Alaska Hatchery Research Program: Findings

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Alaska Department of Fish and Game

BOF Hatchery Committee Meeting

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Alaska Hatchery Research Program: Previous Presentations

- 2019
  - Genetic structure: https://www.adfg.alaska.gov/static/regulations/regprocess/fisheriesboard/pdfs/2018-2019/hc/or4.pdf
- 2020
  - Genetic structure: https://www.adfg.alaska.gov/static/regulations/regprocess/fisheriesboard/pdfs/2019-2020/hc/tab4.pdf
  - Straying: https://www.adfg.alaska.gov/static/regulations/regprocess/fisheriesboard/pdfs/2019-2020/hc/tab5.pdf
  - Fitness: https://www.adfg.alaska.gov/static/regulations/regprocess/fisheriesboard/pdfs/2019-2020/hc/tab6.pdf
- 2022
  - Genetic structure: https://www.adfg.alaska.gov/static/regulations/regprocess/fisheriesboard/pdfs/2021-2022/hc/6_GilkBaumer%20AHRP%20Study%20Question%201%20Population%20Structure.pdf
  - Straying: https://www.adfg.alaska.gov/static/regulations/regprocess/fisheriesboard/pdfs/2021-2022/hc/7_Templin%20AHRP%20Study%20Question%202%20Straying%20and%20Run%20Reconstruction.pdf
  - Fitness: https://www.adfg.alaska.gov/static/regulations/regprocess/fisheriesboard/pdfs/2021-2022/hc/8_Shedd%20AHRP%20Study%20Question%203%20Relative%20Reproductive%20Success%20Update.pdf
- General Information
  - AHRP Website: https://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesResearch.current_research
  - Informational Meetings: https://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesResearch.meetings#infomeetings

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 fitness (productivity) of natural pink and chum stocks due to straying hatchery pink and chum salmon?

More detailed information available at:
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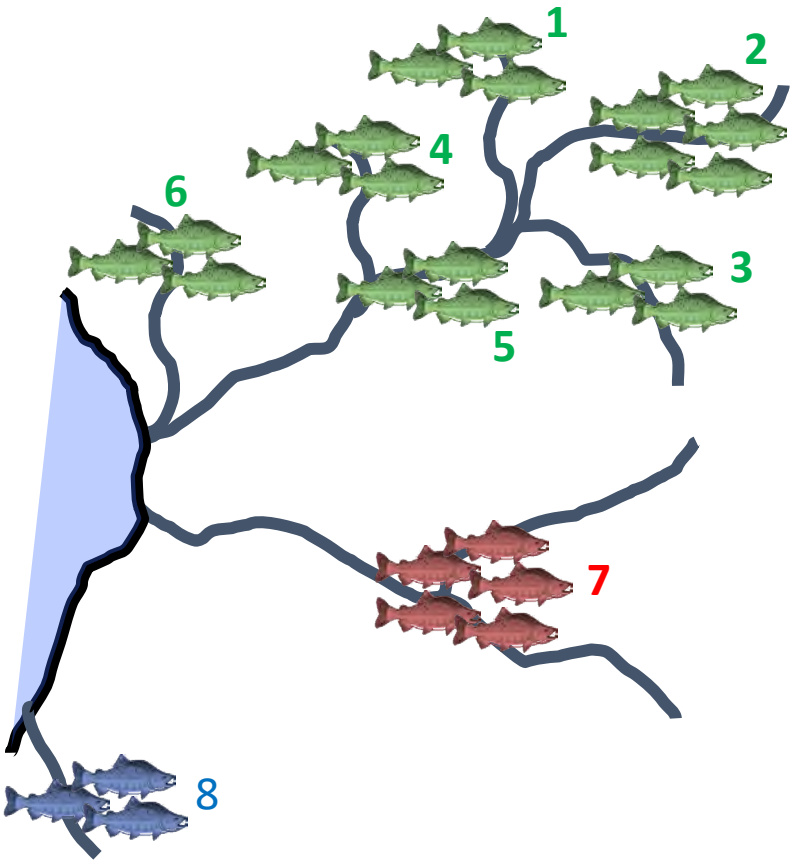
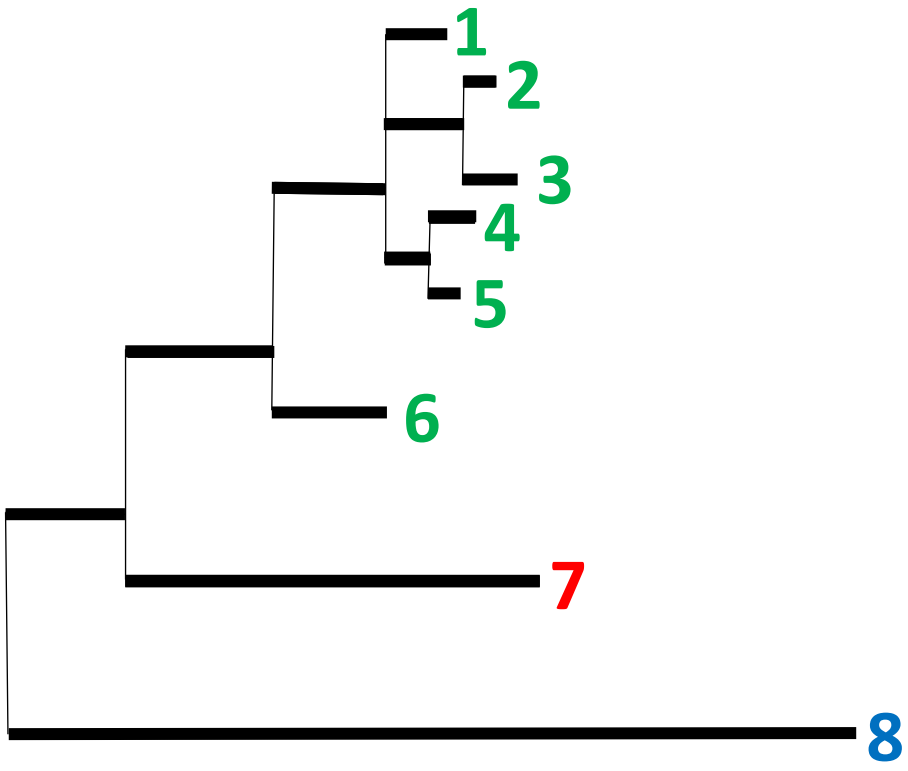
Population Structure: An example

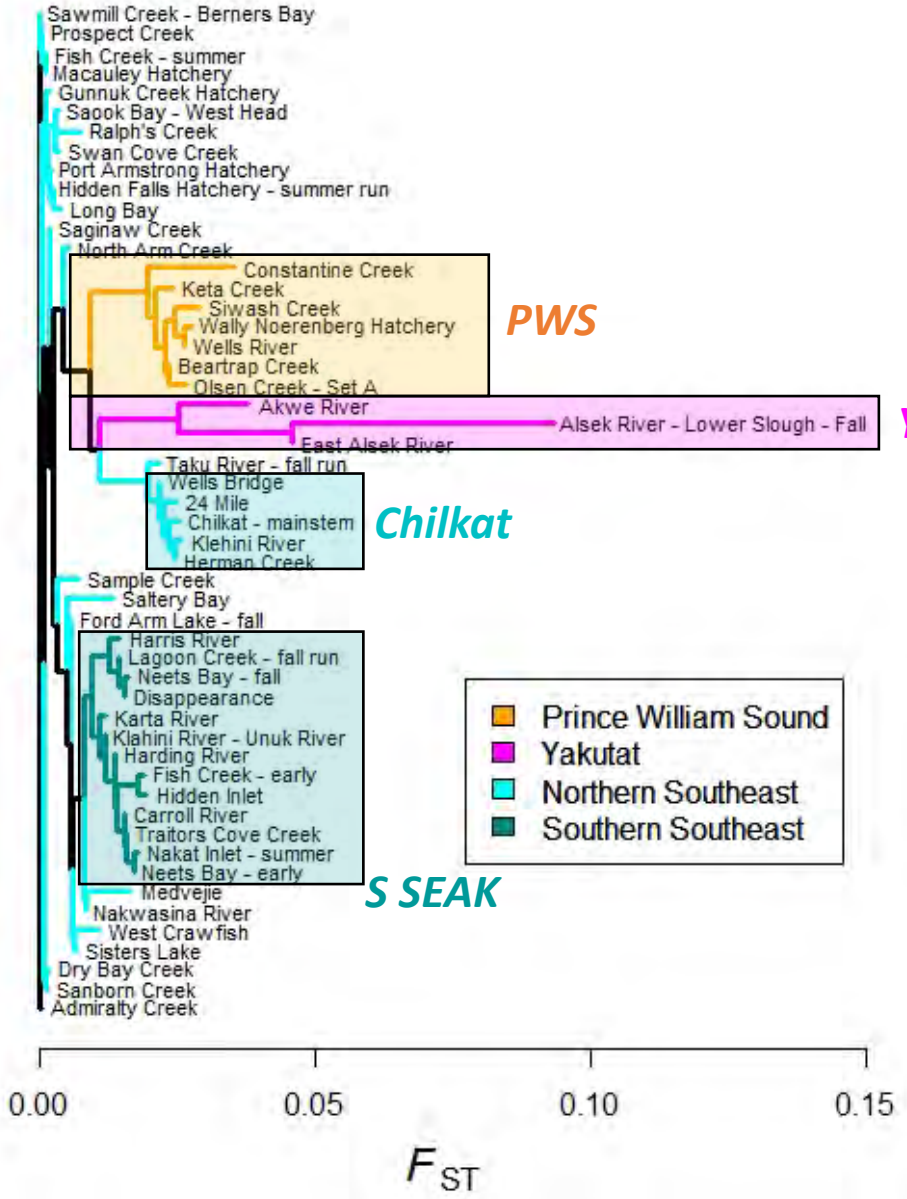


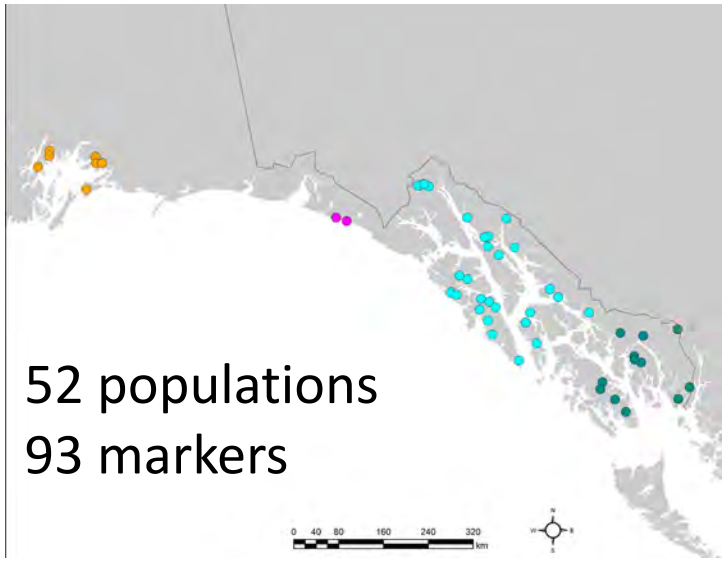


Difference between 1 and 4:

Difference between 2 and 7:

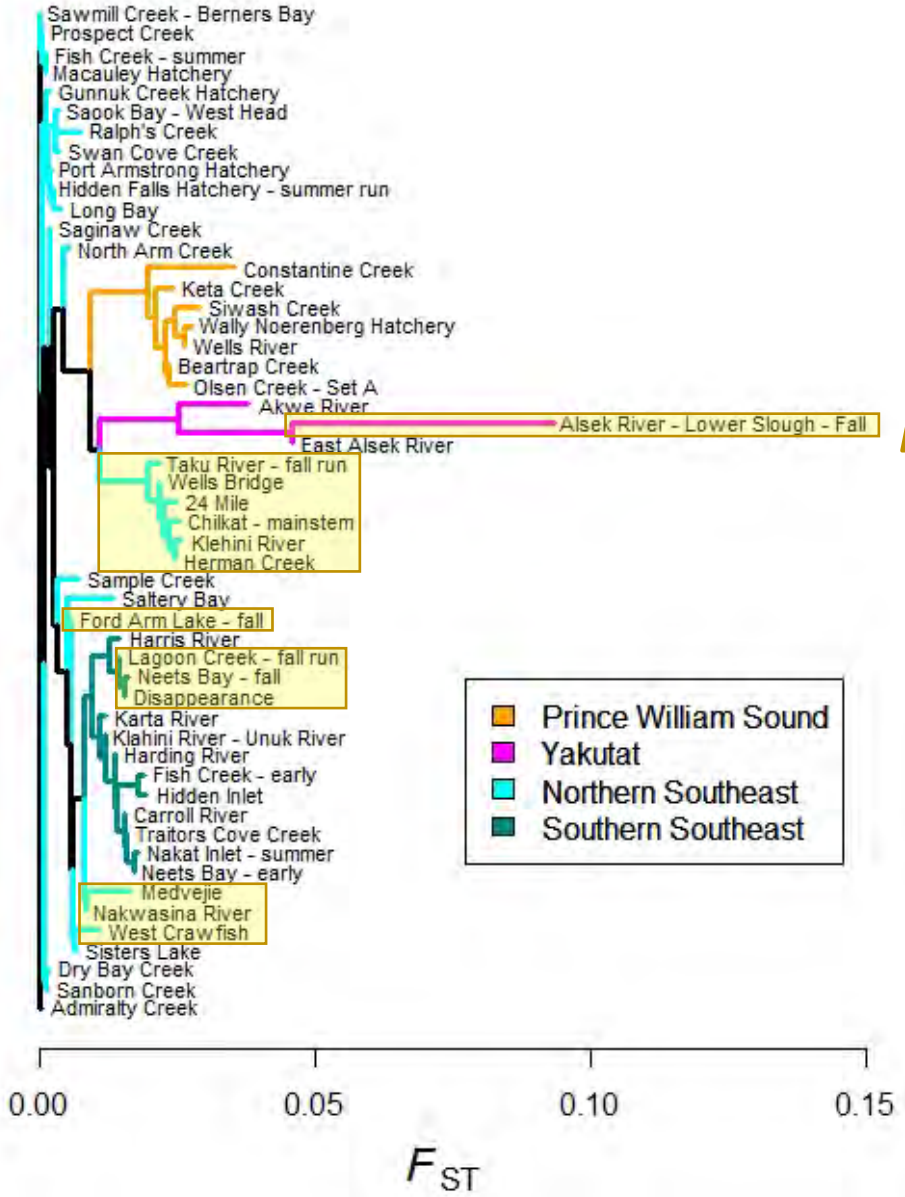
Chum Salmon: Genetic Structure



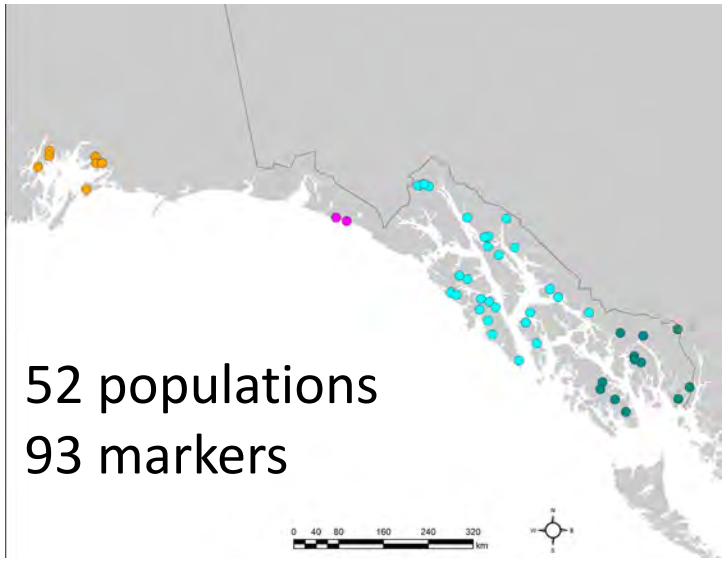


52 populations
93 markers

Chum Salmon: Genetic Structure



Late run timing



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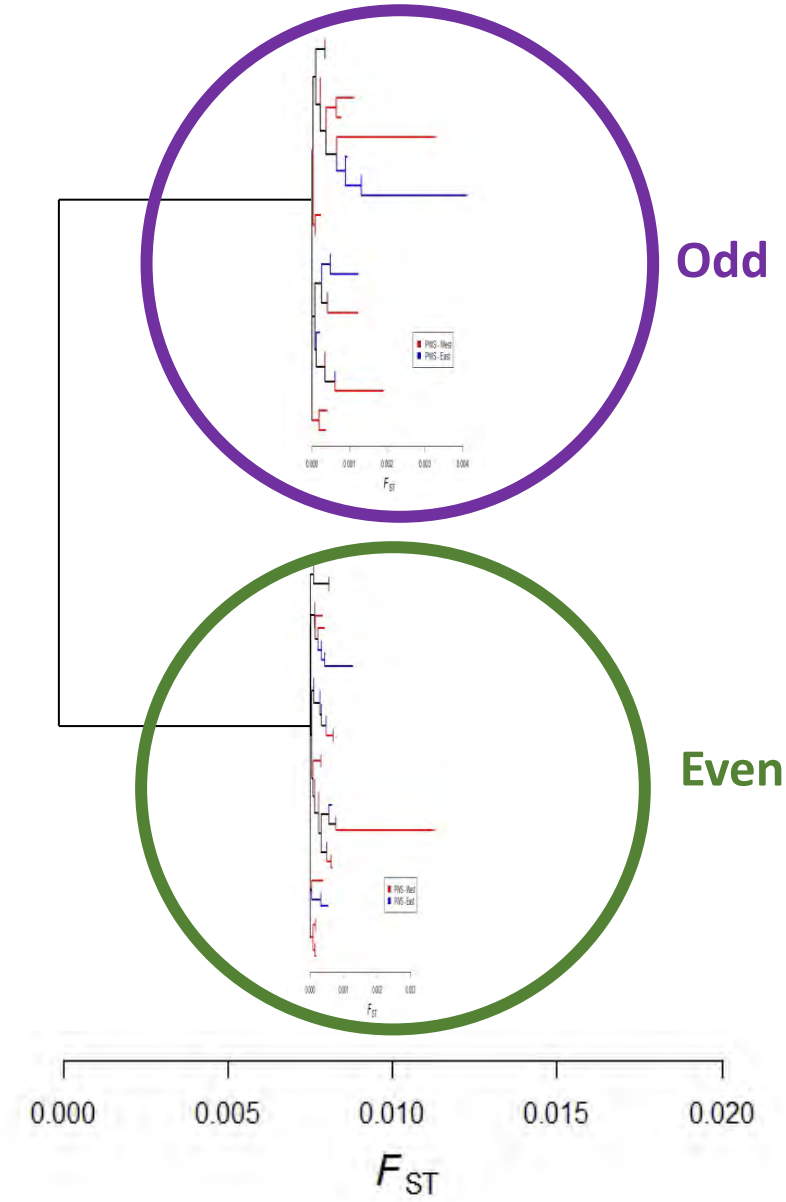
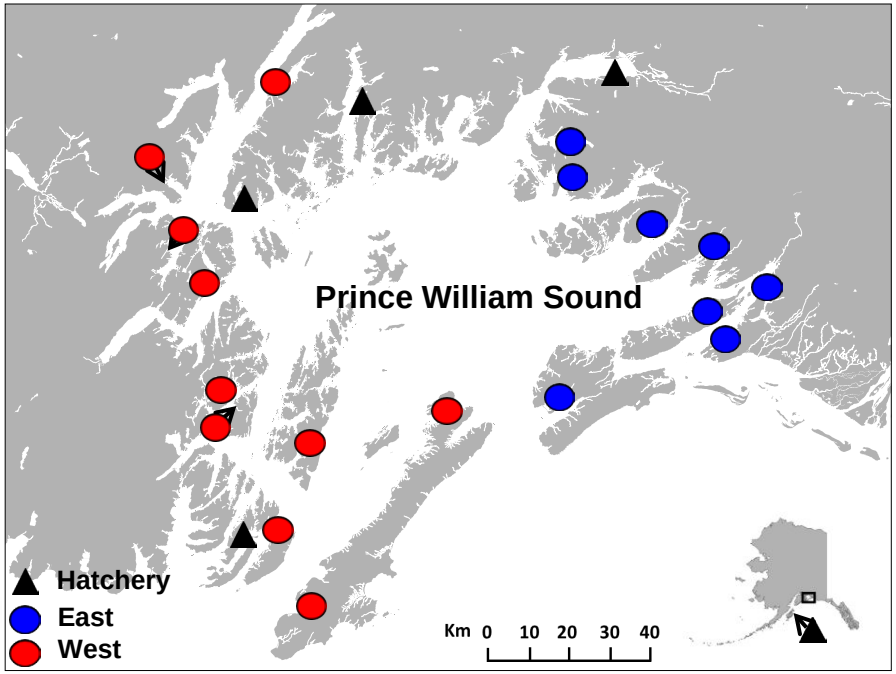
Pink Salmon: Genetic Structure

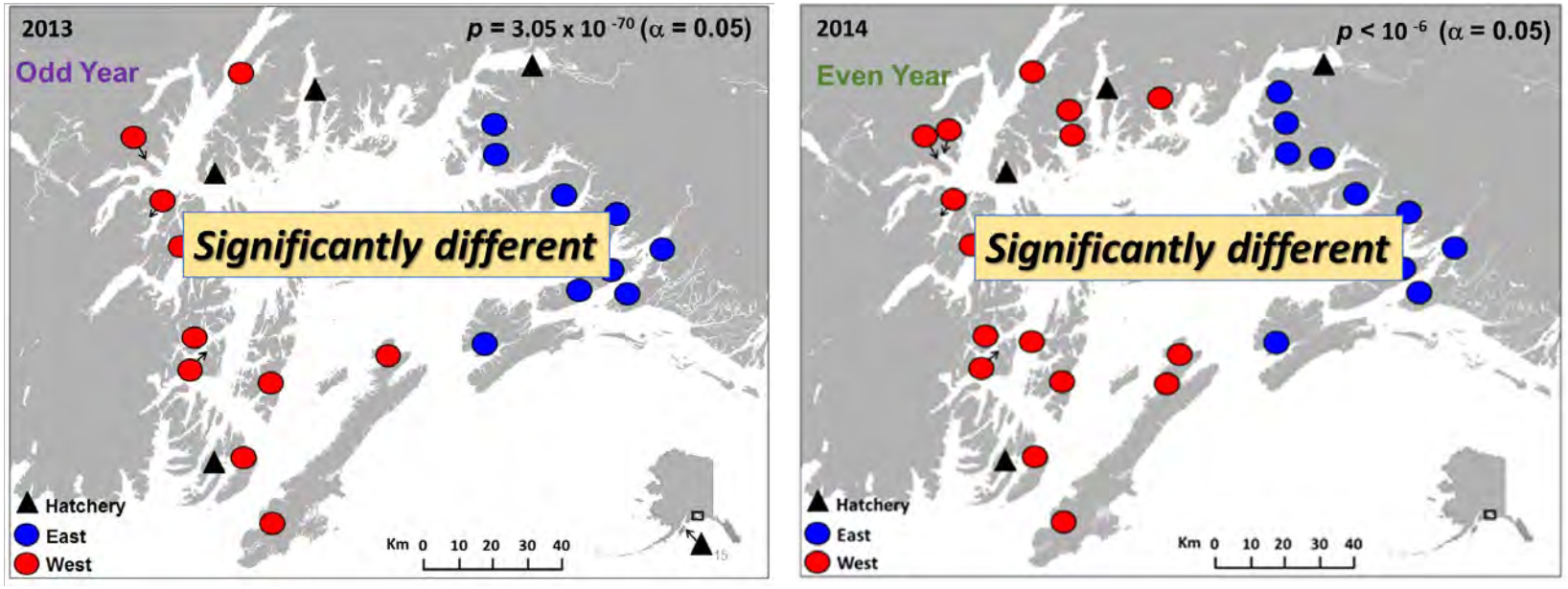




Pink Salmon: PWS Population Structure Analyses

Genetic differences:

1. Among contemporary collections of natural fish
   - *Population structure exists for both lineages, though variation is small*



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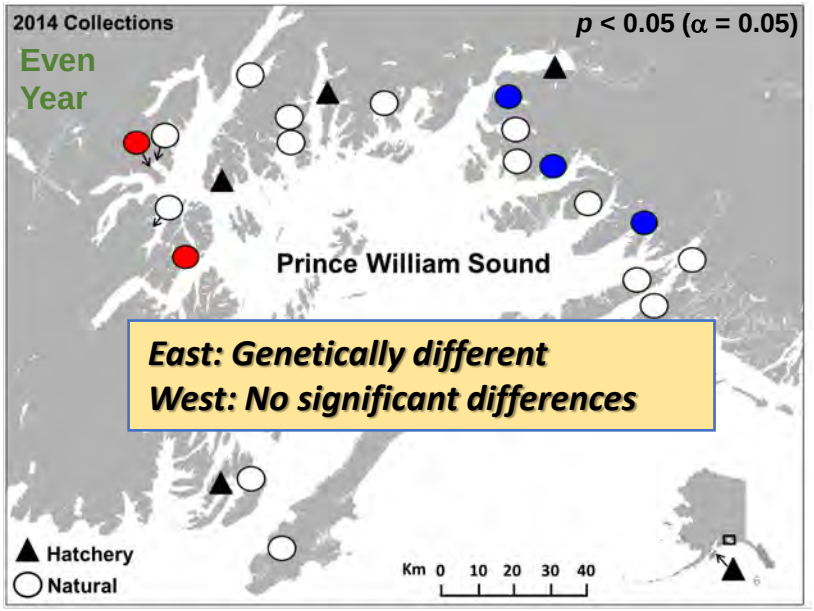

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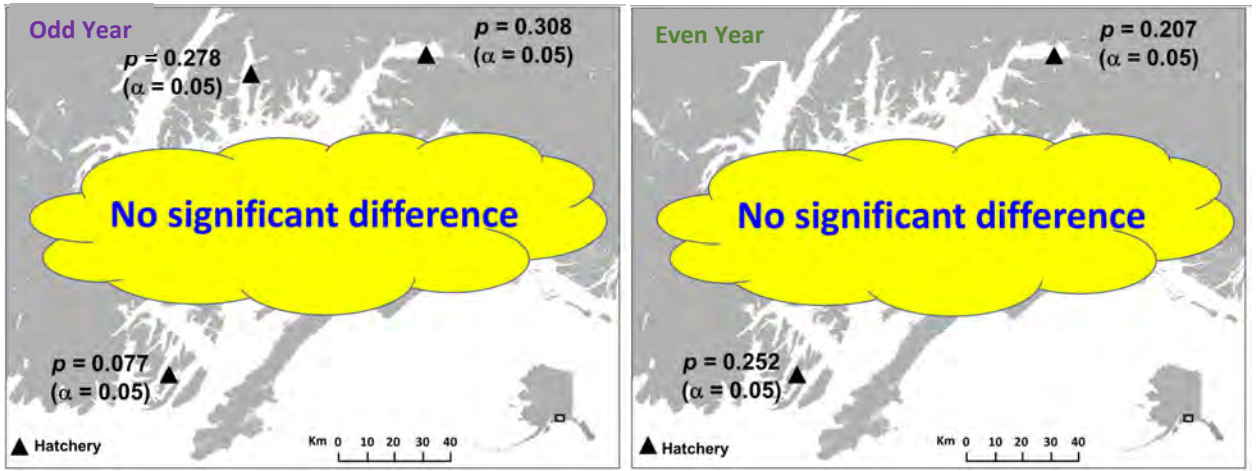
2. Between contemporary & historical, hatchery only
   - *Hatchery stocks show temporal stability*



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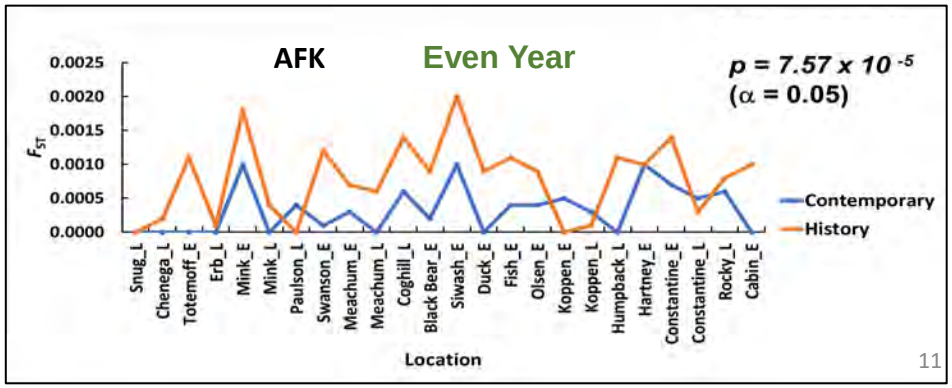
2. Between contemporary & historical, hatchery only
   - *Hatchery stocks show temporal stability*
3. Between contemporary & historical, hatchery and natural
   - *Limited evidence for homogenization over time*



Take-Home: 1. Genetic Structure

- Chum salmon
  - Structure driven by run timing and geography
- Pink salmon
  - Even and odd lineages genetically distinct
  - Genetic variation among populations
    - Odd year: small
    - Even year: even smaller
  - Genetic differentiation among populations
    - Odd year: east/west
    - Even year: early/late
  - Hatchery fish have not changed over time but may have affected natural populations

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More detailed information available at:
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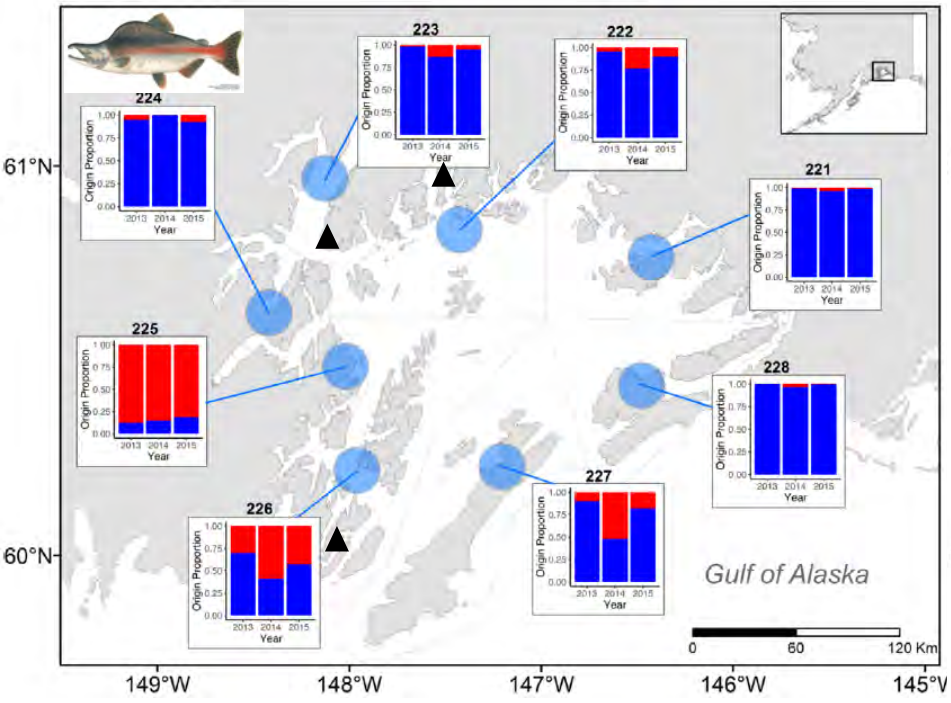
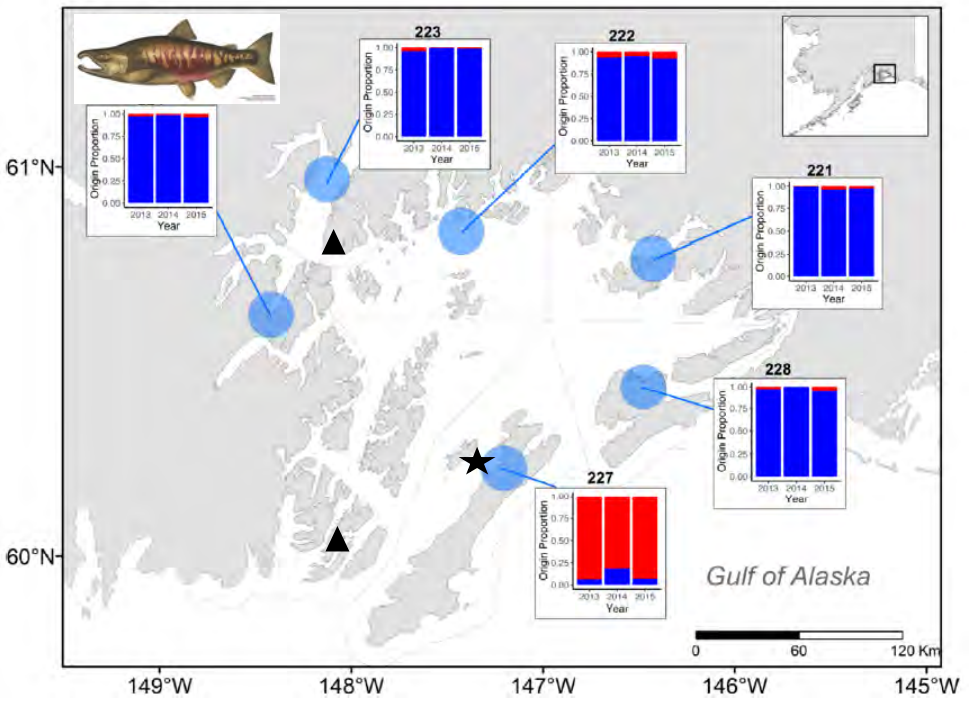
PWS Hatchery Proportions in Escapement

By District, 2013-2015

Pink



Chum



Range: 0.1% -89.9%

- Hatchery Origin
- Natural Origin
- ▲ Hatchery
- ★ Remote Release

0.0% - 84.6%

Knudsen et al. 2021. Hatchery fish straying, run sizes, escapement, and harvest rates of adult Pink Salmon and Chum Salmon returning to Prince William Sound, Alaska in 2013-2015. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 13:58–85 https://doi.org/10.1002/mcf2.10134

PWS Hatchery Proportions in Escapement

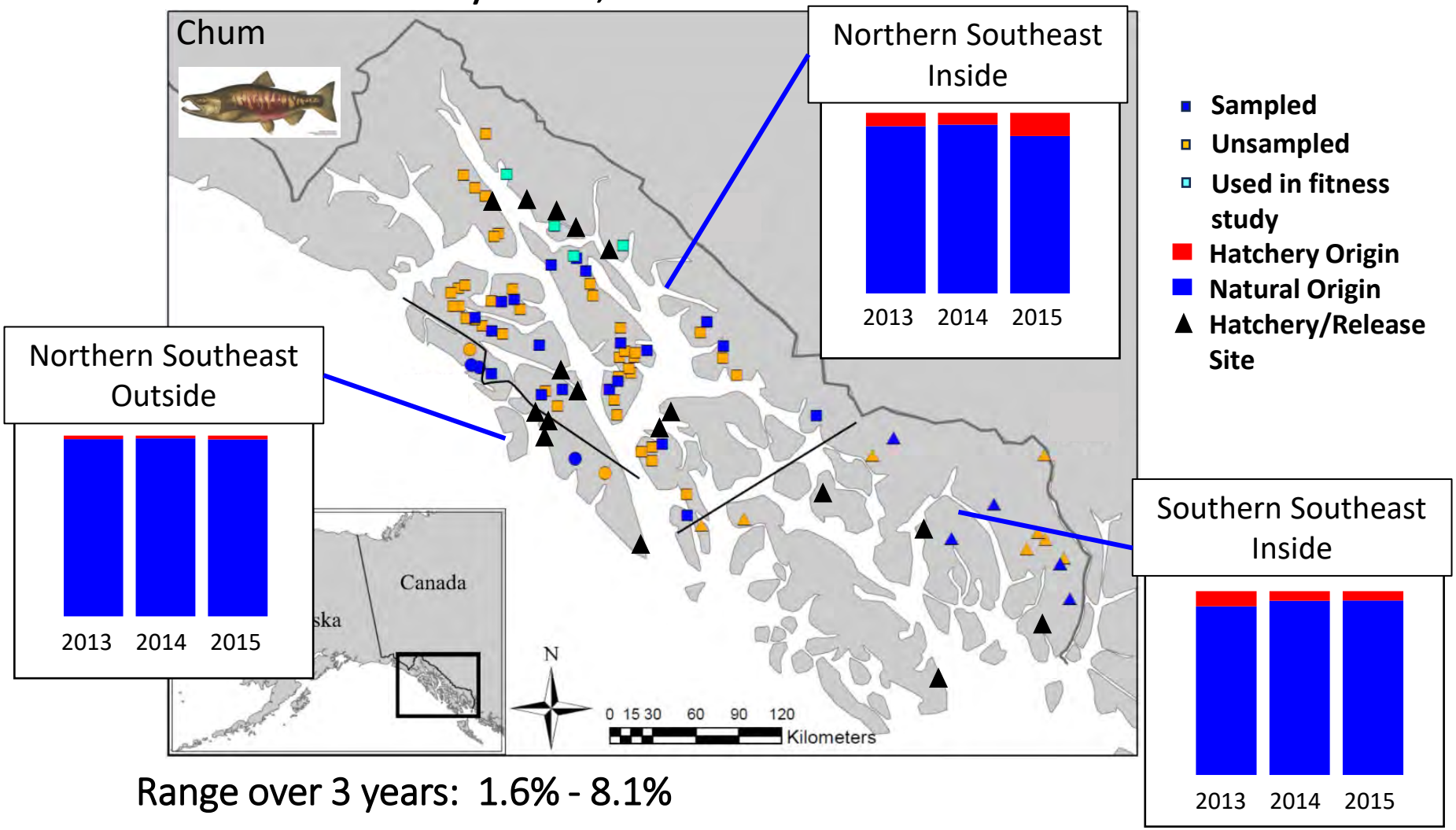
Soundwide, 2013-2015

Species	2013	2014	2015
Pink	4.5%	14.7%	10.5%
Chum	2.8%	3.3%	9.2%

Knudsen et al. 2021. Hatchery fish straying, run sizes, escapement, and harvest rates of adult Pink Salmon and Chum Salmon returning to Prince William Sound, Alaska in 2013-2015. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 13:58–85 https://doi.org/10.1002/mcf2.10134

SEAK Hatchery Proportions in Escapement

By Area, 2013-2015



Range over 3 years: 1.6% - 8.1%

Josephson, R., et al. Proportions of Hatchery Fish in Escapements of Summer-Run Chum Salmon in Southeast Alaska, 2013–2015. North American Journal of Fisheries Management 41.3 (2021): 724-738. https://doi.org/10.1002/nafm.10580

SEAK Hatchery Proportions in Escapement

Regionwide, 2013-2015

Species	2013	2014	2015
Chum	3.2%	3.1%	6.0%

Hatchery fish are found in streams in PWS and SEAK; Proportions higher near hatcheries, release sites, or along migratory pathways

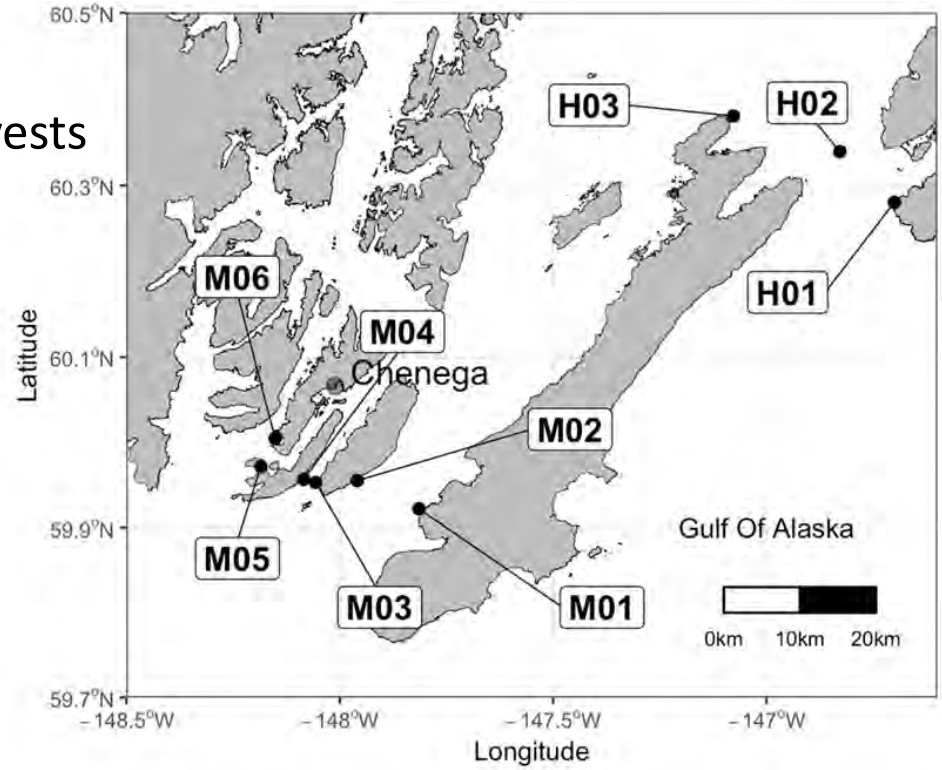
Josephson, R., et al. Proportions of Hatchery Fish in Escapements of Summer-Run Chum Salmon in Southeast Alaska, 2013–2015. North American Journal of Fisheries Management 41.3 (2021): 724-738. https://doi.org/10.1002/nafm.10580

PWS Run Reconstructions

Sources of information

1. Test fishery at entrances to PWS
   - Proportions of hatchery in run
   - Relative abundance of run
2. Commercial and cost recovery harvests
   - Proportion hatchery in harvest
   - Number of fish in harvest
3. Hatchery broodstock
4. Stream carcass surveys
   - Proportion hatchery in escapement
5. Stream escapement surveys
   - Index of escapement

Test Fishery Locations



PWS Run Reconstructions

Ocean sampling

Proportions of hatchery fish in **run**

- Pink salmon: 55 - 86%
- Chum salmon: 51 - 73%

Species Common Name	Year	Hatchery Proportion	SE
Pink Salmon	2013	0.679	.016
	2014	0.864	.03
	2015	0.549	.004
Chum Salmon	2013	0.725	.019
	2014	0.511	.029
	2015	0.688	.015

Knudsen et al. 2021. Hatchery fish straying, run sizes, escapement, and harvest rates of adult Pink Salmon and Chum Salmon returning to Prince William Sound, Alaska in 2013-2015. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 13:58–85 https://doi.org/10.1002/mcf2.10134

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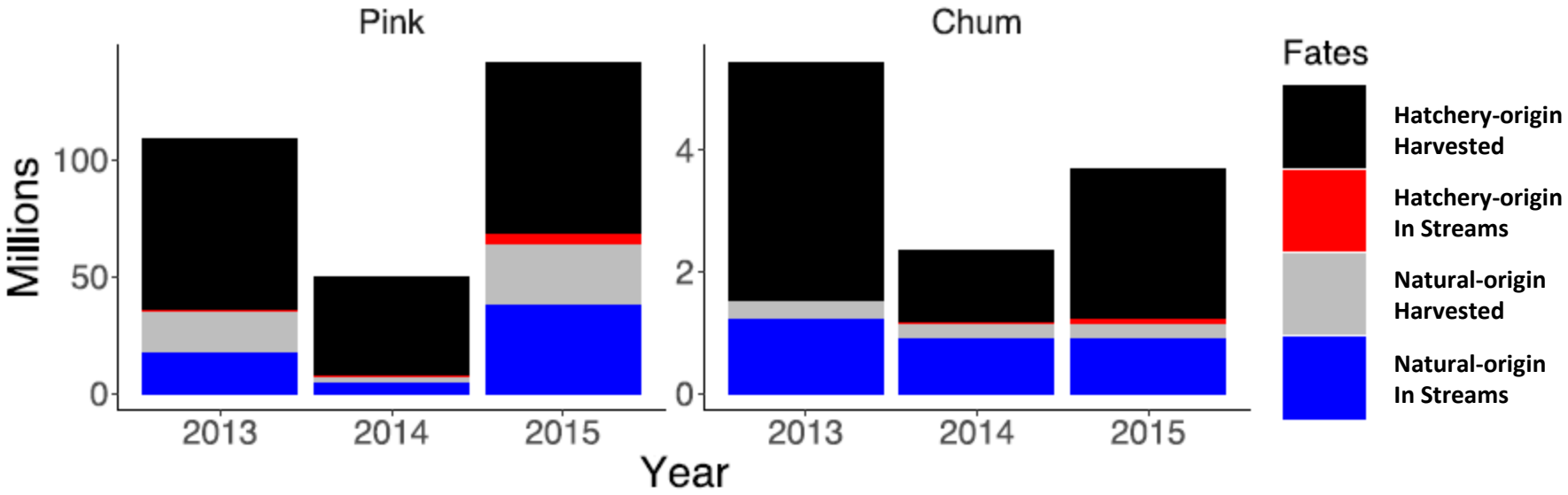

	Harvest Rate			
	Pink		Chum	
Year	Wild	Hatchery	Wild	Hatchery
2013	0.50	0.99	0.17	0.99
2014	0.27	0.98	0.20	0.97
2015	0.40	0.94	0.19	0.96

High harvest rates on hatchery fish

Knudsen et al. 2021. Hatchery fish straying, run sizes, escapement, and harvest rates of adult Pink Salmon and Chum Salmon returning to Prince William Sound, Alaska in 2013-2015. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 13:58–85 https://doi.org/10.1002/mcf2.10134

PWS Run Reconstructions

Hatchery and Stream Stray Rates, Pink Salmon

	2013	2014	2015
Straying out of Hatcheries	1.0%	1.6%	5.2%
Straying into Streams	4.5%	14.7%	10.5%

Proportion of hatchery runs that end up in escapements are small. The proportion of the escapement they comprise can be relatively large

Knudsen et al. 2021. Hatchery fish straying, run sizes, escapement, and harvest rates of adult Pink Salmon and Chum Salmon returning to Prince William Sound, Alaska in 2013-2015. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 13:58–85 https://doi.org/10.1002/mcf2.10134

Take-Home: 2. Straying

- Hatchery fish found in streams
  - Pink: 5 – 15% in PWS
  - Chum: 3 – 9% in PWS, 3 – 6% in SEAK
- Highest proportions near hatcheries or release sites, or along migratory pathways
- Higher harvest rates on hatchery-origin
- Proportion of hatchery run in escapement are low, and that can be a large number of fish

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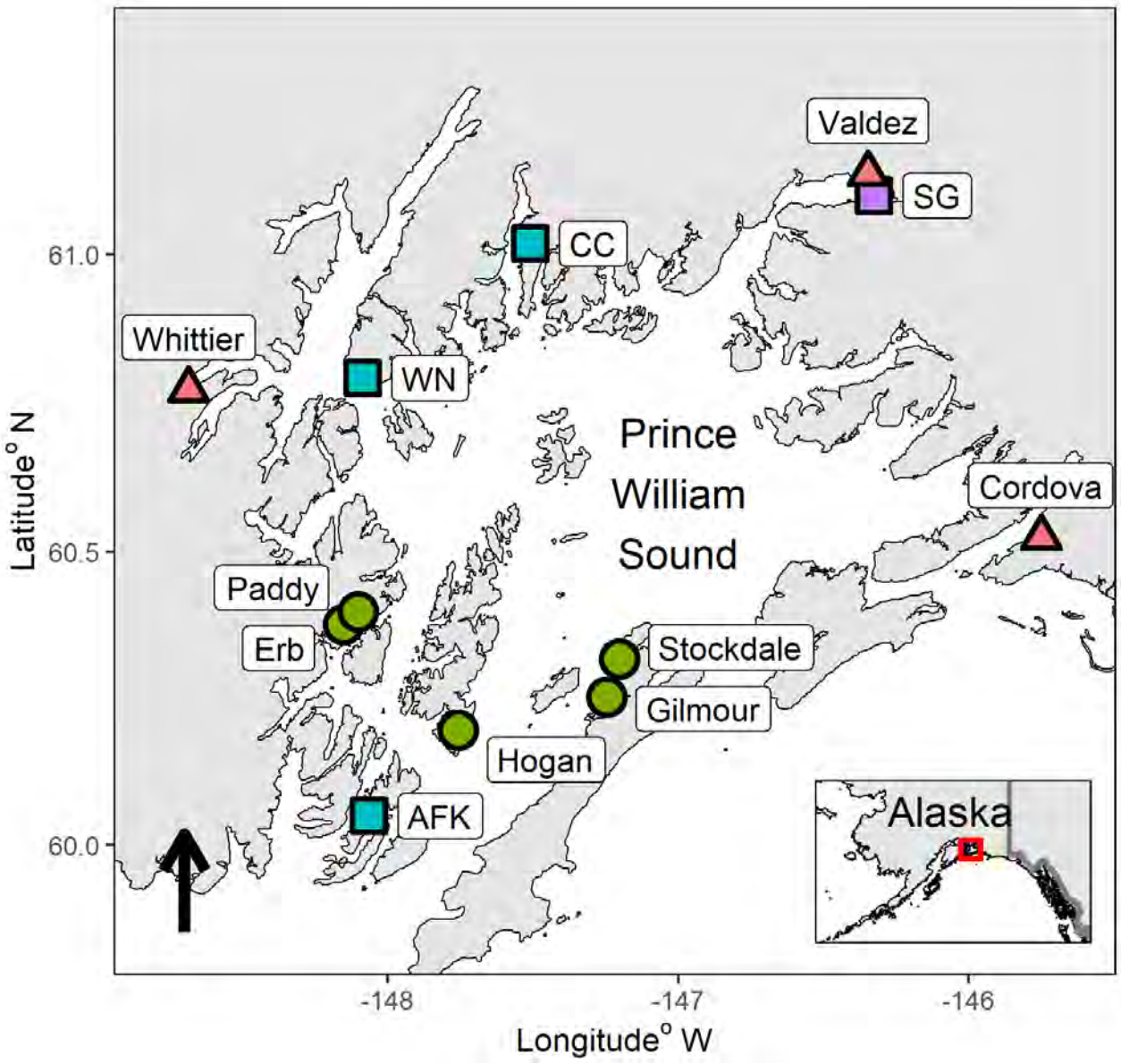
Pink Fitness Study

Pink Fitness Study: PWS Streams



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

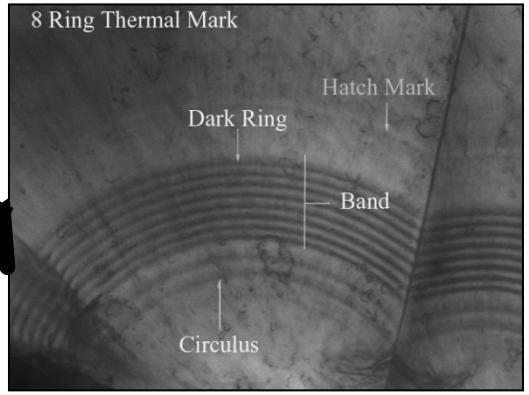
Pink Fitness Study: Field Sampling

- Intensive carcass sampling
  - Body length
  - Date
  - Location
    - Intertidal
    - Upstream
  - Otolith
  - Tissue

Photo credit: Brad von Wichman (PWSSC)

Pink Fitness Study: Otoliths → Origin

Photo credit: David Janka, PWSSC

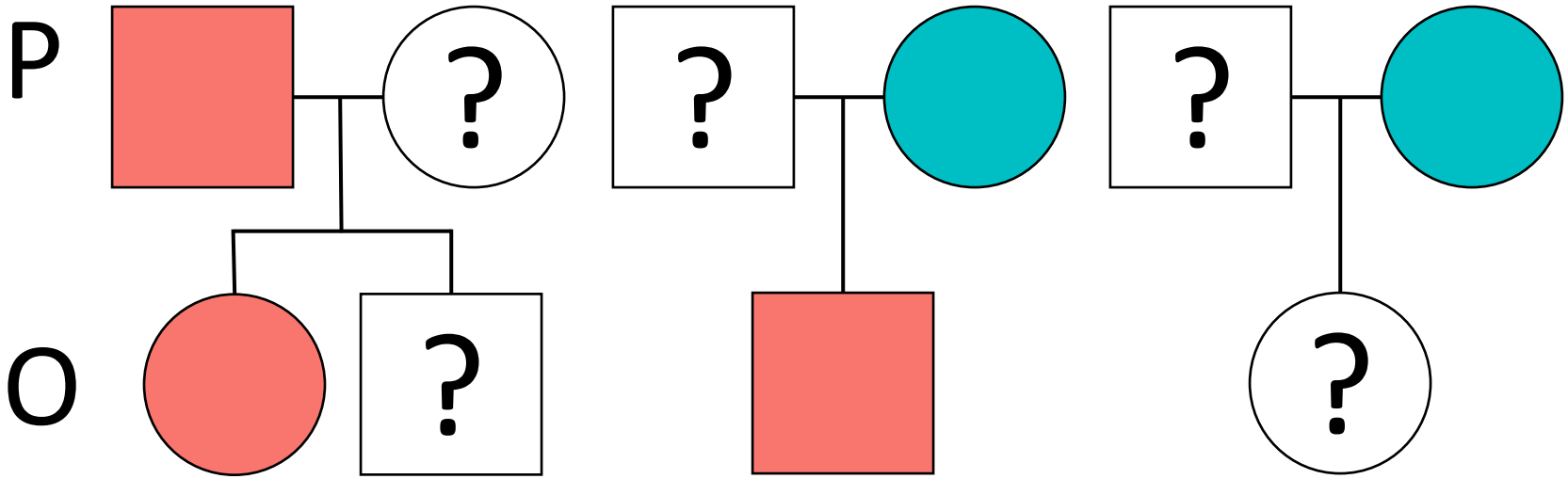


Hatchery-origin

No thermal mark

Natural-origin

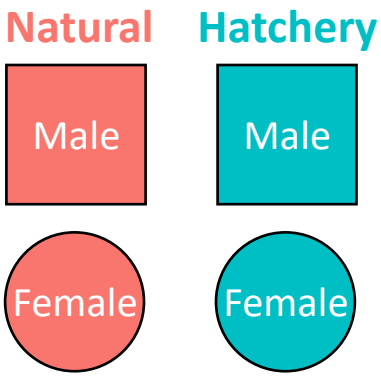
Pink Fitness Study: Measuring Reproductive Success



Reproductive Success (RS) = # of Offspring

Relative Reproductive Success (RRS)

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



Pink Fitness Study: Average Reproductive Success

Stockdale 2014/2016

Female	2014 Parents	2016 Offspring	Average RS
Hatchery	229	233	1.02
Natural	219	520	2.37

$$\text{RRS} = \frac{1.02}{2.37} = 0.43$$

Male	2014 Parents	2016 Offspring	Average RS
Hatchery	202	212	1.05
Natural	137	494	3.61

$$\text{RRS} = \frac{1.05}{3.61} = 0.29$$

Remember: RRS < 1 means hatchery strays had fewer offspring on average

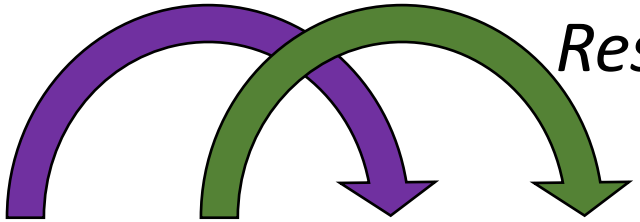
Pink Fitness Study: Study Design

Stream	2013	2014	2015	2016	2017	2018	2019
Stockdale	P	P	P,O	P,O	P,O,G	O,G	O,G

P – parents
O – offspring
G – grand-offspring

Odd-lineage
Even-lineage

Pink Fitness Study: Study Design



Results on slide 28

Stream	2013	2014	2015	2016	2017	2018	2019
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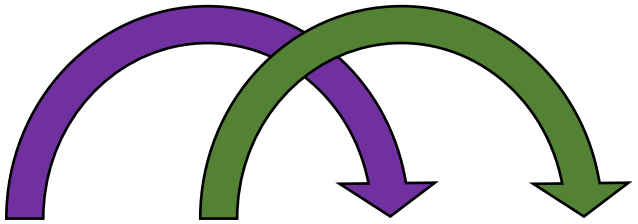

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Stockdale	P	P	P,O	P,O	P,O,G	O,G	O,G	
Gilmour		P	P	P,O	P,O	O,G	O,G	
Paddy	P	P	P,O	P,O	O,G	P,O,G		O,G
Erb	P	P	P,O	P,O	O,G	P,O,G		O,G

P – parents
O – offspring
G – grand-offspring

Odd-lineage
Even-lineage

>235K samples!

Pink Fitness Study: Study Design

Presented 2020

Stream	2013	2014	2015	2016	2017	2018	2019	2020
Hogan	P	P	P,O	P,O	P,O,G	O,G	O,G	
Stockdale	P	P	P,O	P,O	P,O,G	O,G	O,G	
Erb	P	P	P,O	P,O	O,G	P,O,G		O,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. https://doi.org/10.1111/eva.13356

P – parents

O – offspring

G – grand-offspring

Odd-lineage

Even-lineage

>235K samples!

Pink Fitness Study: Study Design

Presented 2022

Stream	2013	2014	2015	2016	2017	2018	2019	2020
Hogan	P	P	P,O	P,O	P,O,G	O,G	O,G	
Stockdale	P	P	P,O	P,O	P,O,G	O,G	O,G	
Gilmour		P	P	P,O	P,O	O,G	O,G	
Paddy	P	P	P,O	P,O	O,G	P,O,G		O,G
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P – parents

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Odd-lineage

Even-lineage

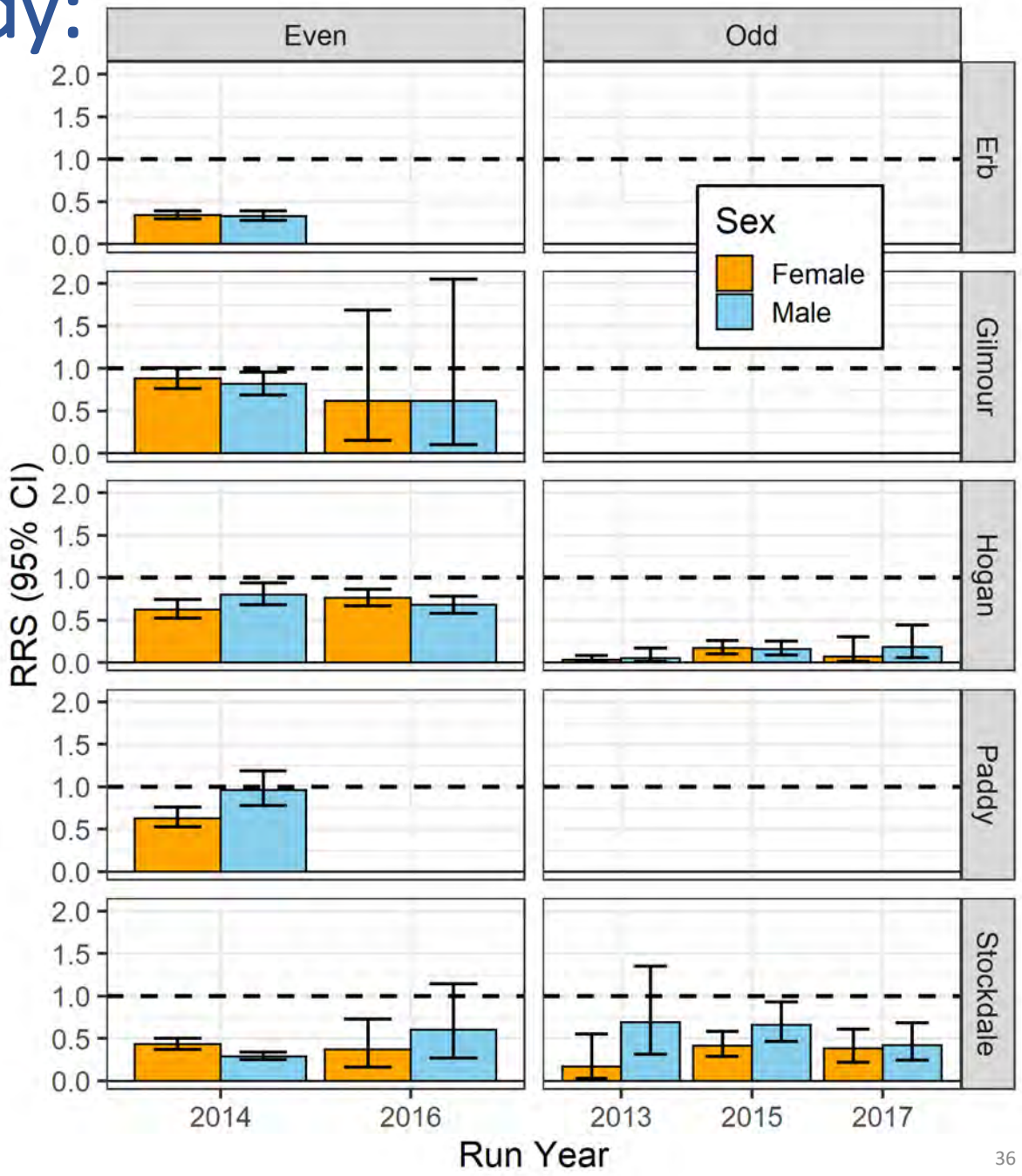
>235K samples!

Pink Fitness Study: Summary of RRS to Date

128K samples analyzed

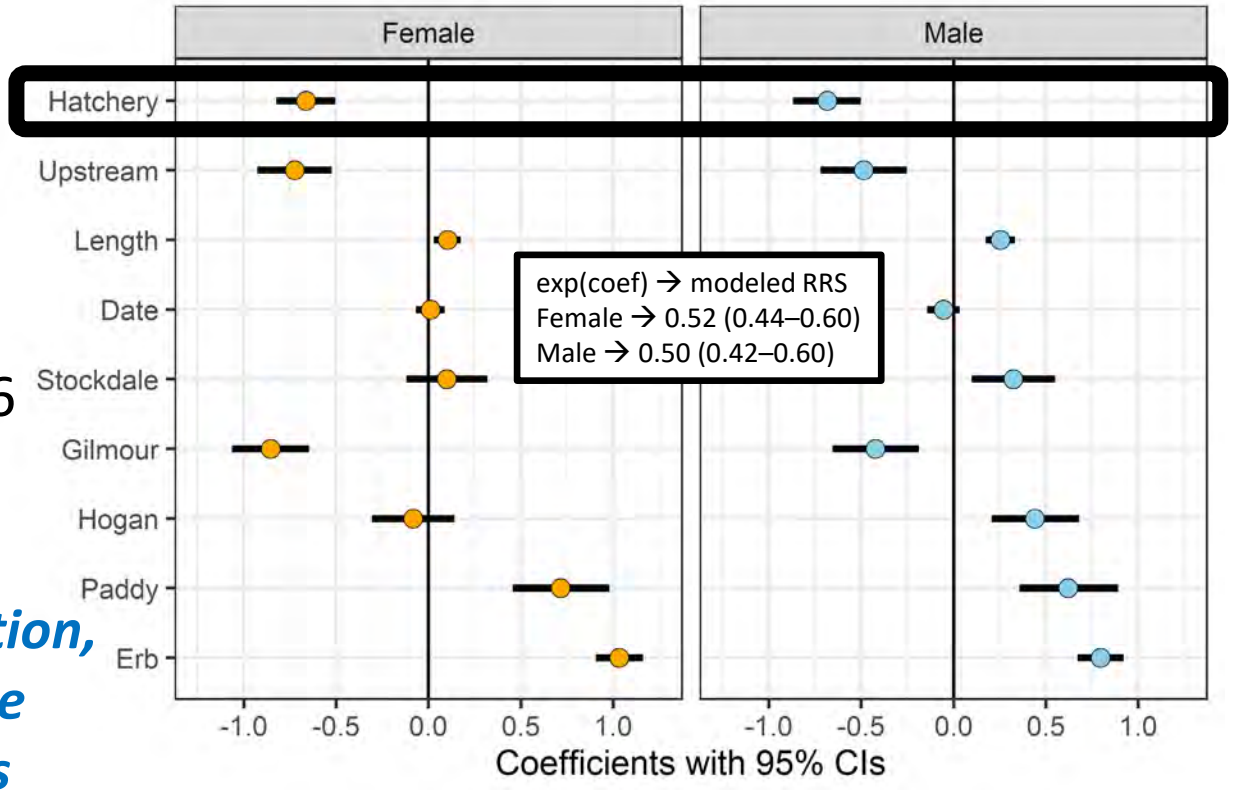
$$RRS = \frac{\overline{RS}_{Hatchery}}{\overline{RS}_{Natural}}$$

Hatchery-origin strays have lower reproductive success



Pink Fitness Study: What about covariates?

- Try to explain variation in reproductive success based on:
  - Stream
  - Sample date
  - Body size
  - Sample location
  - Origin
- Model using 2014/2016 data from all 5 streams

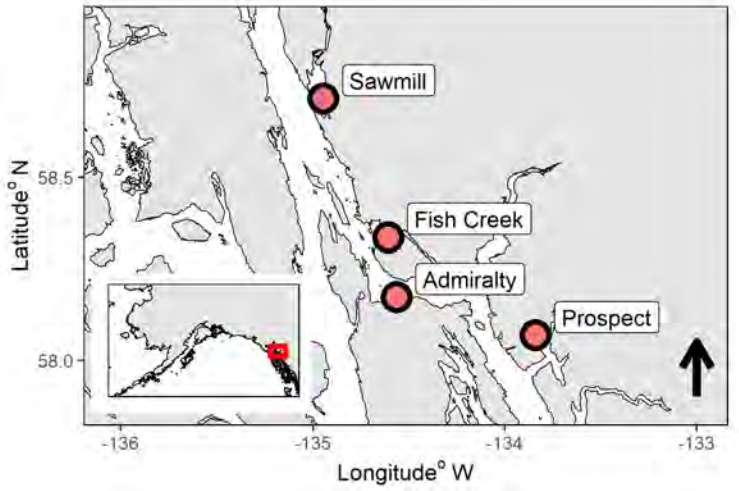


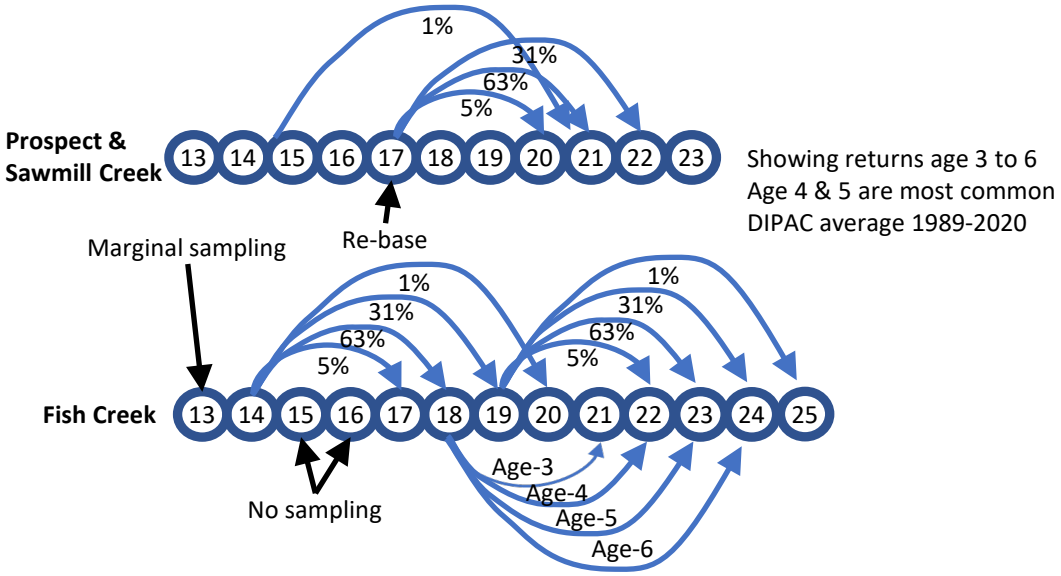
After accounting for variation, hatchery-origin strays have lower reproductive success

Chum Fitness Study

Chum Fitness Study: In Progress

- 4 streams, northern SE Alaska
- Multiple age classes
  - Need consistent sampling for primary age classes (age-4 & -5)
- To date, ~17.7K samples
  - Poor sampling conditions
  - Poor chum returns
  - Few strays in some streams
- Revised study design





Chum Fitness Study: Remaining Work

- Winter 2023: Finalize genetic markers
- Spring 2024: Genotype
- Summer/Fall 2024: Parentage Analysis
- Fall 2024: Calculate RRS
- Winter 2024: Model RRS

Take-home: 3. Impact on Fitness

Pink Salmon

- Hatchery-origin strays spawn in streams
- Hatchery-origin strays have lower reproductive success
- Variability in RRS (streams, years, sexes)
- Body size, sample date, sample location also matter
- Stray hatchery-origin RRS still < 1

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 persistent across generations (grand-offspring and beyond)?
  - We do not know yet

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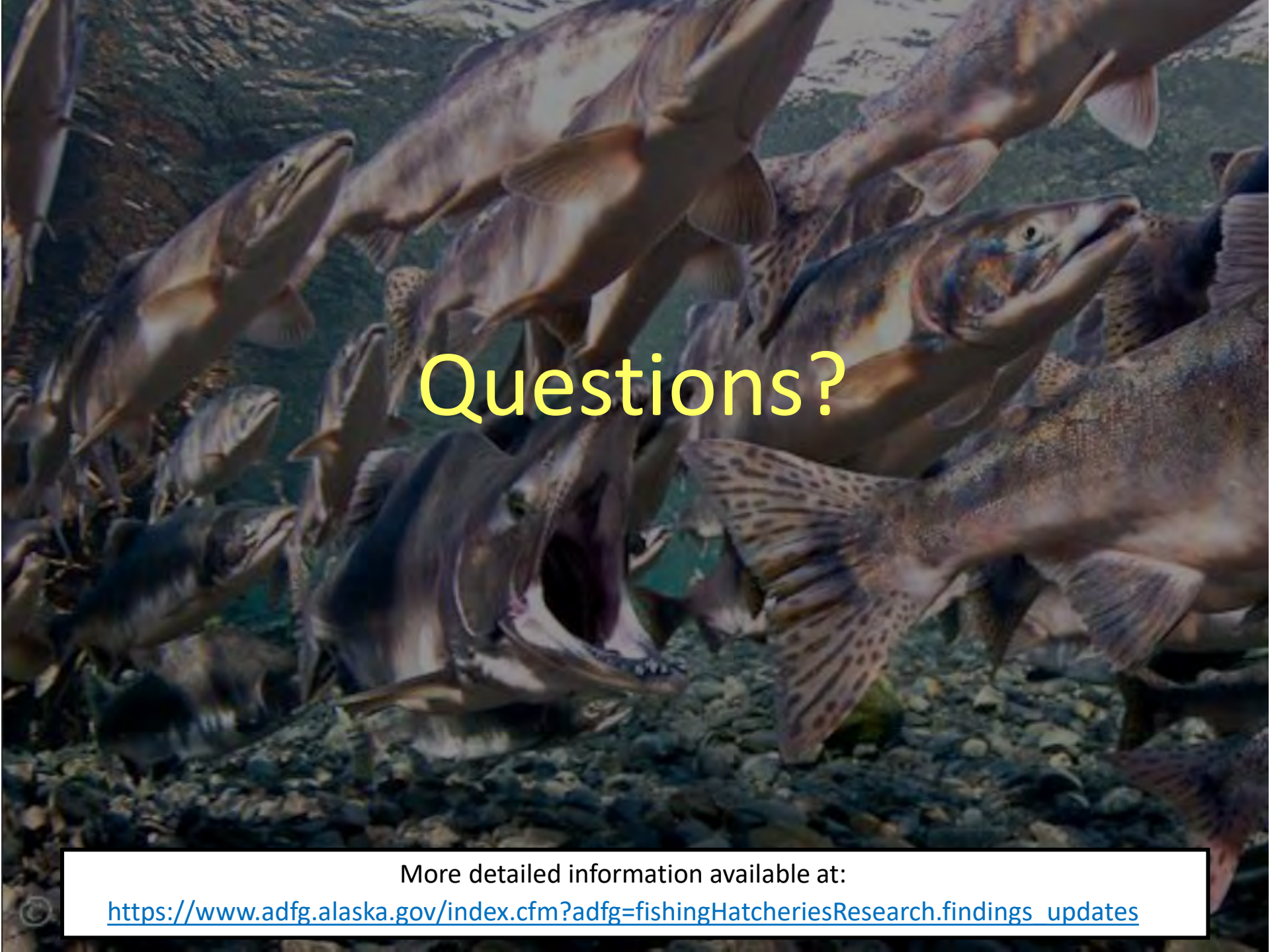
- Prince William Sound Science Center
  - Field collection
- Sitka Sound Science Center
  - Field collection
- ADF&G Mark, Tag, and Age Lab
- ADF&G Cordova Otolith Lab
- University of Washington - Seeb Lab
- University of Alaska Fairbanks
- ADF&G Gene Conservation Laboratory



More detailed information available at:
https://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesResearch.findings_updates