Genetic Parentage Analysis of Fall Creek Spring Chinook Salmon: An Evaluation of Return Timing and Functional Gene Diversity

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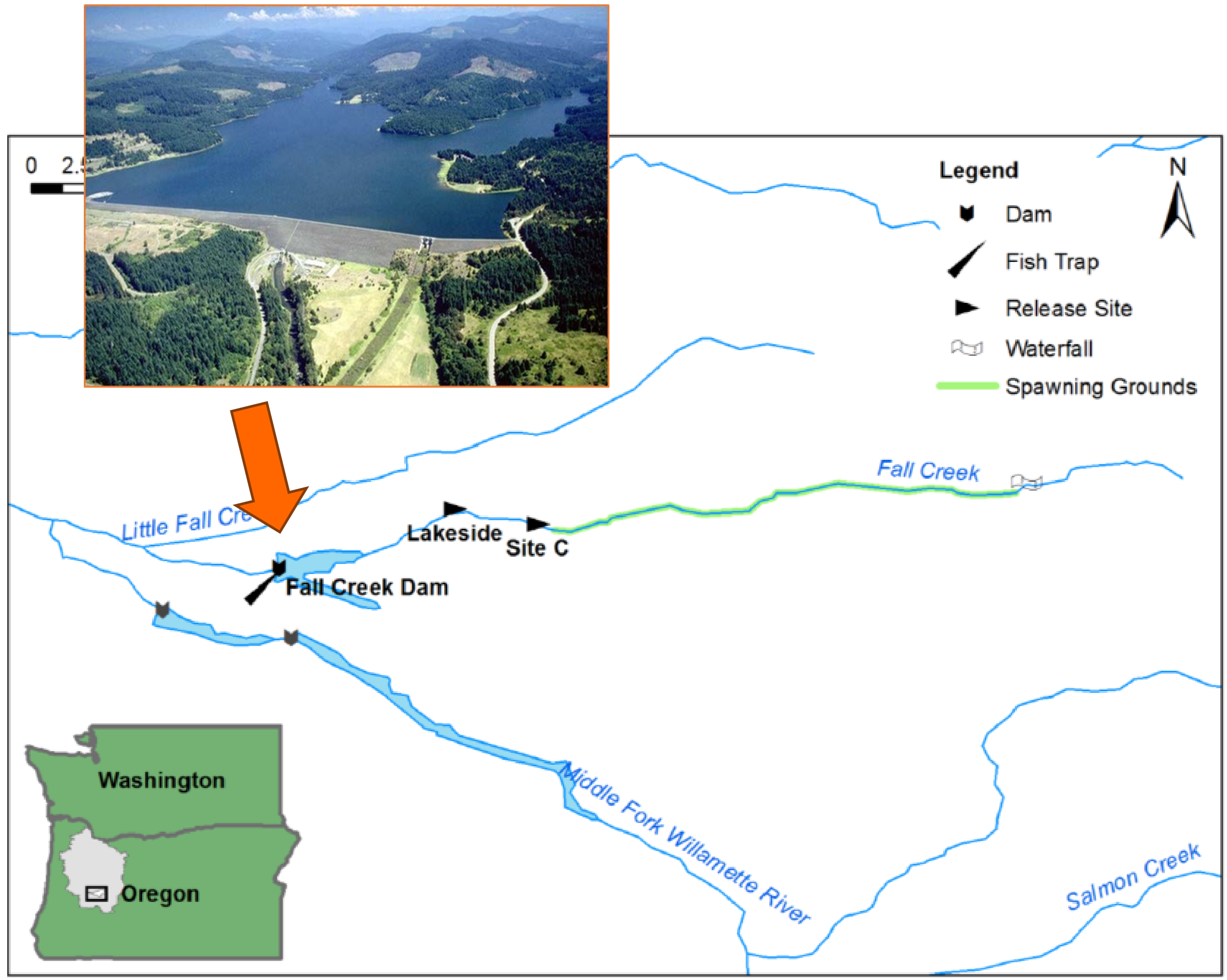
Fall Creek Spring Chinook Salmon

- Upper Willamette ESU

  Threatened

- Fall Creek Dam impedes access to spawning habitat



Fall Creek Spring Chinook Salmon

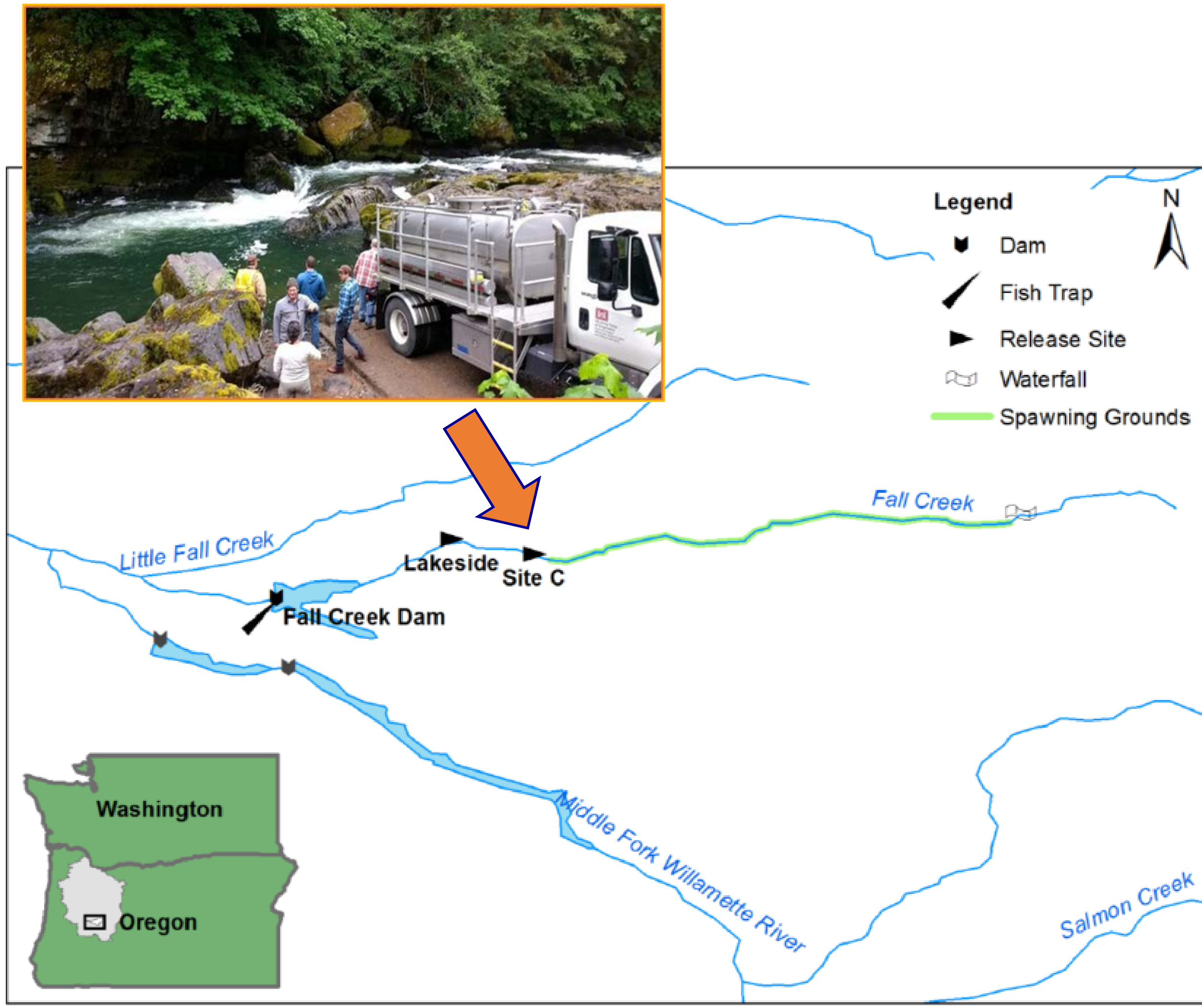
- Upper Willamette ESU

  Threatened

- Fall Creek Dam impedes access to spawning habitat

- Since 1998, Hatchery-origin (HOR) salmon released above

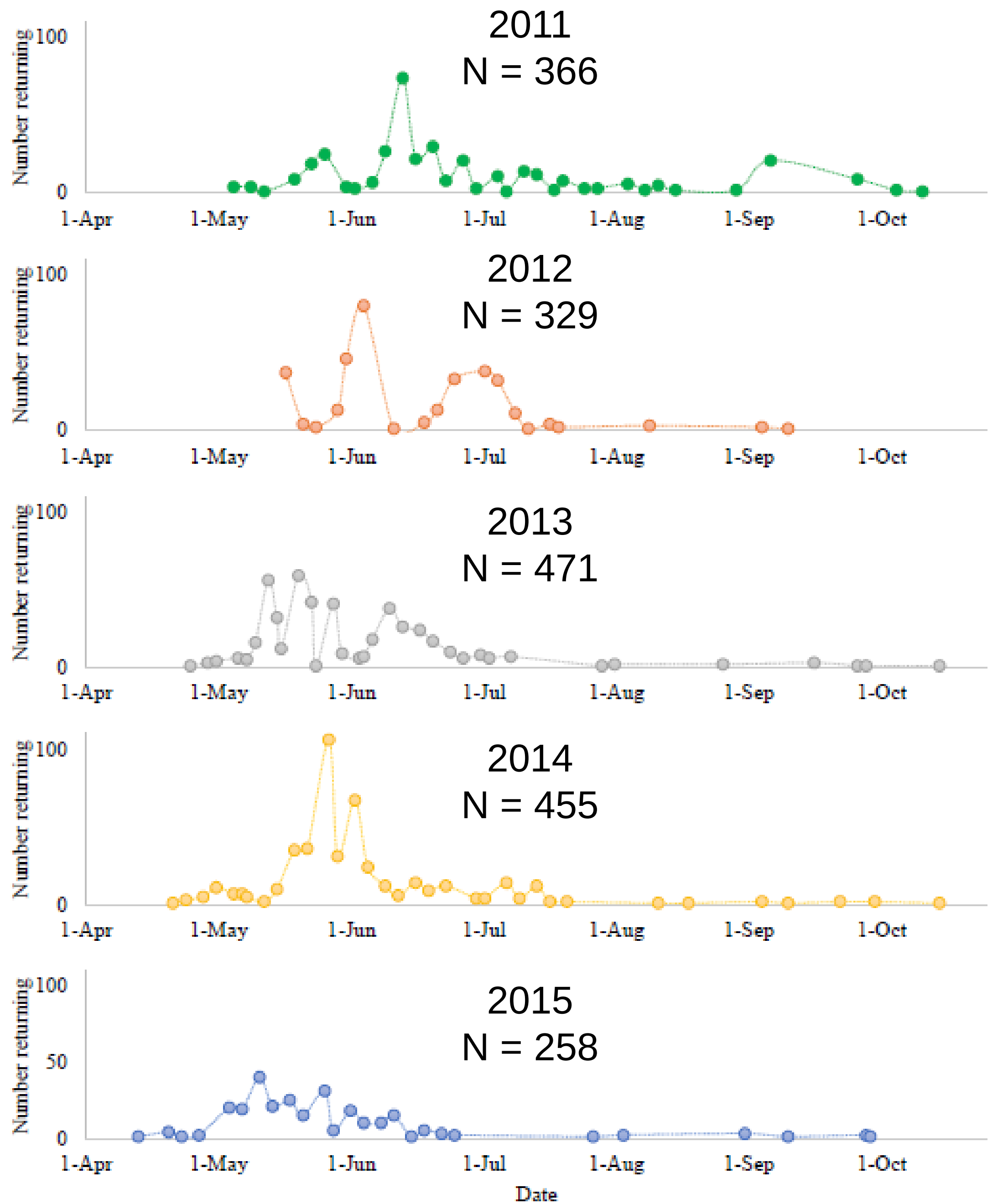
- Since 2010, only Natural-origin (NOR) salmon have been released above



Shift in Return Timing

2011 - 18% of the total run returned in May

2015 - 68% of the total run returned in May



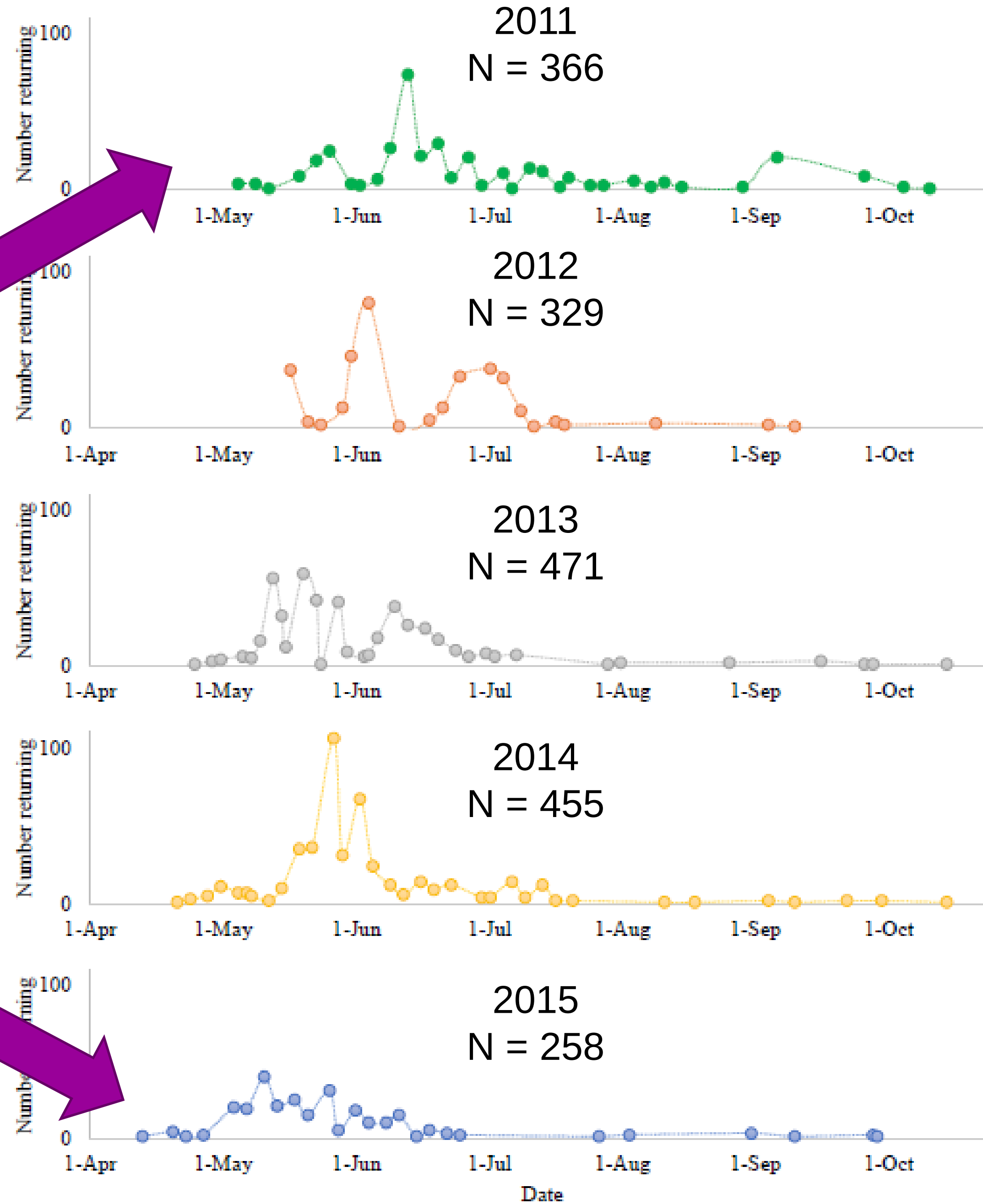
Shift in Return Timing

2011 - 18% of the total run returned in May

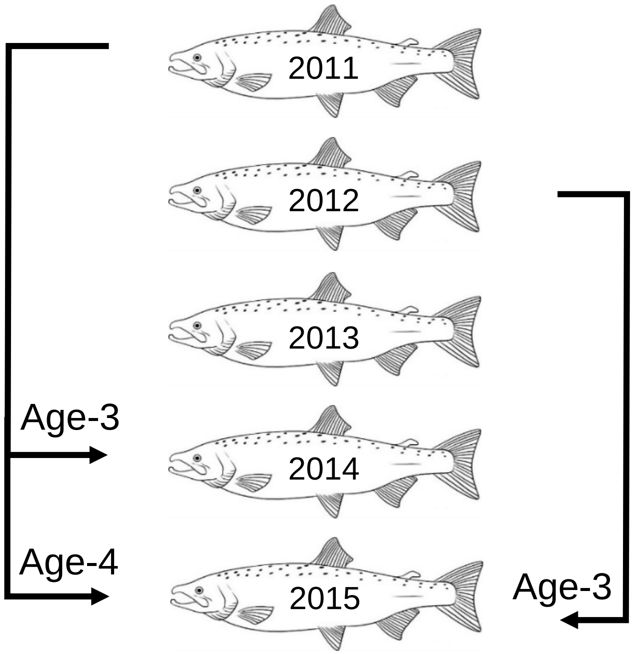
Date of 1st return - May 5th

Date of 1st return - April 13th

2015 - 68% of the total run returned in May



Goals



1. Evaluate the population productivity of reintroduced spring Chinook salmon

2. Investigate whether the shift in return timing (2011-2015) is genetically based and represents an adaptation of salmon in Fall Creek

	Year	**N**
Parent	2011	364
Parent	2012	326
Offspring	2014	453
Offspring	2015	257

O'Malley et al. (2017)

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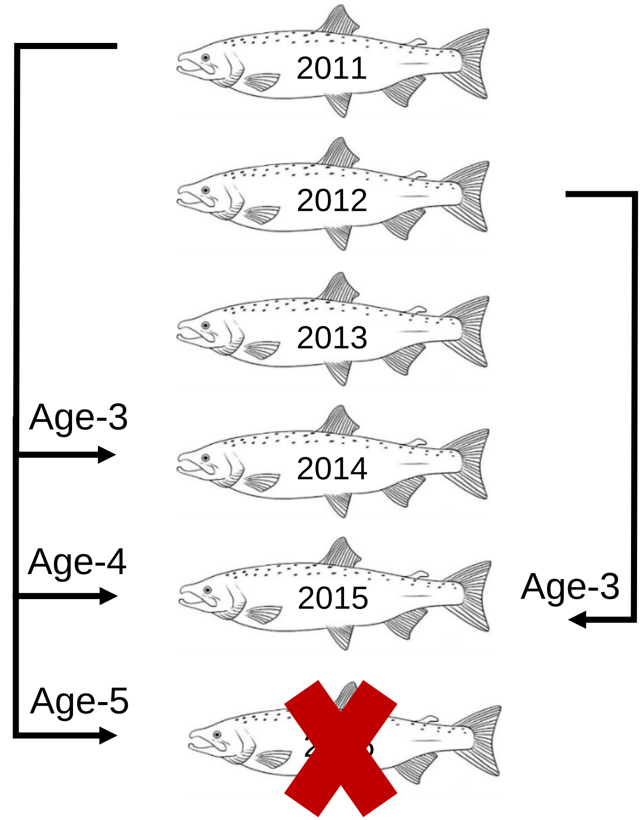

O'Malley et al. (2017)

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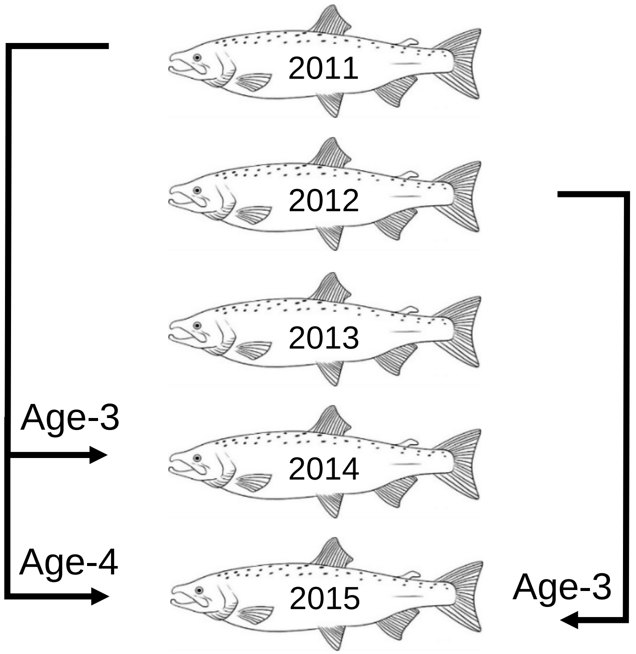


Year	N
2011	364
2012	326
2013	462
2014	453
2015	257

O'Malley et al. (2017)

Goals and Objectives

1. Evaluate the population productivity of reintroduced spring Chinook salmon
    - ❑ Assign 2014 and 2015 adult returns to salmon reintroduced in 2011 and 2012
    - ❑ Estimate fitness for salmon reintroduced in

        2011 based on age-3 and age-4 progeny only

        2012 based on age-3 progeny only
    - ❑ Calculate a preliminary female replacement rate for the 2011 cohort

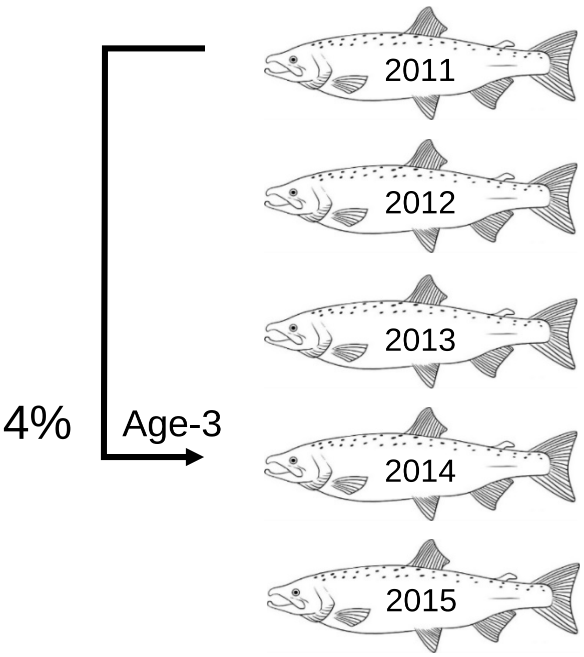
2. Investigate whether the shift in return timing (2011-2015) is genetically based and represents an adaptation of salmon in Fall Creek

Results: 2014 Assignment Rates

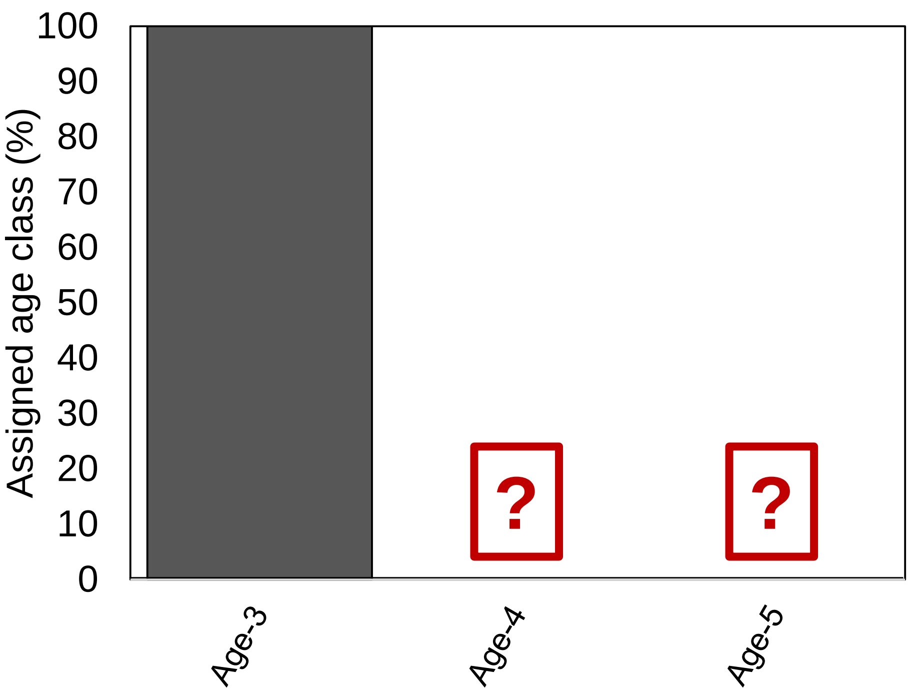
- 10% (46/453) of the 2014 adult returns assigned as offspring of adults reintroduced above Fall Creek Dam in 2011

Results: 2014 Age Structure

Predicted Based on 2014 Scale Data



Observed Based on Genetic Data

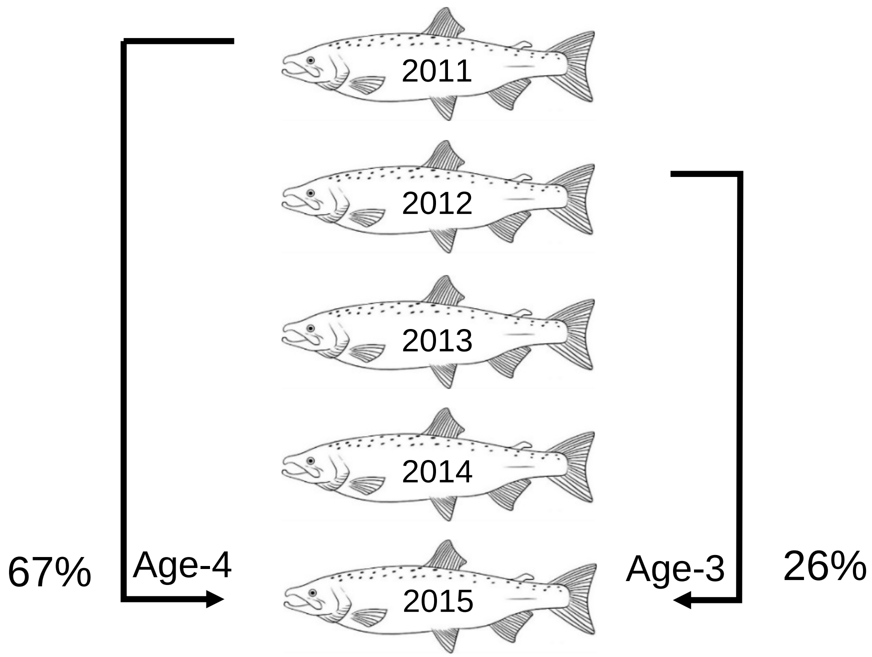


Results: 2015 Assignment Rates

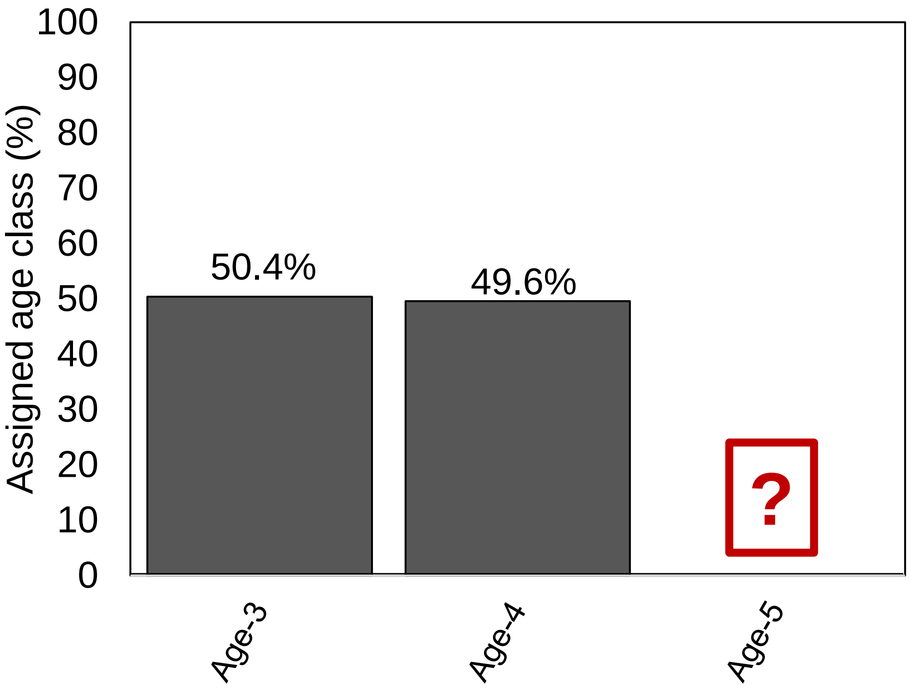
- 87% (224/257) of the 2015 adult returns assigned as offspring of adults reintroduced above Fall Creek Dam in 2011 or 2012

Results: 2015 Age Structure

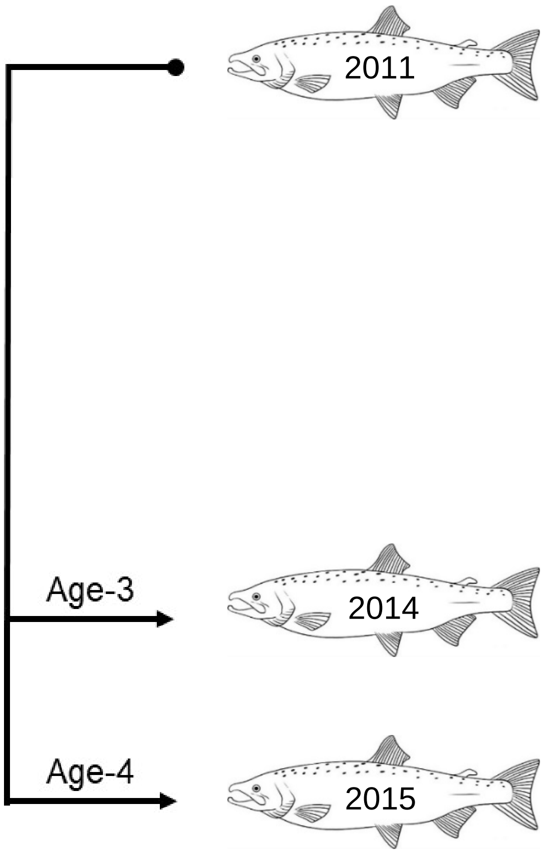
Predicted Based on 2015 Scale Data



Observed Based on Genetic Data



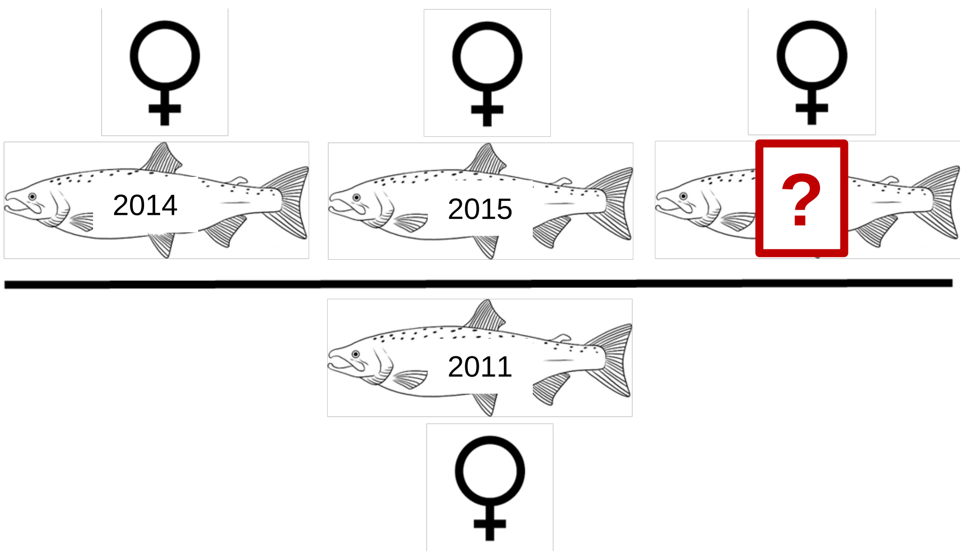
Results: Preliminary Fitness of Salmon Reintroduced in 2011



- Only 18% (65/364) produced at least one adult return to Fall Creek in 2014 and 2015

Year	Sex	N	Mean	SD	Range
2011	M	208	0.65	2.41	0 - 22
	F	156	0.94	4.47	0 - 40

Results: Preliminary Female Replacement Rate for the 2011 Cohort



$$= \frac{72}{156} = 0.46$$

Goals and Objectives

1. Evaluate the population productivity of reintroduced spring Chinook salmon

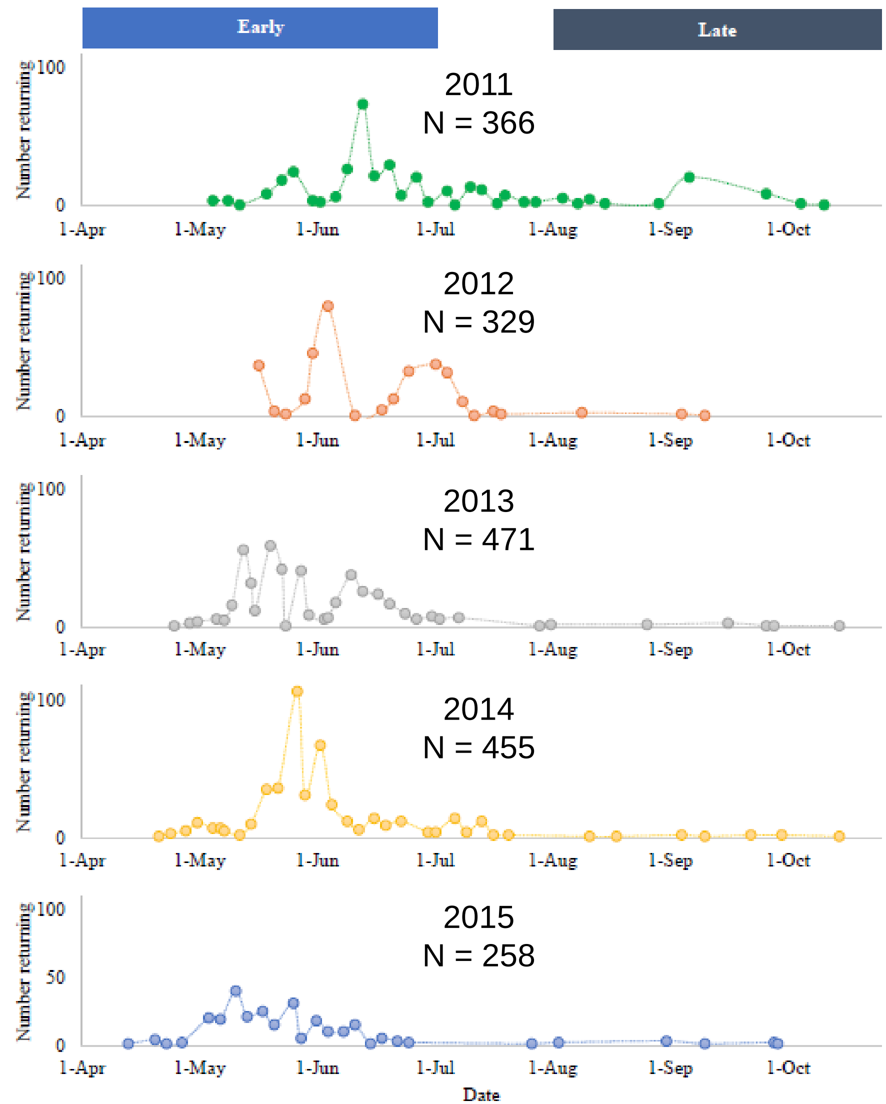
2. Investigate whether the shift in return timing (2011-2015) is genetically based and represents an adaptation of salmon in Fall Creek

   - ❑ Test for a shift in allele frequencies at 4 circadian clock genes that corresponds to the shift in return timing

   - ❑ Compared results to those for 11 neutral microsatellite markers to determine if allele frequency differences were potentially adaptive

Results: Genetic Differences Between Early- and Late-returning Salmon within Years

- No evidence for allele frequency differences between early- and late-returning salmon in 2011
  - 11 neutral markers
  - 4 clock circadian clock genes



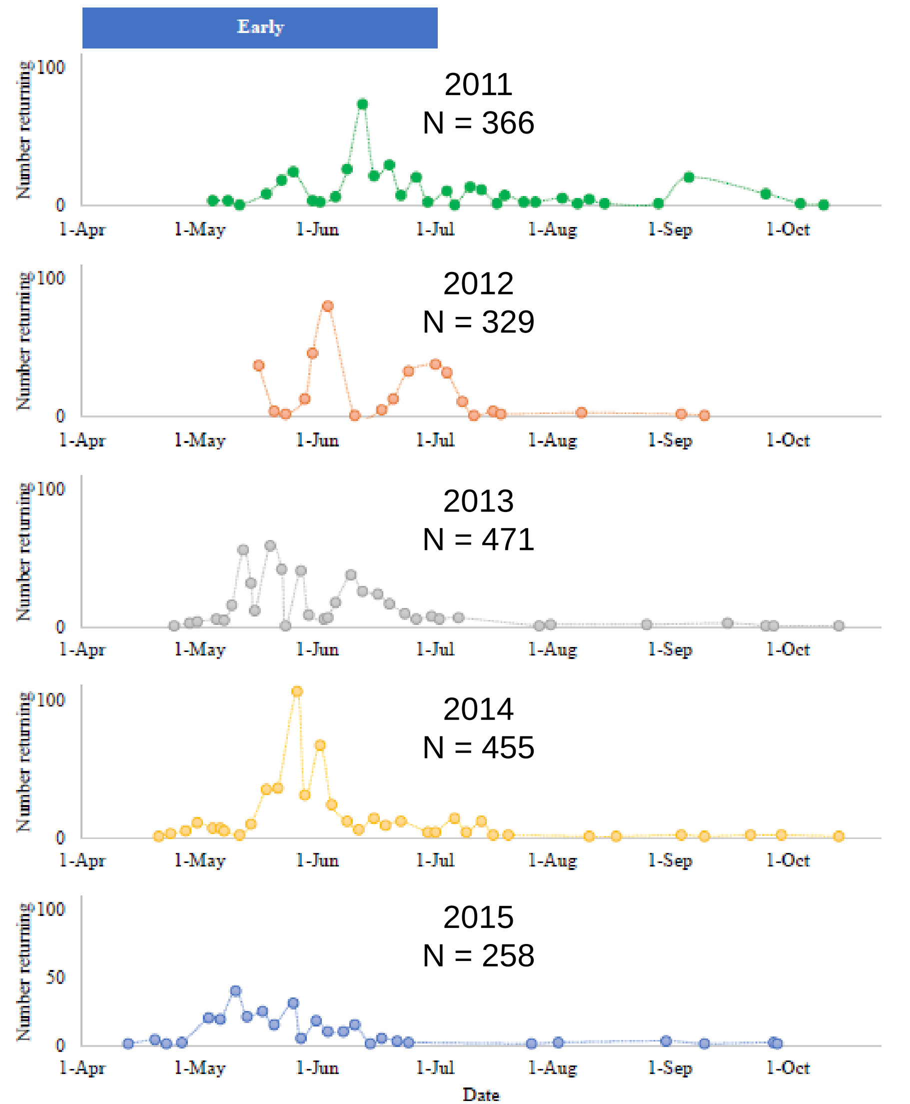
Results: Genetic Differences Among Early-returning Salmon Across Years

- Allele frequency differences among early-returning salmon across years
  - 11 neutral markers
  - 2 clock circadian clock genes

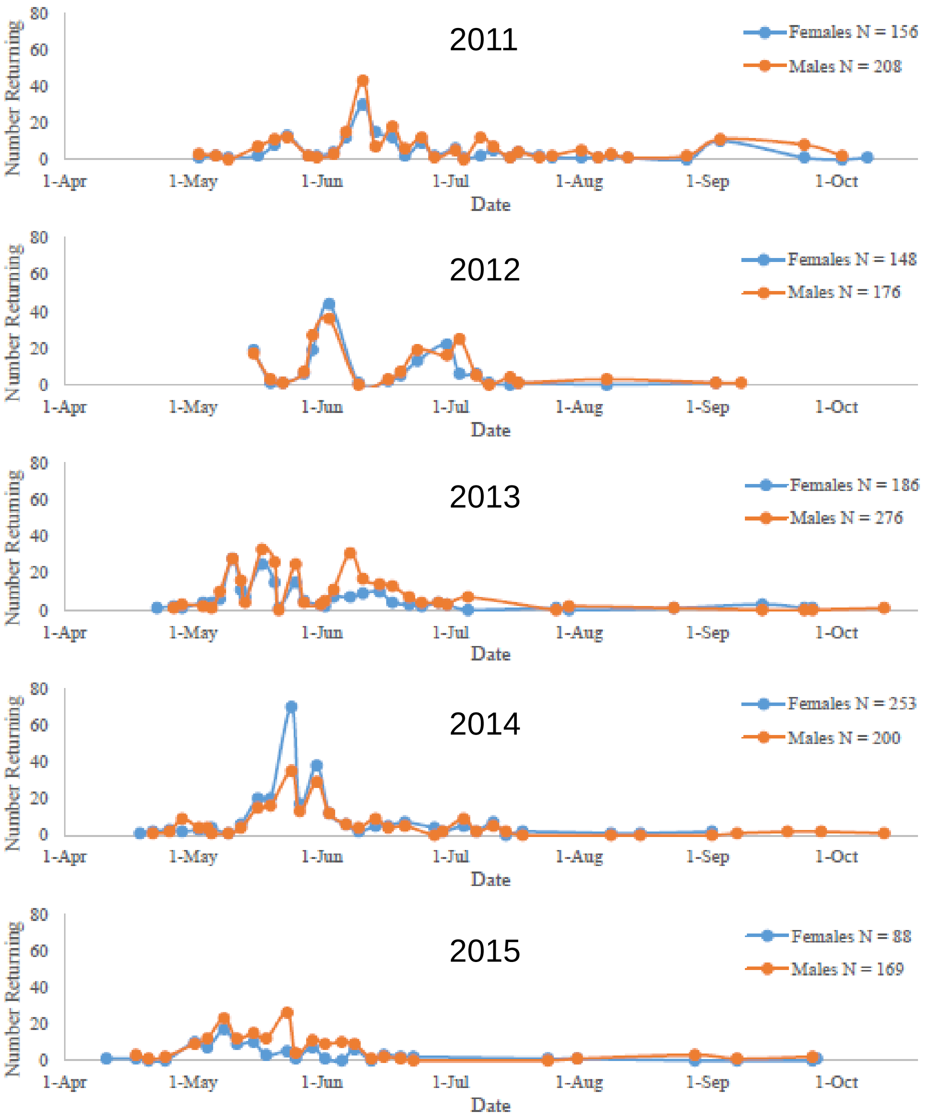
❑ Magnitude of difference similar for neutral and clock genes
  - No evidence for adaptive differences

- Notable exception - larger difference between 2011 vs. 2015 based on variation at one circadian clock gene

❑ Evidence for potential adaptive difference



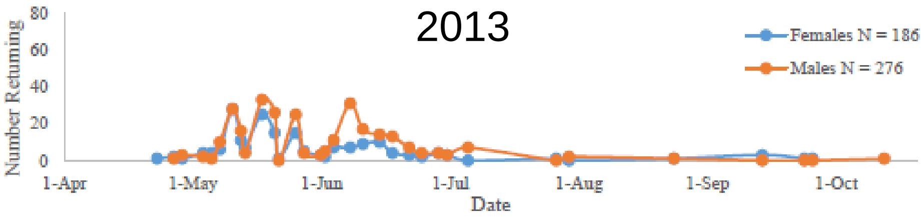
Results: Genetic Differences Between Males and Females Within Years

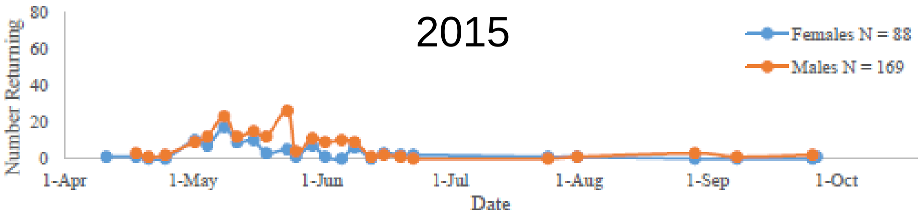


Results: Genetic Differences Between Males and Females Within Years

- Allele frequency differences between the sexes in 2013 and in 2015 when males returned later than females
    - 11 neutral markers
    - 2 clock circadian clock genes

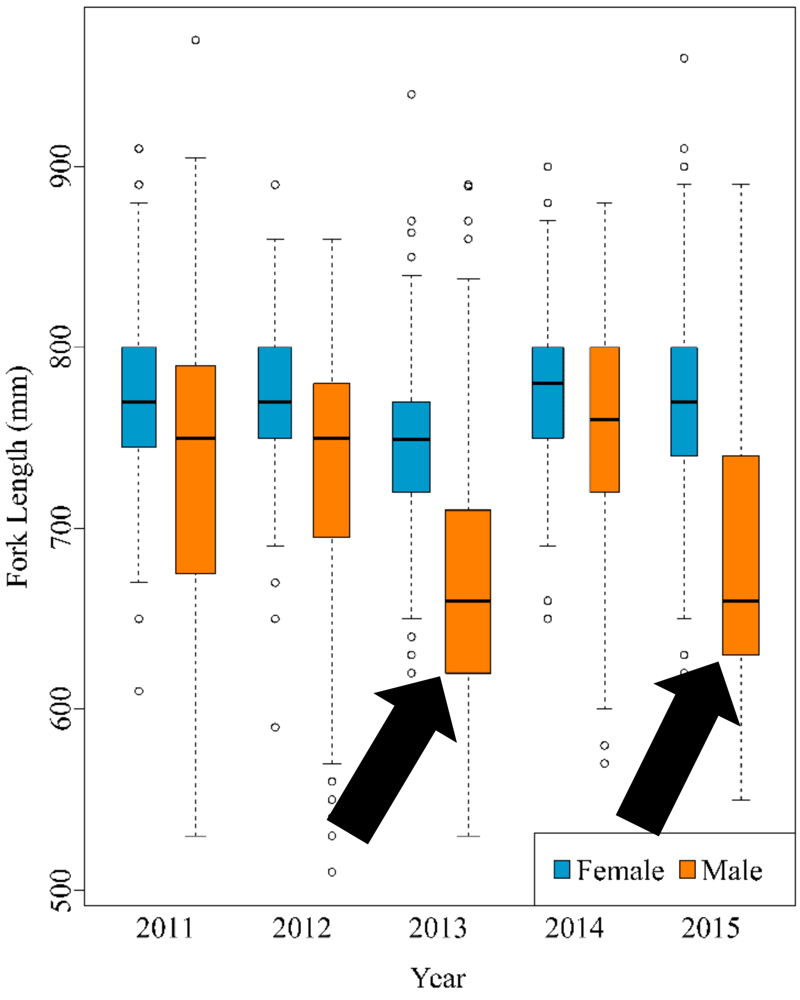
❑ Magnitude of difference similar for neutral and clock genes
  - No evidence for adaptive differences





Results: Genetic Differences Between Males and Females Within Years

- In 2013 and 2015, males were shorter (FL) than females in the same respective year and also shorter than males returning in all other years



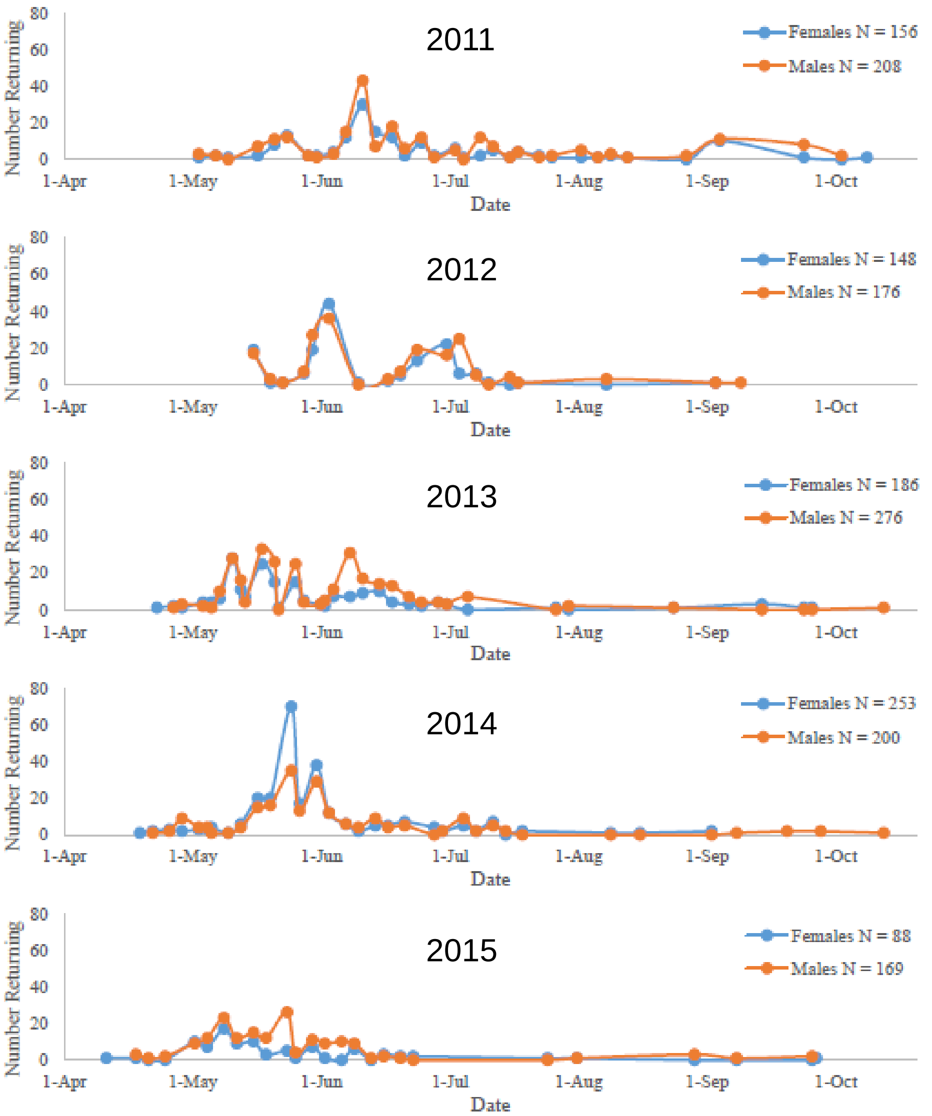
Results: Genetic Differences Within Each Sex Across Years

- Allele frequency differences at 2 circadian clock genes within males and females across years:

Males: (2011, 2012) vs. (2015)

Females: (2011) vs. (2013, 2014, 2015)

❑ Evidence for potential adaptive differences



Discussion – Population Productivity

- 87% of the salmon released above Fall Creek Dam in 2015 were progeny of salmon reintroduced in 2011 and 2012
  - Likely an underestimate since the putative parents of age-5 progeny were not sampled for genetic analysis
- Preliminary fitness estimates for salmon reintroduced in 2011 averaged 0.77 (± 3.45 SD; range = 0-40) progeny
  - Likely an underestimate since the 2016 adult returns (i.e. age-5 progeny) were not included in the parentage analysis
- Preliminary female replacement rate for the 2011 cohort is 0.46
  - Likely an underestimate since the 2016 adult returns (i.e. age-5 progeny) were not included in the parentage analysis

Discussion – Return Timing

- Evidence for potential adaptive differences between early-returning salmon in 2011 vs. 2015 based on variation at the clock gene, *Ots515NWFSC*
    - Date of 1st return in 2015 was 22 days earlier than Date of 1st return in 2011
    - *Ots515NWFSC* previously shown to differentiate between temporally divergent migratory runs of Chinook salmon[1]
- In 2013 and 2015, males were genetically different from females based on variation at neutral and adaptive markers
    - Males were shorter and returned later in 2013 and 2015
    - Larger proportion of age-3 males in 2015

[1] O'Malley et al. (2007) Mol Ecol

Discussion – Return Timing

- Potential adaptive differences within each sex based on variation at *Ots515NWFSC*[1] and *Omy1009UW*[2]
    - Males: 2011 and 2012 vs. 2015
    - Females: 2011 vs. 2013, 2014, 2015

Year	**Males**	**Females**
	Date of 1st return	Date of 1st return
2011	May 5th	May 5th
2012	May 17th	
2013		April 25th
2014		April 21st
2015	April 20th	April 13th

[1]O'Malley et al. (2007) Mol Ecol; [2]O'Malley et al. (2013) Evol App

Future Research

- In the 2015, there was a much higher proportion of age-3 males (70%) compared to age-4 males (30%)
    - Continued genetic parentage analysis will determine whether this represents a long-term shift in the age at return of male spring Chinook salmon in Fall Creek or if the 2015 results are an anomaly

- Reservoir drawdown may favor survival of faster growing juveniles that exit at a larger size and thus may be more likely to return as age-3 males
    - Sampling of juveniles exiting the reservoir (i.e. fin clip and FL) would permit the evaluation of how age/size/timing of juvenile outmigrants corresponds to adult age/timing

Future Research

- Genotyping of the 2016 and 2017 adult returns at *Ots515NWFSC* and *Omy1009UW* would determine if adaptive differences among early-returning salmon and within each sex persist over time

- Incorporating the 2016 and 2017 adult returns into the genetic parentage analysis would permit estimates of total lifetime fitness and female replacement rates for the 2011 and 2012 cohorts

Acknowledgements

US Army Corps of Engineers®

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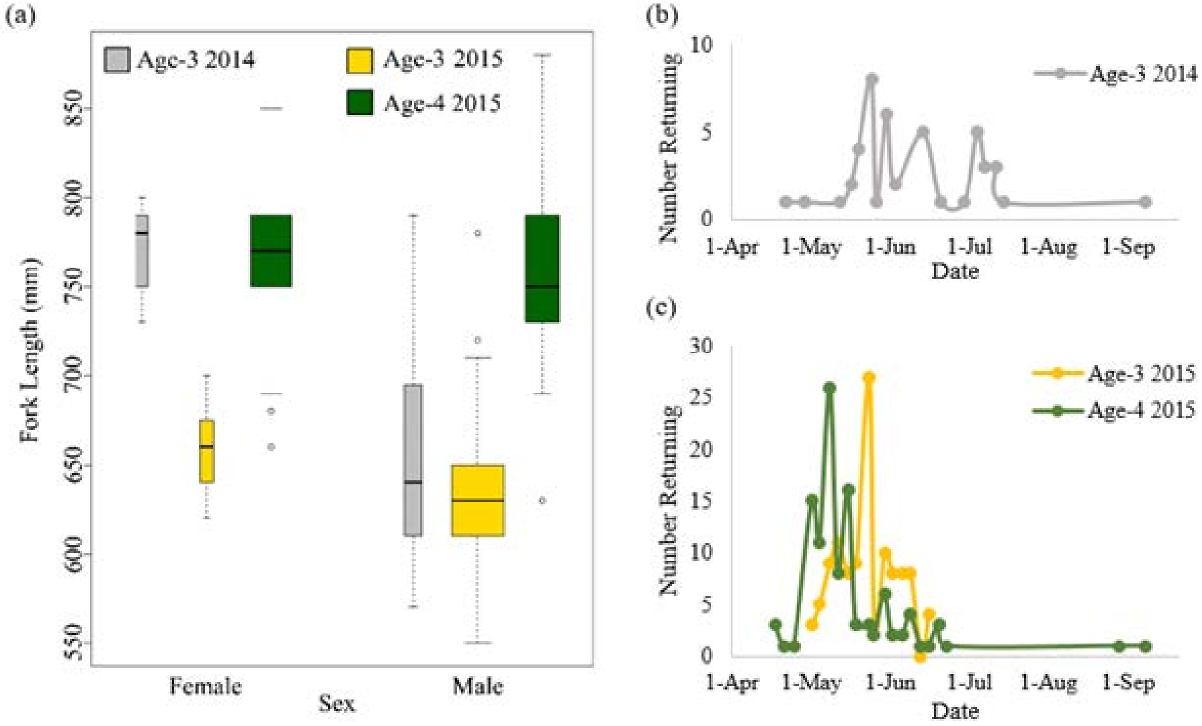
- USACE field staff

Summary and Discussion



Summary and Discussion