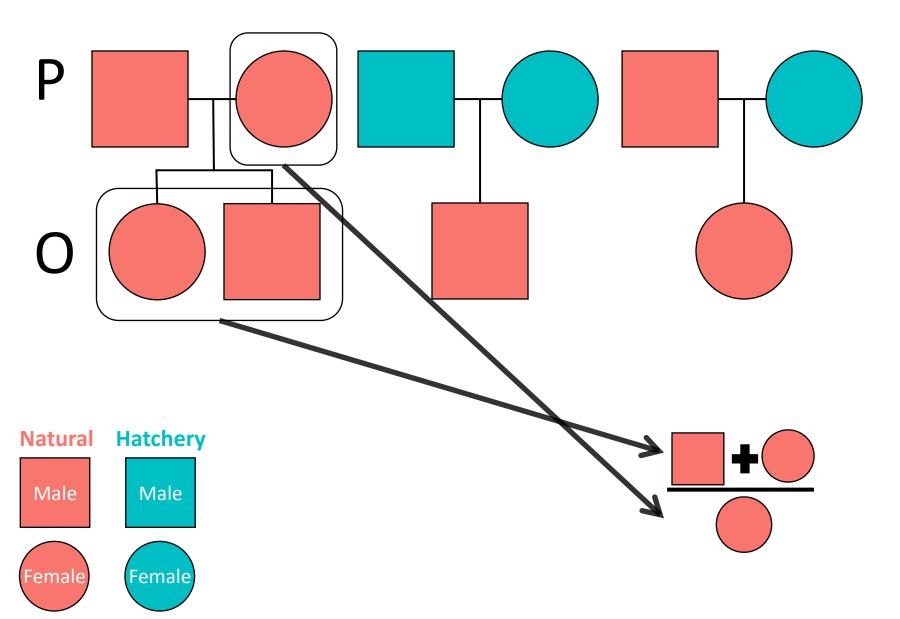


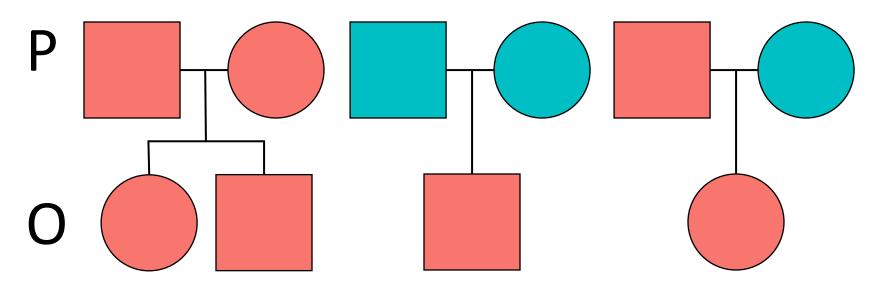




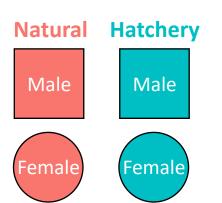
RS_{H Female} = 1

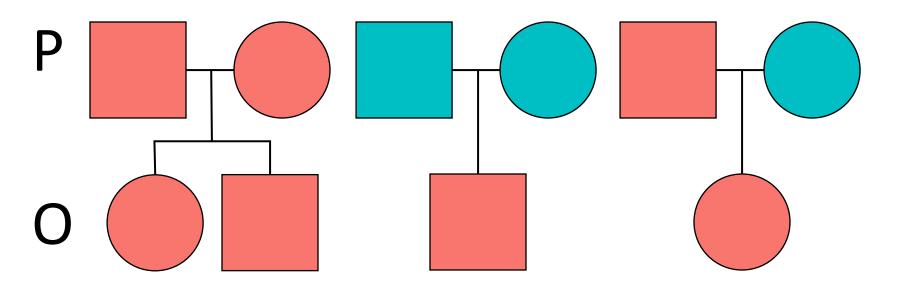




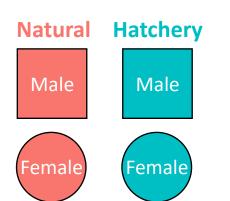


RS_{N Female} = 2 RS_{H Female} = 1



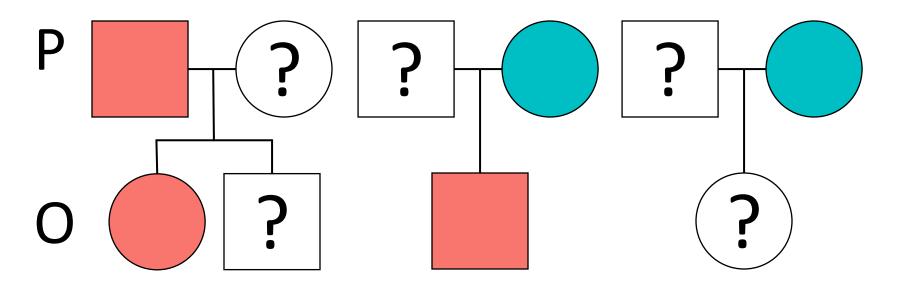


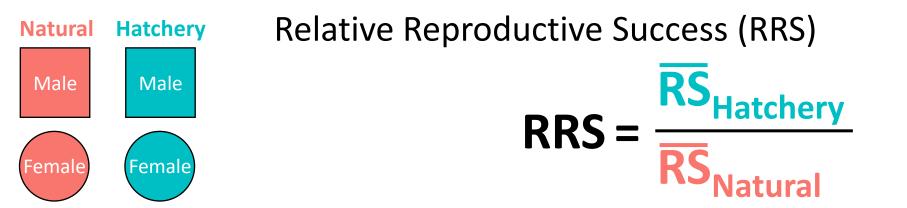




Relative Reproductive Success (RRS)

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

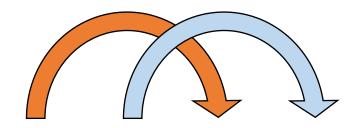




Stream	2013	2014	2015	2016	2017	2018	2019
Hogan	Р	Ρ	P,O	P,O	P,O,G	0,G	0,G

- P parents
- O offspring
- G grand-offspring

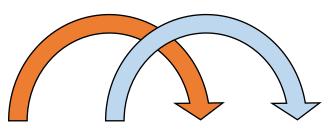
Odd-lineage Even-lineage



Stream	2013	2014	2015	2016	2017	2018	2019
Hogan	Р	Ρ	P,O	Р,О	P,O,G	0,G	0,G

- P parents
- O offspring
- G grand-offspring

Odd-lineage Even-lineage



Stream	2013	2014	2015	2016	2017	2018	2019
Hogan	Р	Ρ	P,O	P,O	P,O,G	0,G	0,G

- P parents
- O offspring
- G grand-offspring

Odd-lineage Even-lineage

Stream	2013	2014	2015	2016	2017	2018	2019	2020
Hogan	Р	Р	P,O	Р,О	P,O,G	0,G	0,G	
Stockdale	Р	Ρ	P,O	Р,О	P,O,G	O,G	0,G	
Gilmour		Ρ	Р	Р,О	P,O	0,G	O,G	
Paddy	Р	Р	P,O	P,O	O,G	P,O,G		O,G
Erb	Р	Р	P,O	Р,О	O,G	P,O,G		0,G

- P parents
- O offspring
- G grand-offspring
- Odd-lineage

>235K samples!

AHRP Streams in PWS Presented 2019

Stream	2013	2014	2015	2016	2017	2018	2019	2020
Hogan	Р	Р	P,O	P,O	P,O,G	0,G	0,G	
Stockdale	Р	Р	P,O	Р,О	P,O,G	O,G	O,G	
Gilmour		Ρ	Р	P,O	P,O	0,G	O,G	
Paddy	Р	Ρ	P,O	P,O	O,G	P,O,G		0,G
Erb	Р	Р	P,O	P,O	0,G	P,O,G		0,G

- P parents
- O offspring
- G grand-offspring
- Odd-lineage >235K samples!

AHRP Streams in PWS Presented 2020

Stream	2013	2014	2015	2016	2017	2018	2019	2020
Hogan	Р	Р	P,O	P,O	P,O,G	0,G	0,G	
Stockdale	Р	Р	P,O	P,O	P,O,G	O,G	O,G	
Gilmour		Р	Р	Р,О	P,O	O,G	O,G	
Paddy	Р	Р	P,O	P,O	0,G	P,O,G		0,G
Erb	Р	Р	P,O	Р,О	0,G	P,O,G		0,G

- P parents
- O offspring
- G grand-offspring

Odd-lineage Even-lineage

>235K samples!

AHRP Streams in PWS Presented 2020

HoganPP,OP,O,GO,GO,GStockdalePPP,OP,O,GO,GO,G	Stream	2013	2014	2015	2016	2017	2018	2019	2020
Stockdale P P P,O P,O P,O,G O,G O,G	Hogan	Р	Р	P,O	P,O	P,O,G	0,G	0,G	
	Stockdale	Р	Р	P,O	Р,О	P,O,G	0,G	0,G	

Shedd, K.R., Lescak, E.A., Habicht, C., Knudsen, E.E., Dann, T.H., Hoyt, H.A., Prince, D.J. and Templin, W.D. 2022. Reduced relative fitness in hatchery-origin Pink Salmon in two streams in Prince William Sound, Alaska. Evolutionary Applications. <u>https://doi.org/10.1111/eva.13356</u> G – grand-offspring

AHRP Streams in PWS Presenting 2022

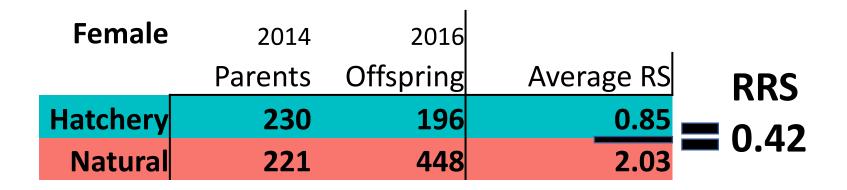
2013	2014	2015	2016	2017	2018	2019	2020
Р	Р	P,O	Р,О	P,O,G	0,G	0,G	
Р	Р	P,O	P,O	P,O,G	0,G	0,G	
	Р	Р	P,O	Р,О	0,G	O,G	
Р	Р	P,O	Р,О	O,G	P,O,G		O,G
Р	Р	P,O	Р,О	0,G	P,O,G		0,G
	P P P	P P P P P P P P P P P P	P P P,O P P P,O P P P,O P P P P P P P P P P P P,O	P P,O P,O P P,O P,O	P P,O P,O P,O,G P P,O P,O P,O,G P P,O P,O P,O,G P P P,O P,O P,O,G P P P,O P,O P,O,G P P P,O P,O P,O P P P,O P,O O,G	P P,O P,O P,O,G O,G P P,O P,O P,O,G O,G P P,O P,O P,O,G O,G P P P,O P,O P,O O,G P P P,O P,O P,O O,G P P P,O P,O P,O P,O O,G P P P,O P,O P,O P,O P,O P P P,O P,O P,O P,O P,O P P P,O P,O P,O P,O P,O P P P,O P,O P,O P,O P,O	P P,O P,O P,O,G O,G O,G P P,O P,O P,O,G O,G O,G P P,O P,O P,O,G O,G O,G P P P,O P,O P,O,G O,G O,G P P P,O P,O P,O,G O,G O,G P P P,O P,O P,O,G O,G,G O,G P P P,O P,O P,O,G P,O,G O,G,G P P P,O P,O P,O,G P,O,G P,O,G P P P,O P,O,G P,O,G P,O,G P,O,G

- P parents
- O offspring
- G grand-offspring
- **Odd-lineage** Even-lineage

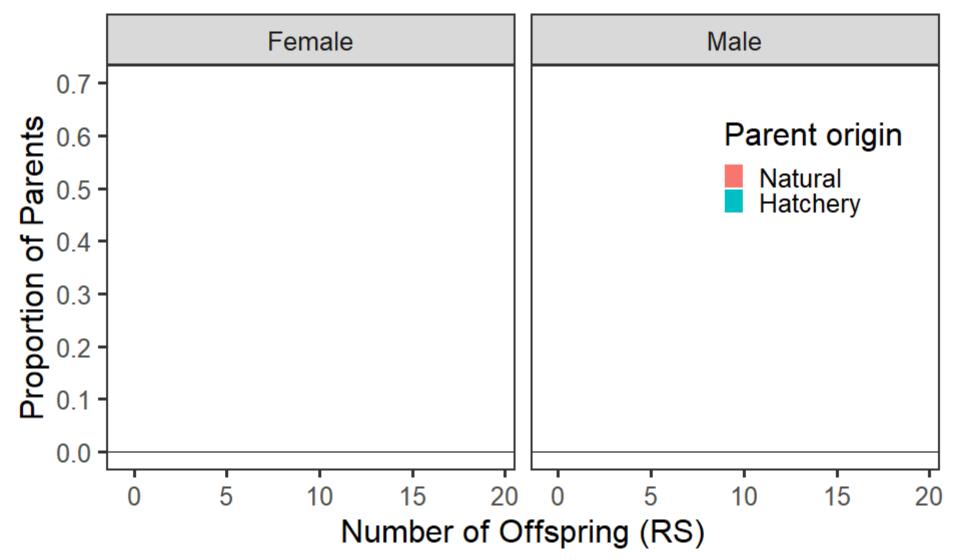
>235K samples!

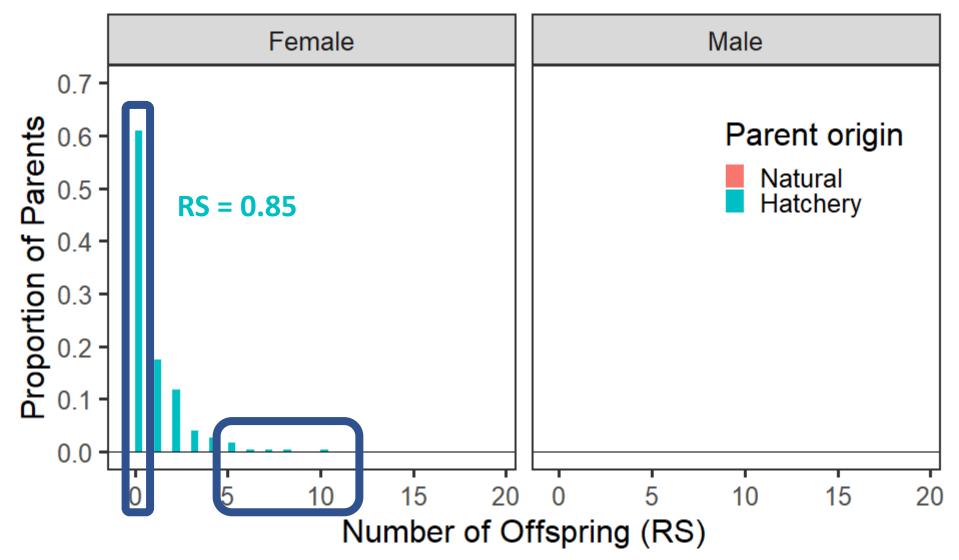
Average Reproductive Success

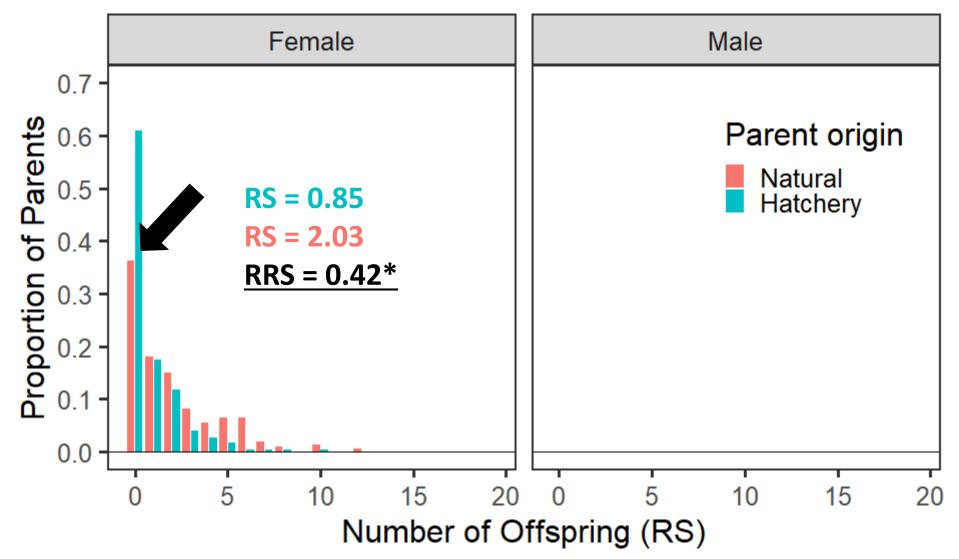
Stockdale 2014/2016

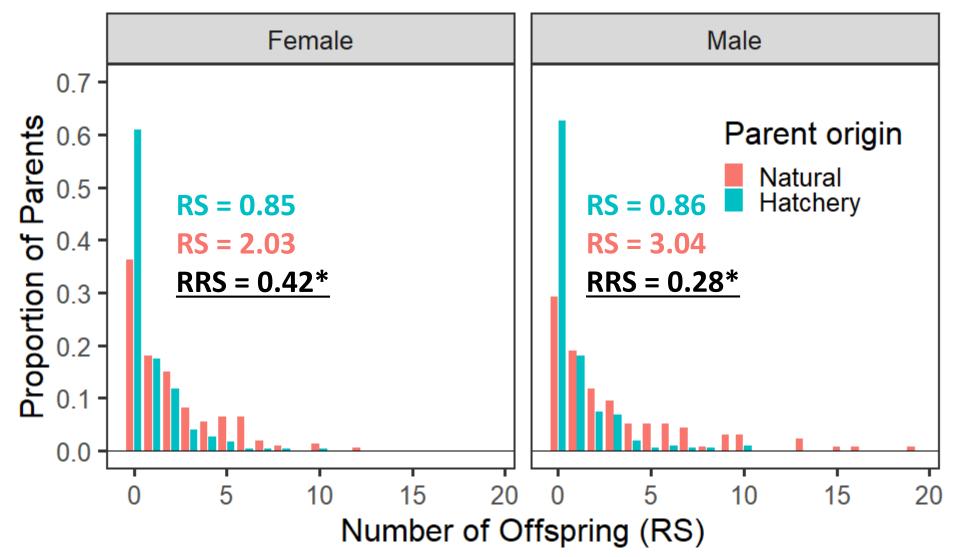


Male	2014	2016		
	Parents	Offspring	Average RS	RRS
Hatchery	206	177	0.86	
Natural	137	417	3.04	= 0.28





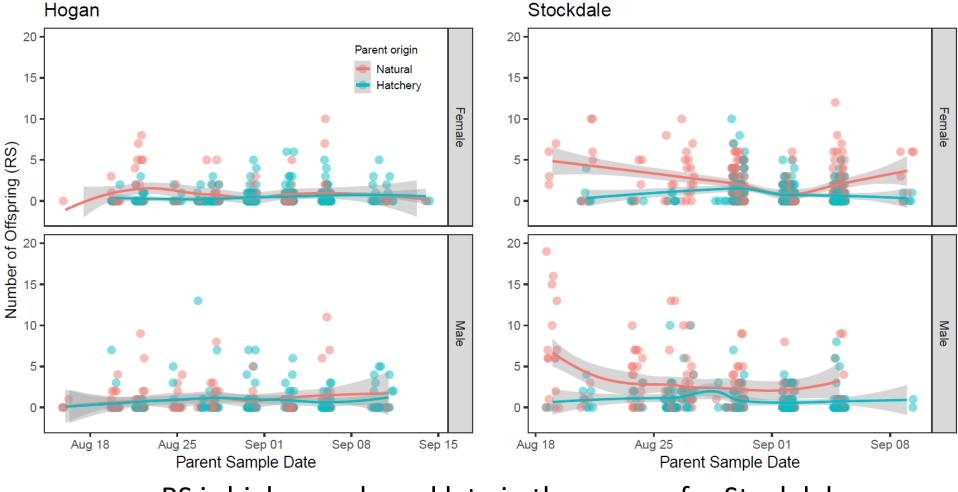




Accounting for Phenotypic Differences

- Phenotypic differences between hatchery/natural
 - Body length
 - Sample date (run timing)
 - Sample location (within a stream)
 - Intertidal vs. freshwater spawners
- Correlated with number of offspring (RS)

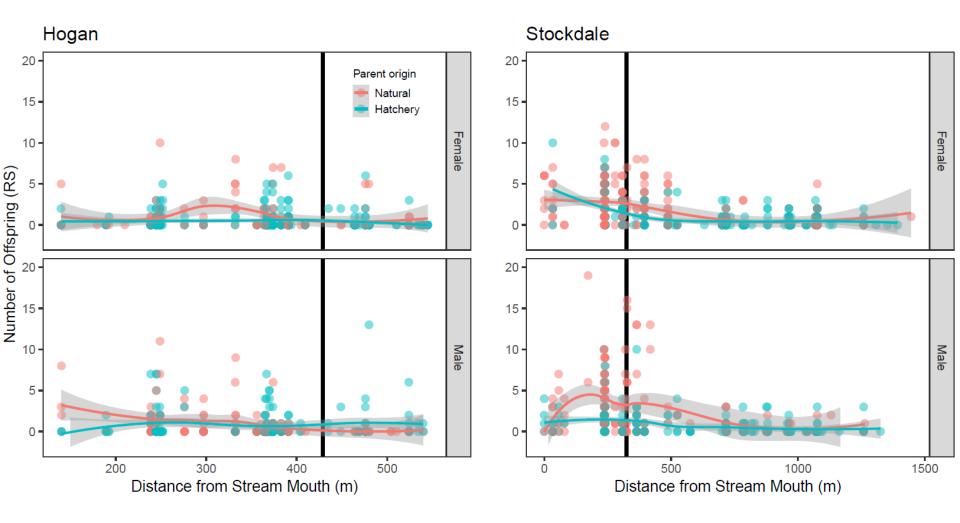
RS vs. Sample Date (2014/2016)



<u>RS is higher early and late in the season for Stockdale...</u> but not for hatchery fish

Figure 4 – Shedd et al. 2022

RS vs. Sample Location (2014/2016)



RS is higher near the intertidal in Stockdale

Figure 5 – Shedd et al. 2022

RS vs. Body Length (2014/2016)

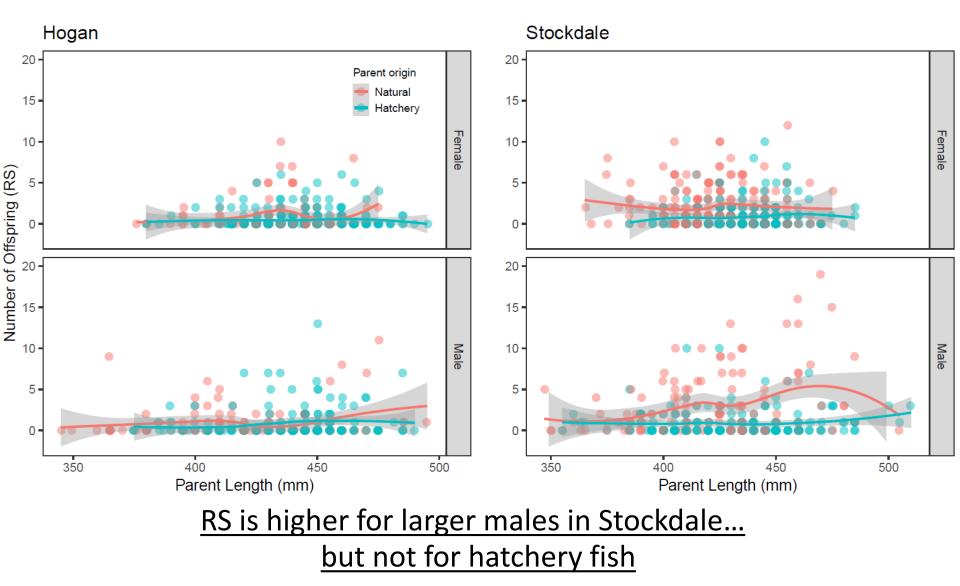
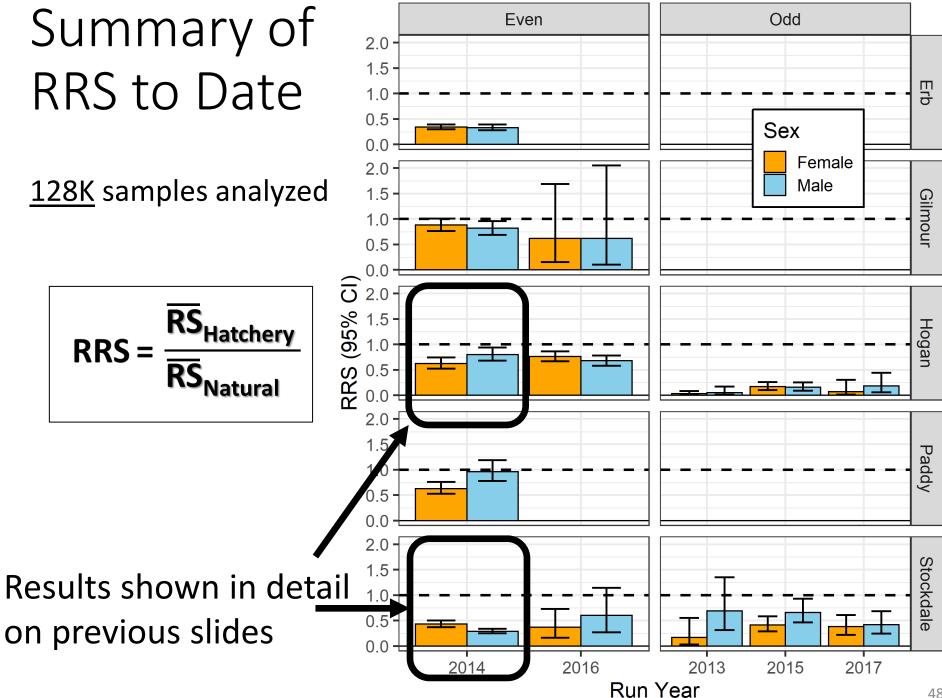


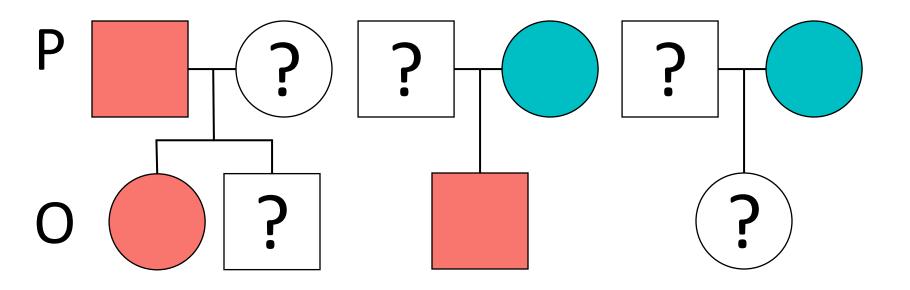
Figure 6 – Shedd et al. 2022

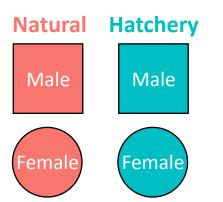
Accounting for Phenotypic Differences

- Differences between hatchery/natural
 - Body length
 - Sample date (run timing)
 - Sample location (within a stream)
- Correlated with number of offspring (RS)
- Generalized linear models (GLM)
 - Origin RRS ~ 42-60%

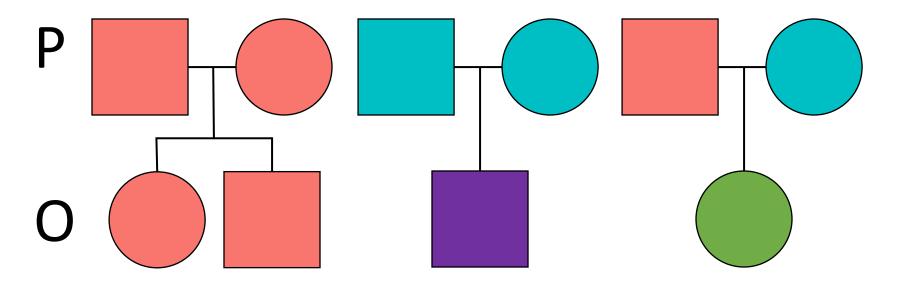


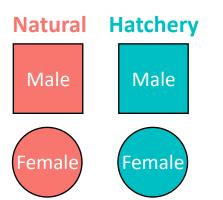
Parent-Offspring Duos

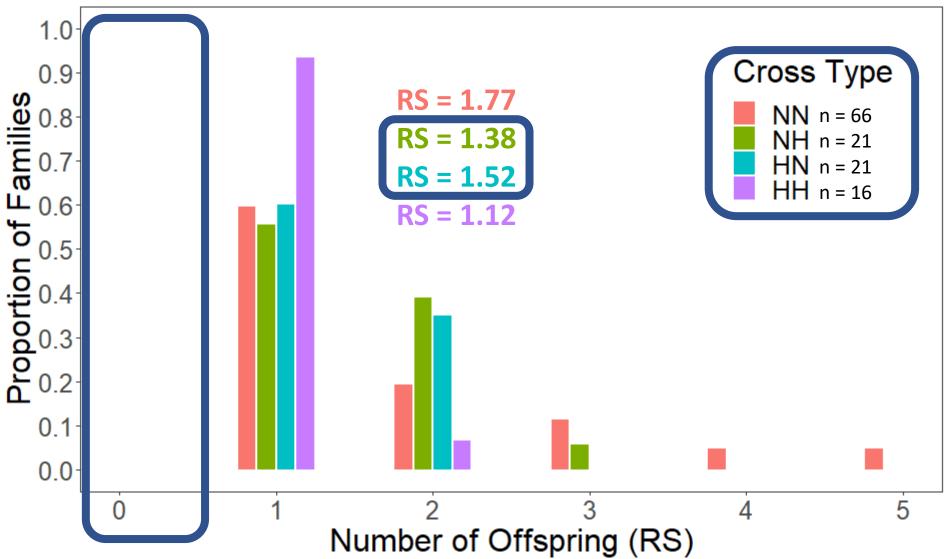


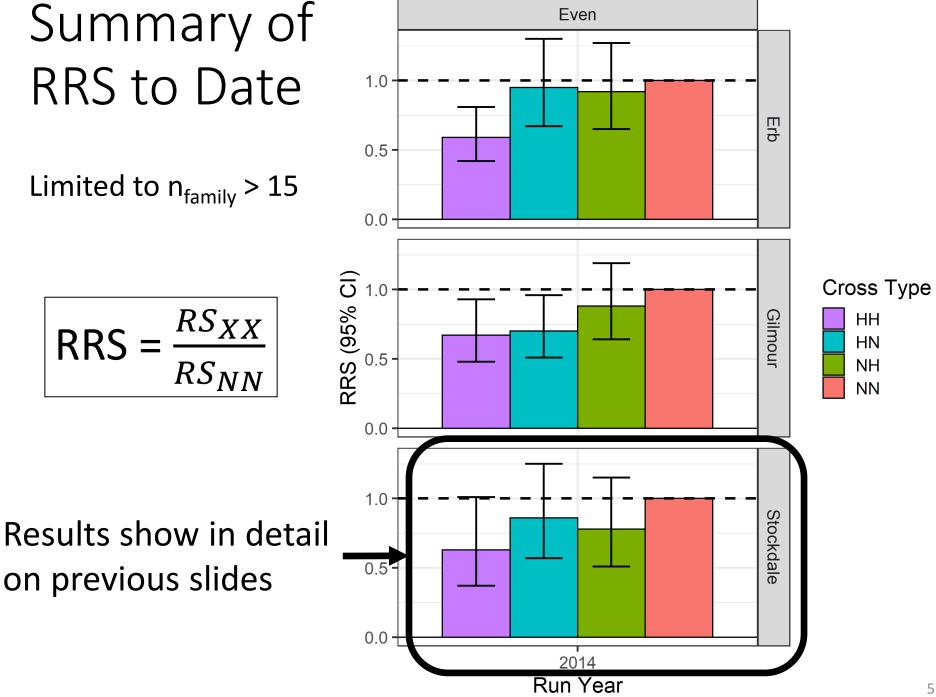


Parent-Pair-Offspring Trios









Conclusions

- Hatchery-origin strays spawn in streams
- Stray hatchery-origin RRS < 1
- Variability in RRS (streams, years, sexes)
- Body size, sample date, sample location matter...
- But stray hatchery-origin RRS still < 1
- Hybrids had intermediate RRS

Remaining Questions

- Are observed reductions in hatchery-origin RRS an artifact of the study design?
 - Returning adults that are harvested?
 - Returning adults that stray to other streams?
 - Sampling proportion through time?
 - Both possible, but unlikely to fully explain our results
- Are results consistent in other streams and years?
 - Yes, RRS consistently < 1, but lots of variation
- Do hatchery/natural hybrids consistently produce fewer offspring than two natural-origin pink salmon?
 - Yes, on average
- Are reductions in fitness <u>persistent across generations</u> (grand-offspring and beyond)?
 - We do not know yet

Acknowledgements

- Alaska Hatchery Research Program
 - State of Alaska
 - Seafood industry
 - Private non-profit hatcheries
- North Pacific Research Board (Project #1619)
 - Funding for Hogan Bay analyses (2013-2016)
- Saltonstall-Kennedy (NA16NMF4270251)
 - 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



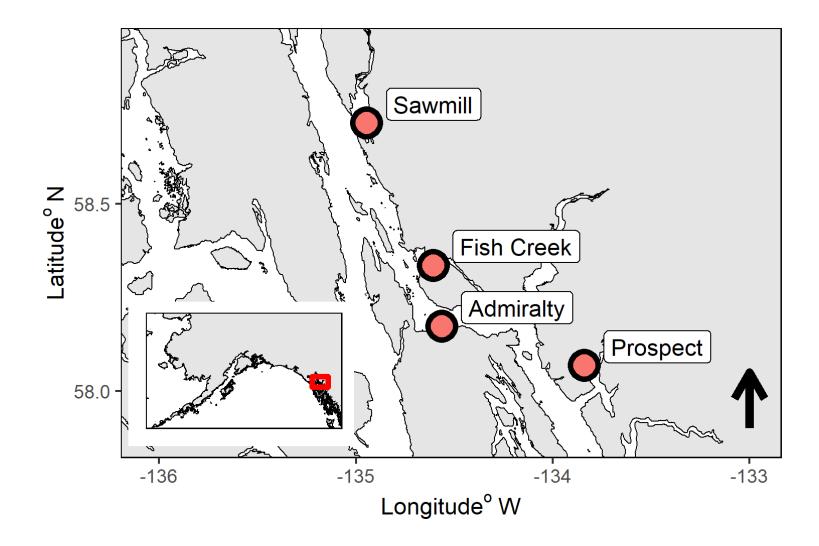




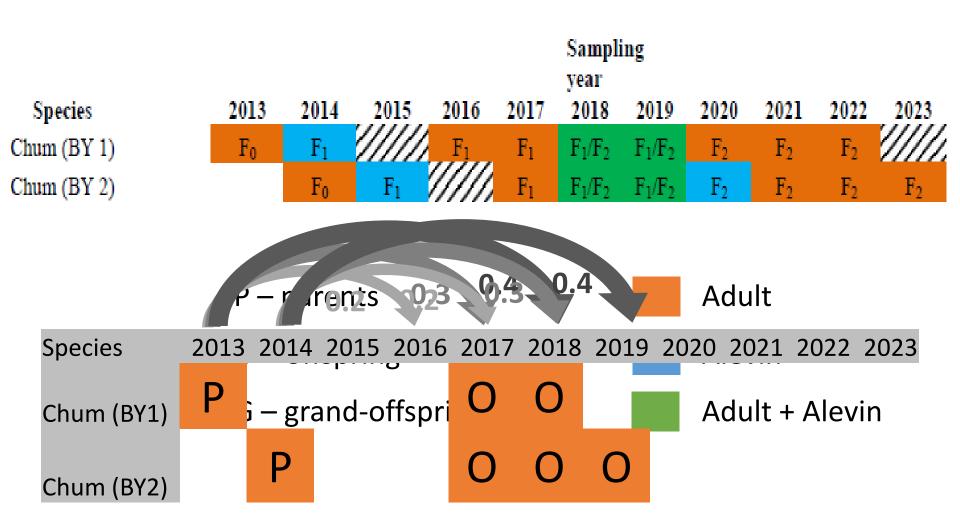


AHRP Fitness Study: SEAK Chum Salmon

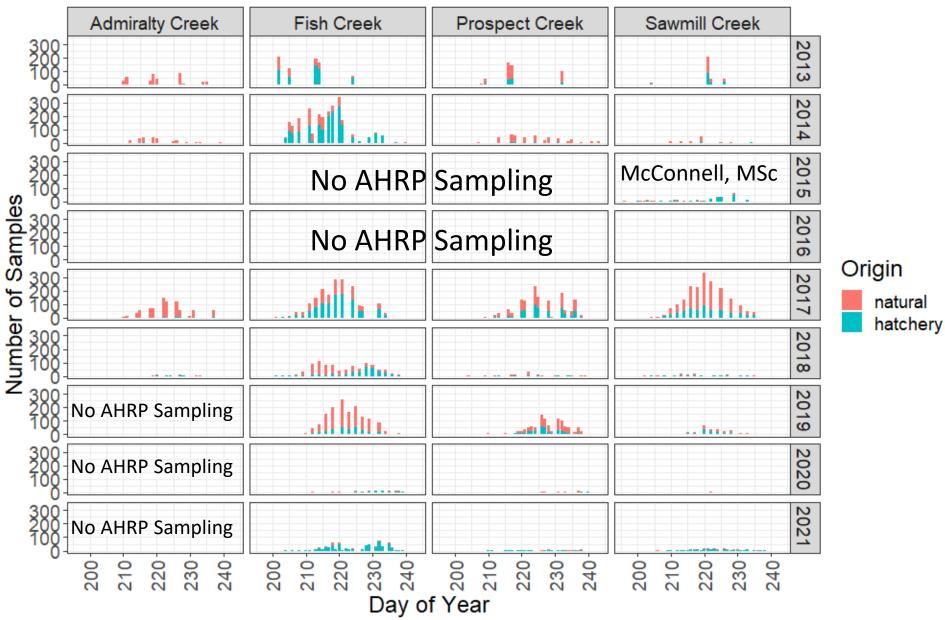
AHRP Streams in SEAK



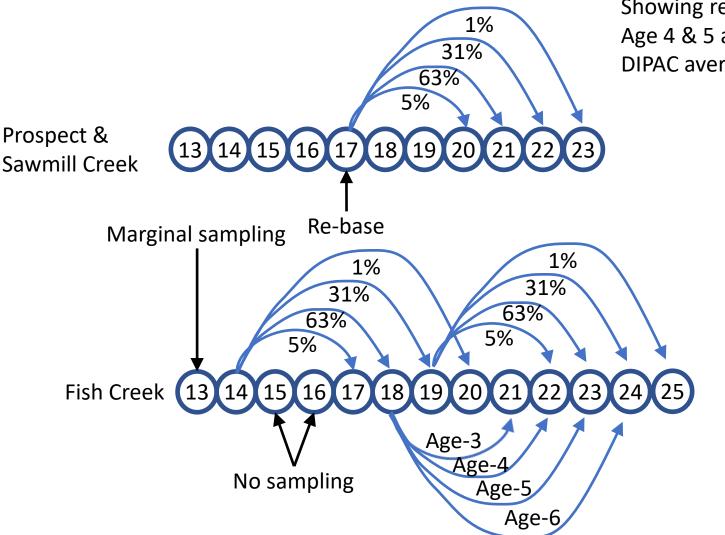
Study Design: Original



Samples Collected to Date



Study Design: Revised



Showing returns age 3 to 6 Age 4 & 5 are most common DIPAC average 1989-2020

Remaining Work

- Field sampling in 2022 & 2023
- Design genetic markers for parentage
- Genotype samples
- Parentage analysis
- Calculate RRS
- GLM to account for length, date, and location

Acknowledgements

- Alaska Hatchery Research Program
 - State of Alaska
 - Seafood industry
 - Private non-profit hatcheries
- Pacific Salmon Commission
 - Northern Endowment Fund
- Sitka Sound Science Center
 - Field collection
- ADF&G Mark, Tag and Age Lab
- ADF&G Gene Conservation Laboratory



Questions?