Evidence for Genetic Adaptation to Captivity and a Potential Mechanism to Account for Domestication in Hatchery-Reared Steelhead

Neil Thompson

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1. F1 vs. natural-origin RRS
   - Christie *et al.* 2014 Evol Apps.
2. Causes of fitness loss in *mykiss*
   - Christie *et al.* 2012 PNAS
   - Ford et al. 2016 PloS One
   - Araki et al. 2009

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   - Ford et al. 2016 PloS One
   - Araki et al. 2009
3. Domestication mechanism hypothesis
   - Thompson and Blouin. 2015. CJFAS
4. Field test in the Hood River, Oregon
   - Thompson et al. In review. Aquaculture

Do early-generation hatchery fish have lower fitness than natural fish?

51 point estimates

Weighted geometric mean **RRS= 0.534**

(0.538 without steelhead)

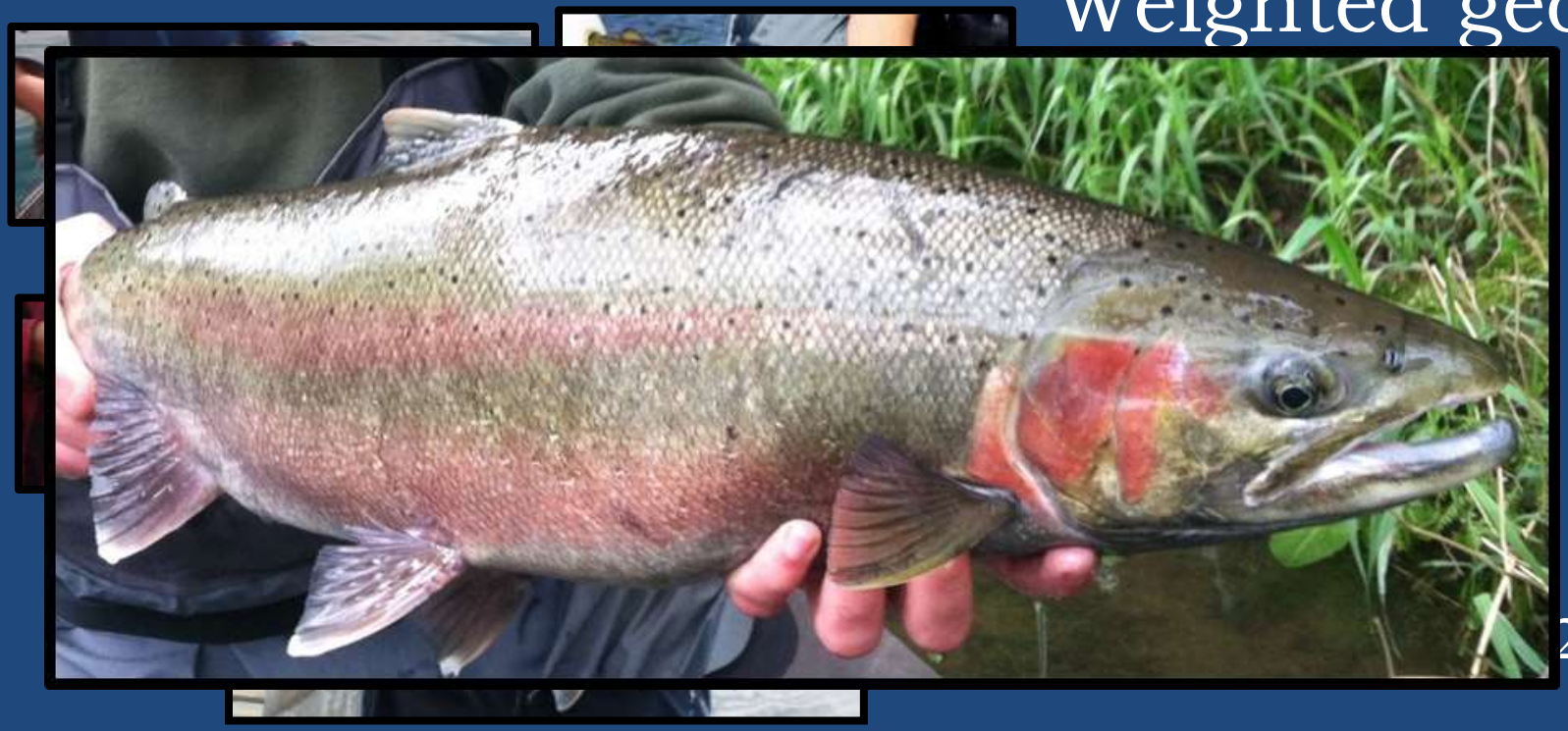
Christie *et al.* 2014

Do early-generation hatchery fish have lower fitness than wild fish?

51 point estimates

Weighted geometric

0.534



2014

Causes of fitness loss – genetic effects

multi-generation effect?

Hatchery N_{HH}

Natural N_{NN}

Hood River steelhead: Araki *et al.*, 2009 *Biology Letters*

Causes of fitness loss – genetic effects

multi-generation effect?

Hatchery

N_{HH}

Natural

N_{NN}

N_{HH}

N_{NN}

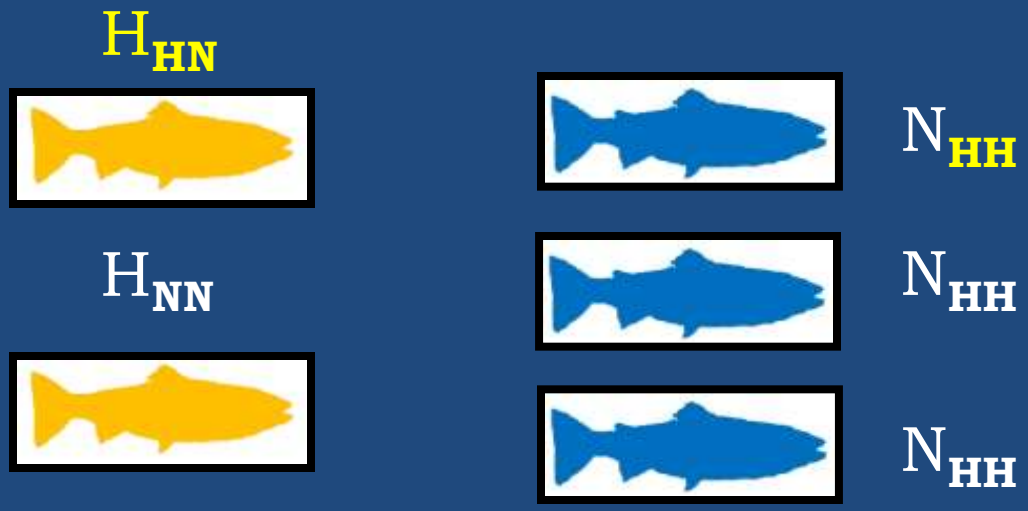
N_{NN}

N_{HH} RRS = 0.3 - 0.4 compared to N_{NN}

Hood River steelhead: Araki *et al.*, 2009 *Biology Letters*

Causes of fitness loss– genetic effects

multi-generation effect?

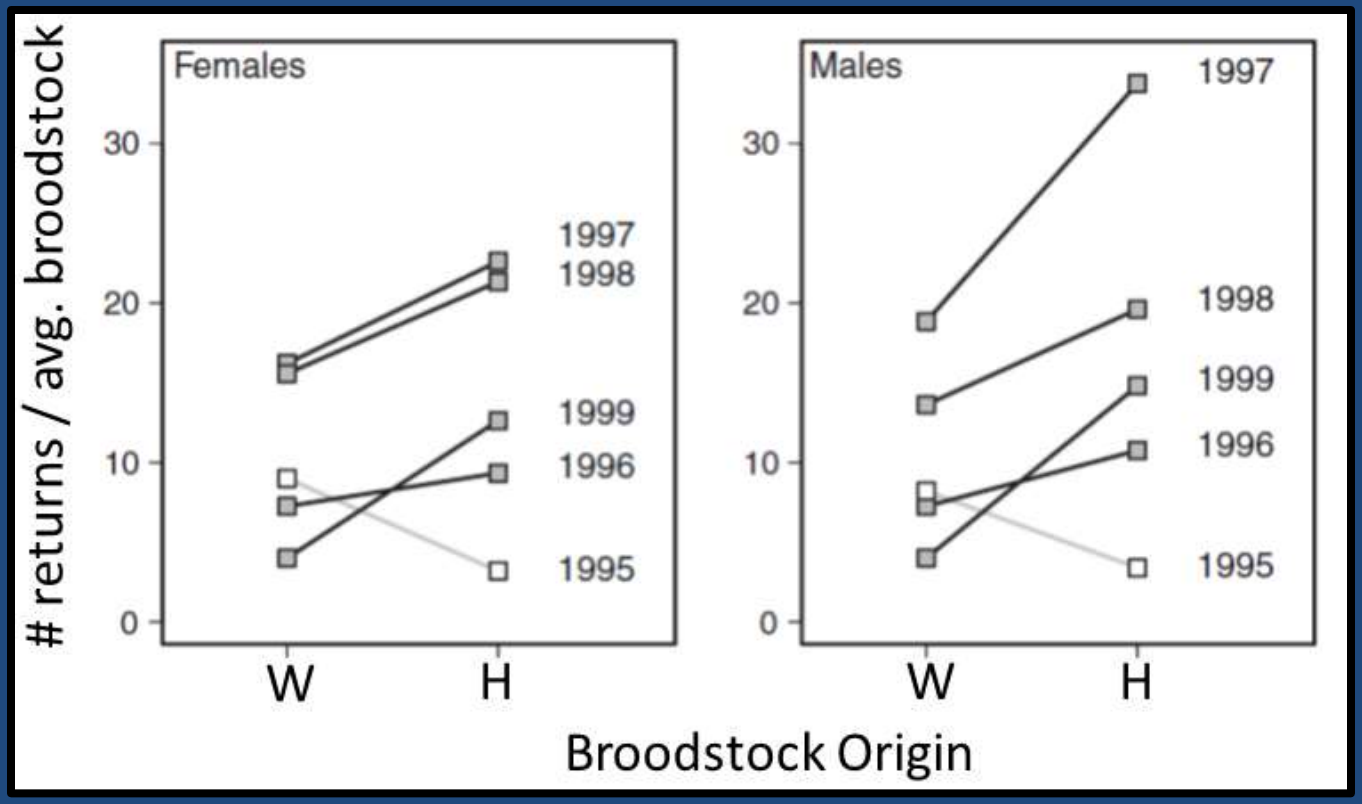


$H_{HN} < H_{NN}$ RRS

Wenatchee River steelhead: Ford *et al.*, 2016 PLOS ONE

Genetic adaptation to captivity

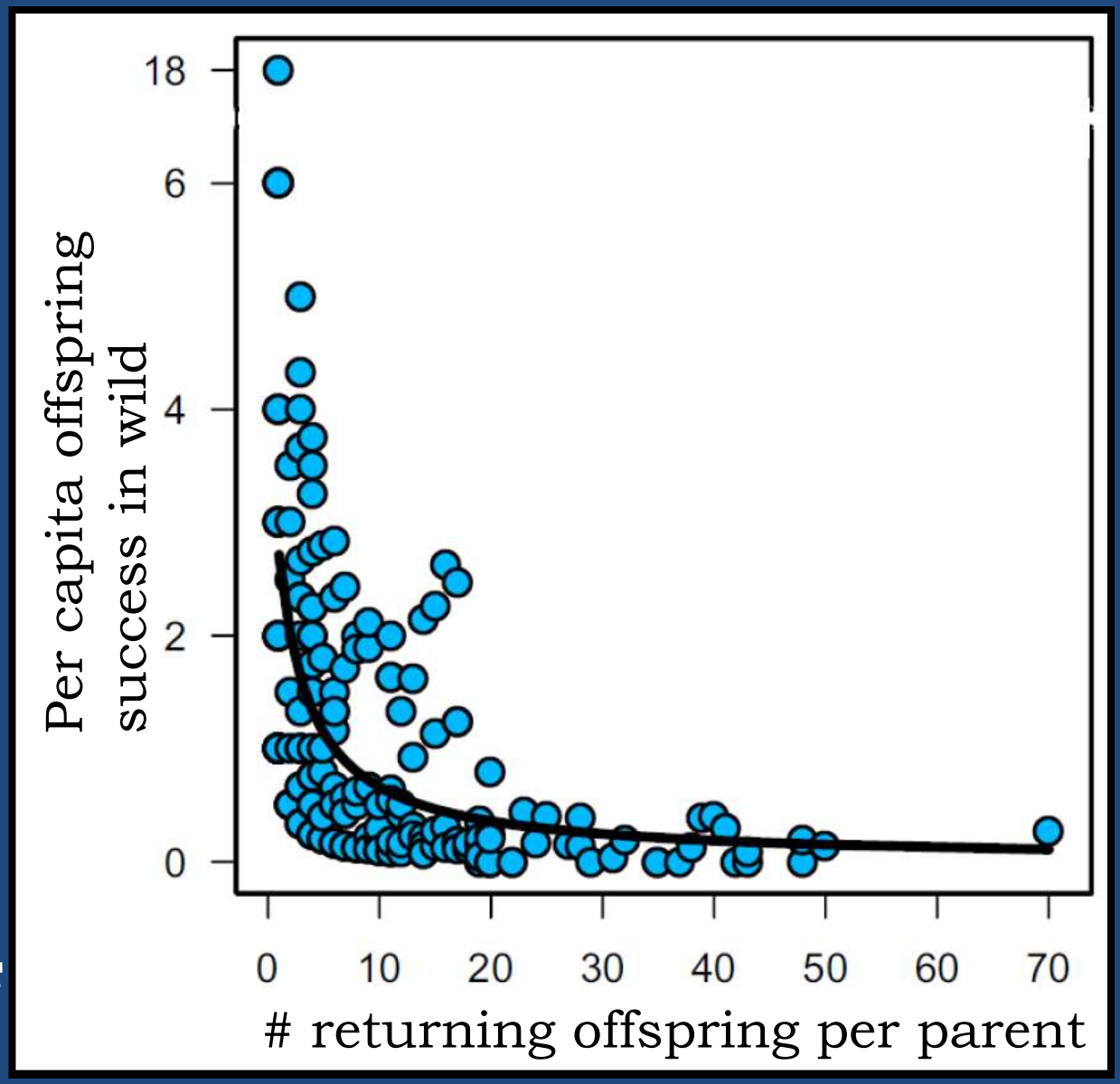
broodstock performance in the hatchery



Christie *et al.* 2012 *PNAS*
steelhead, Hood River

Genetic adaptation to captivity

Fitness tradeoff across environments

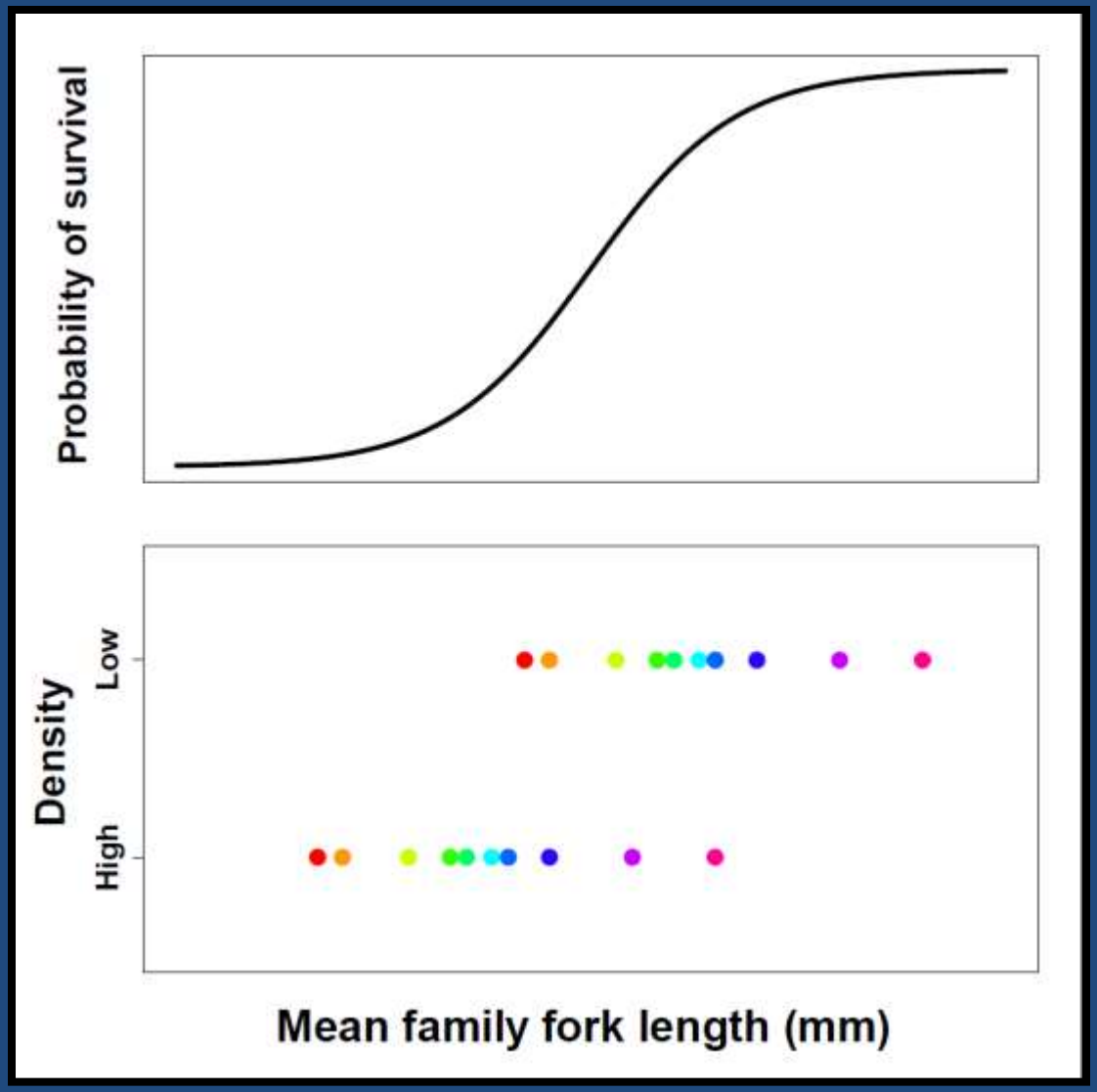


Christie *et al.* 2012 *PNAS*
Hood River steelhead

What's domestication?

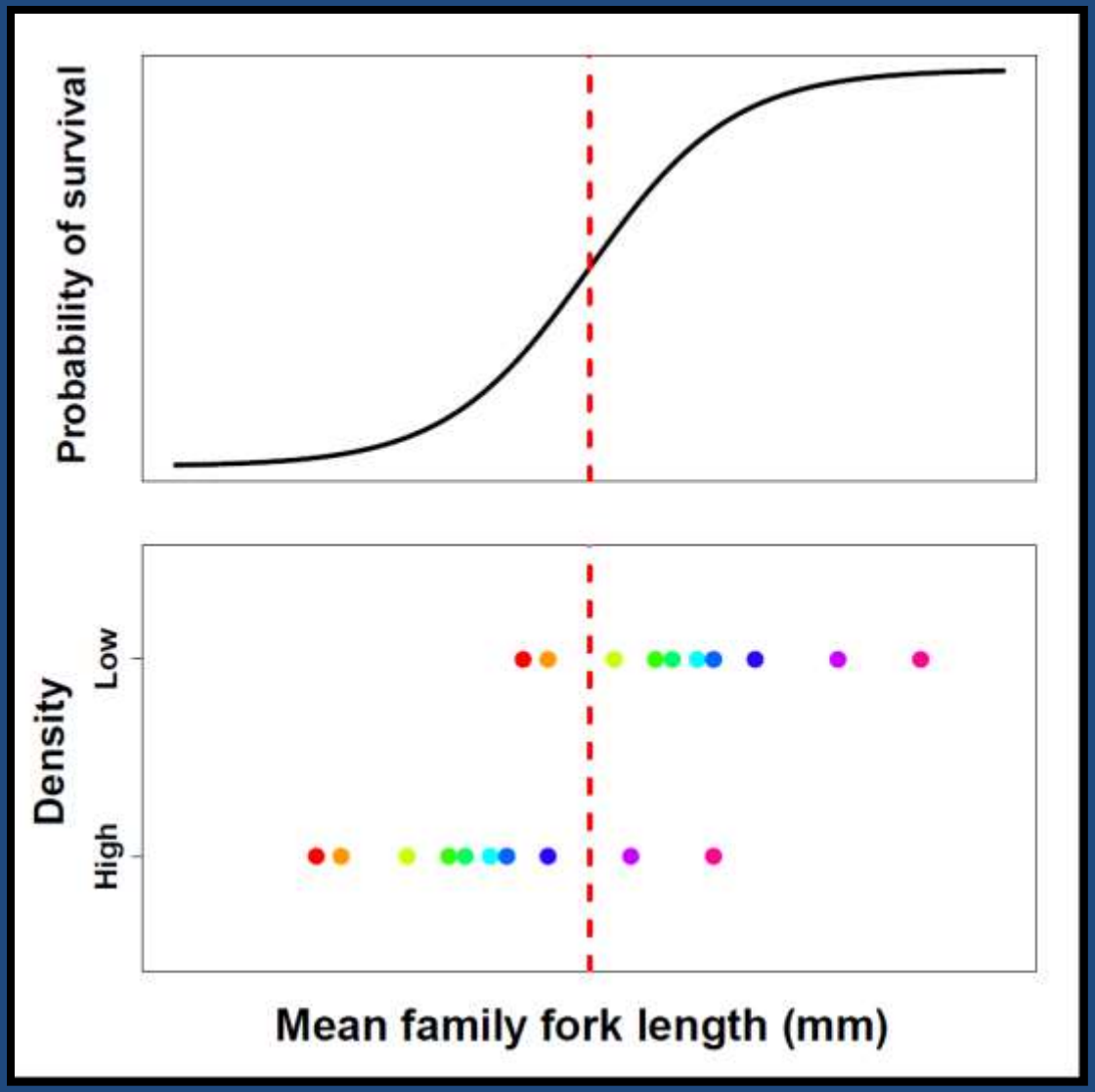
Selection for traits that are advantageous for survival and reproduction when reared in captivity

Domestication mechanism hypothesis



Thompson and Blouin. 2015. CJFAS

Domestication mechanism hypothesis



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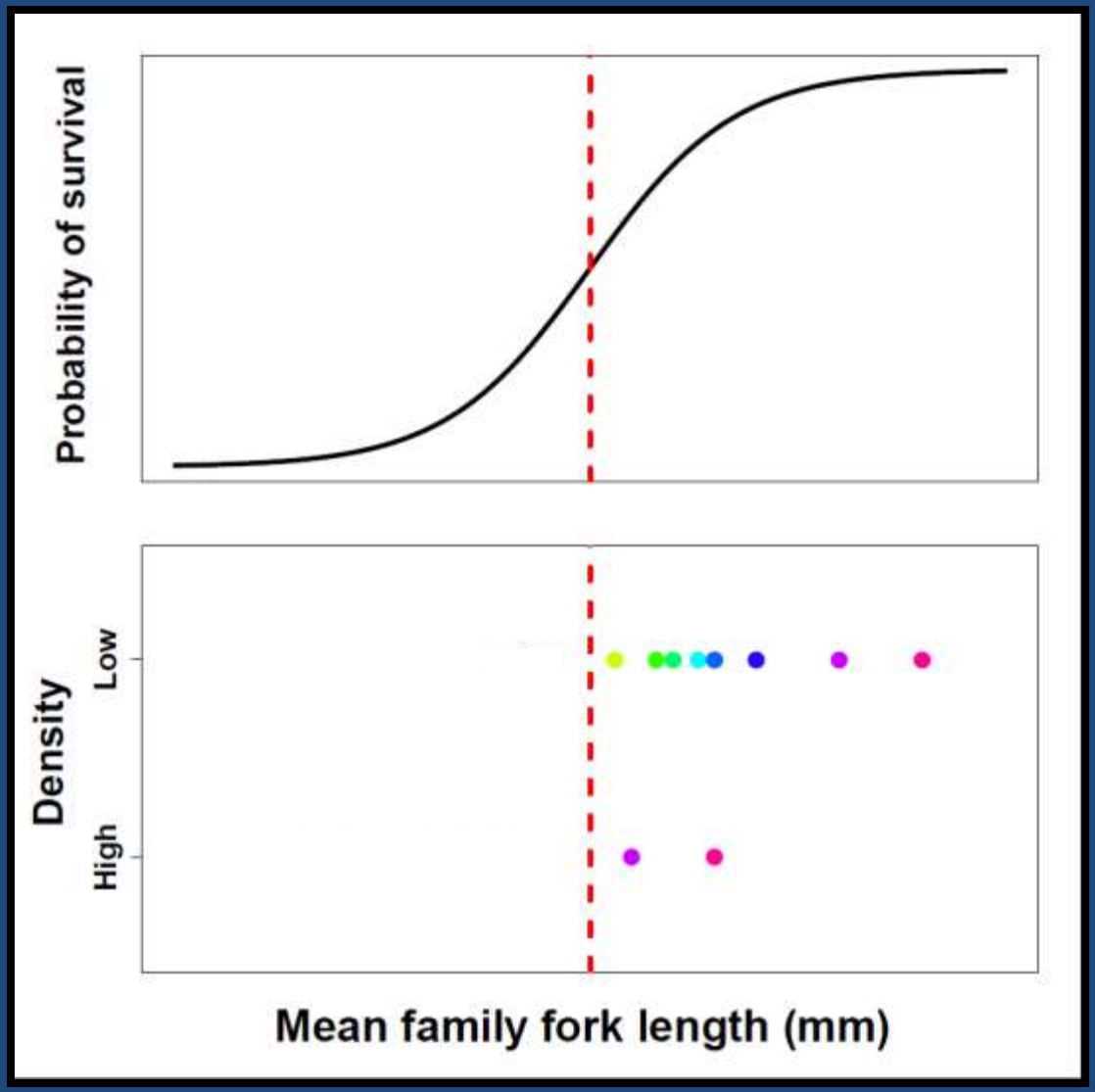


Thompson and Blouin. 2015. CJFAS

Domestication mechanism

1. Differences in body size at release among families
   - Thompson and Blouin 2015 CJFAS
   - Berejikian et al. 2016 CJFAS

2. Size-biased survival after release
   - Tipping 1997; Washington
   - Bond et al. 2008; California
   - Clarke et al. 2014; Oregon
   - Osterback et al. 2014 California

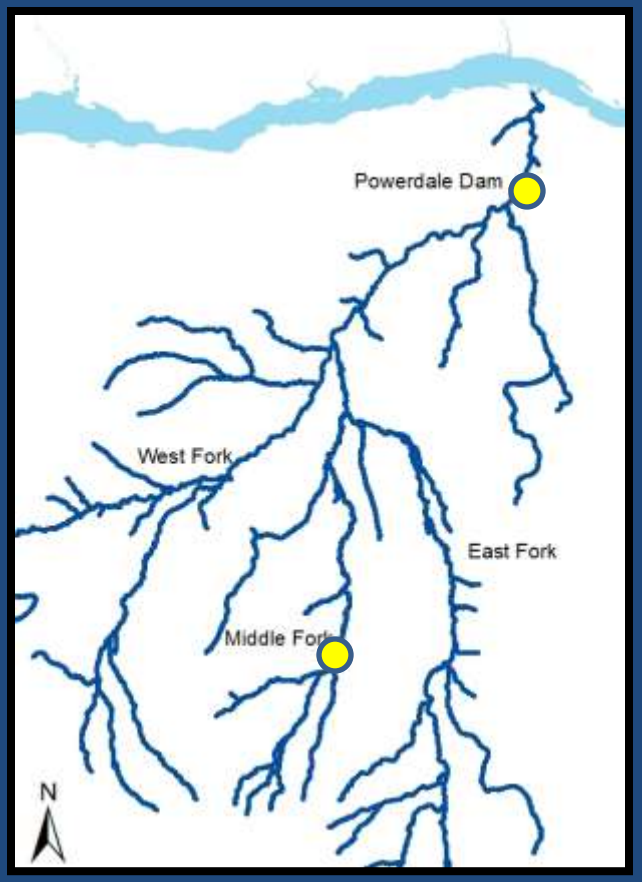
   - Reisenbichler et al. 2004; Oregon
   - Berejikian et al. 2016; Washington

Thompson NF, Clemens BJ, Ketchum LK, Simpson PC, Reagan RE, Blouin MS.

Family influence on length at release and size-biased survival post release in hatchery-reared steelhead: a mechanism to explain how domestication occurs.

In review at Aquaculture

Hood River winter steelhead program



Family effects on body size at release in production?

Oak Springs Hatchery
Maupin, Oregon

Family effects on body size at release in production?

2 cohorts → 2010, 2016

Sample 400 smolts pre-release

- Fork length
- Fin clip

OSU Oregon State University
CENTER FOR GENOME RESEARCH & BIOCOMPUTING

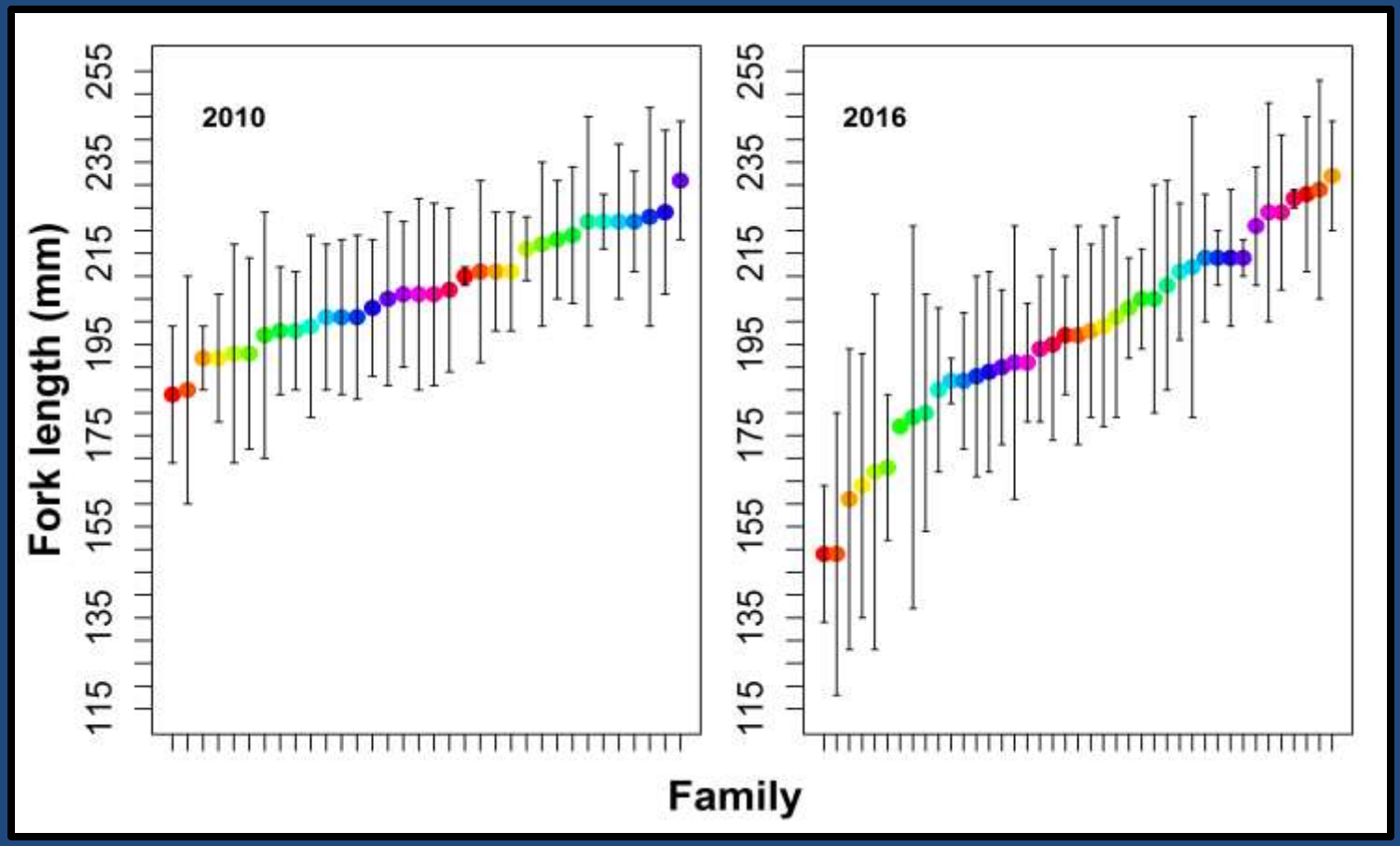
Genetic Parentage Analysis

Solomon, exclusion based methods

Family effects on body size at release in production?

Mixed effects model:
Fork length ~ intercept + 1|year|family
Likelihood ratio test

Does family ID effect variance in body size at release?



likelihood ratio test; $p < 0.0001$

Size-biased survival after release?

Size-biased survival after release?

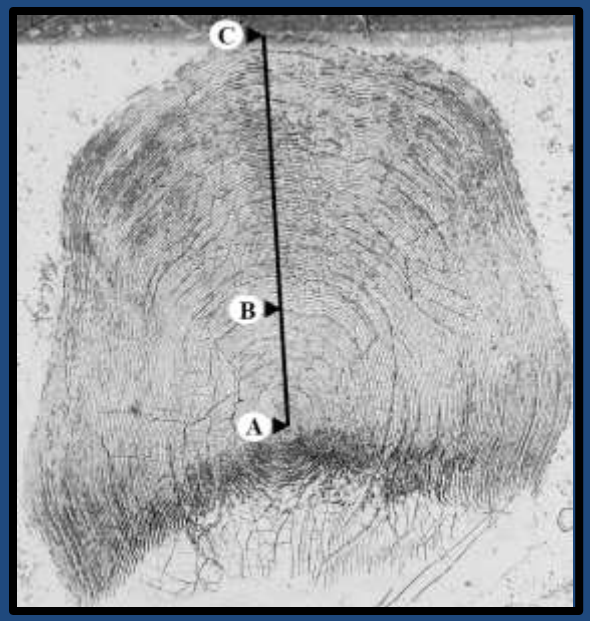
Compare smolt length distributions:

pre-release : surviving adults

Statistics:

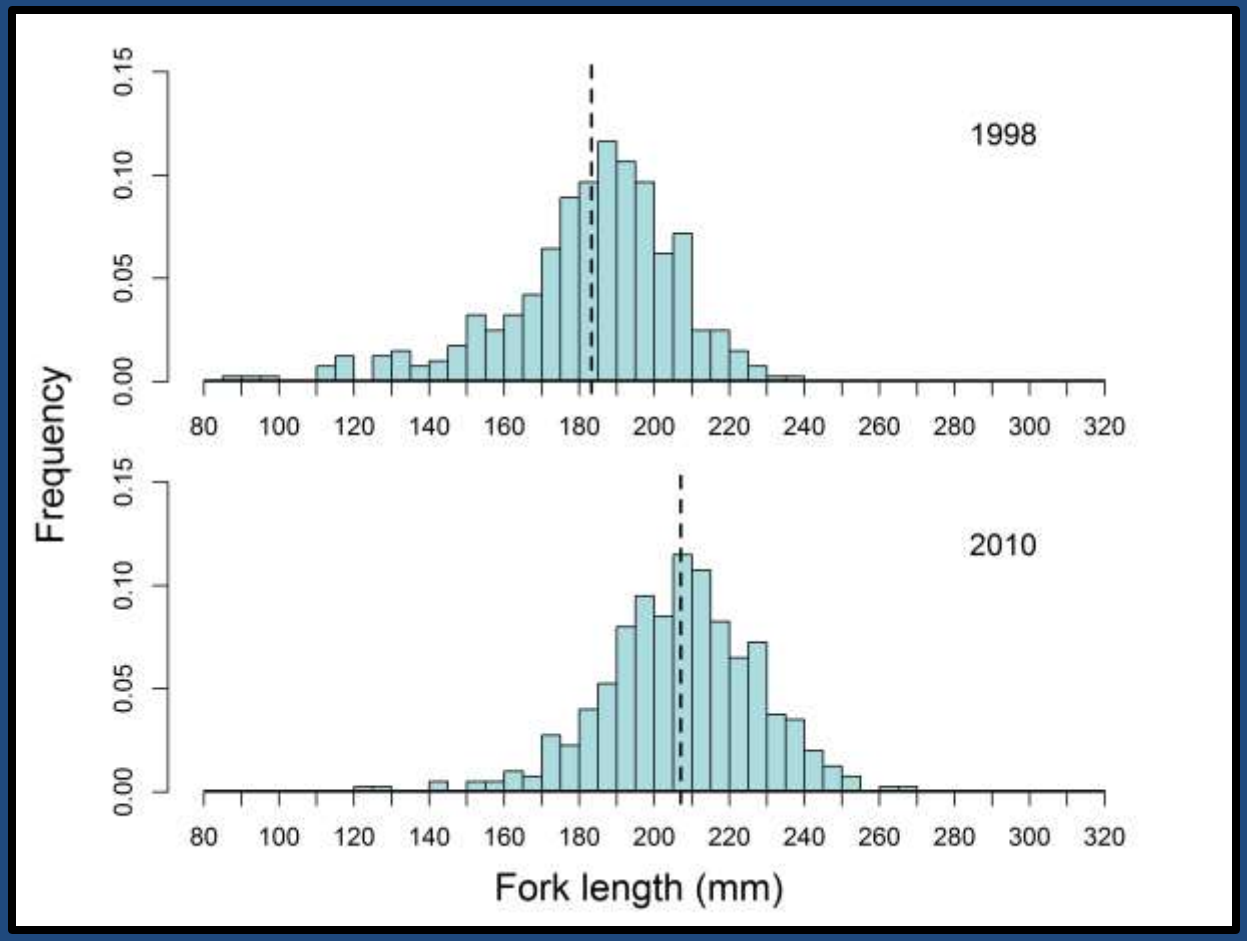
- Welch's t-test
- Kolmogorov Smirnov test

Back-calculated length at ocean entry

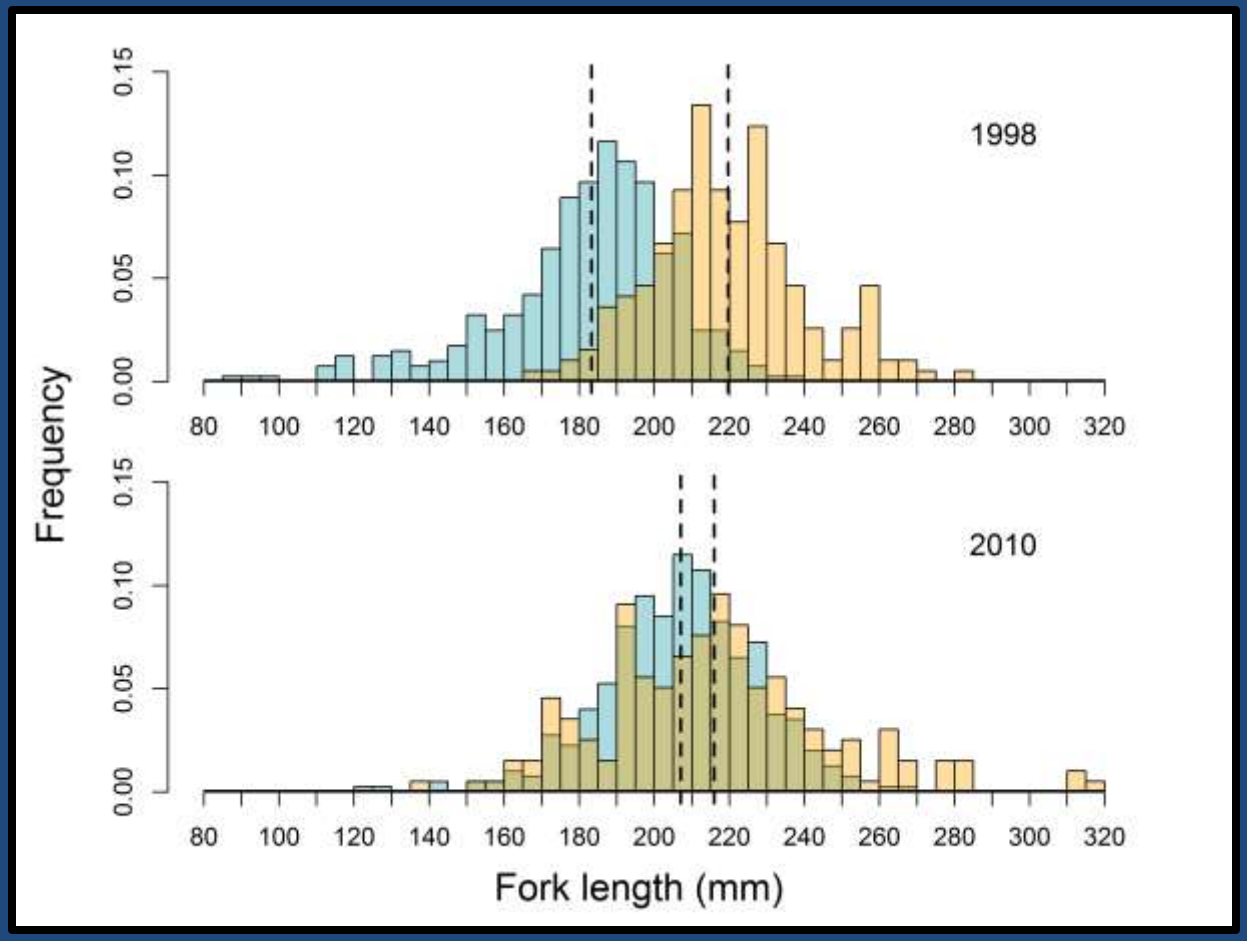


Fraser – Lee back-calculation method

Size selective survival after release?



Size selective survival after release?



Welch's t-test; $p < 0.0001$

Kolmogrov-Smirnov; $p < 0.0001$

Questions?

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Selection intensity

Selection intensity =

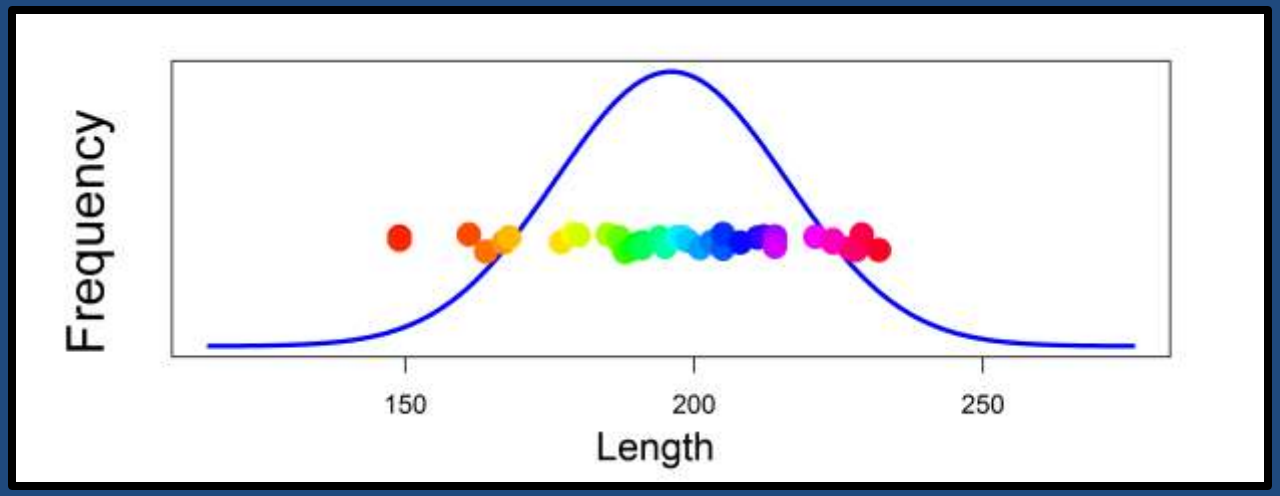
$$FL_{adults} - FL_{smolts} \; / \; SD$$

the number of phenotypic standard deviations above the mean trait value that the surviving fish are at release from the hatchery

Selection intensity

Smolt Year	Fish origin	Watershed	Selection intensity fork length	Source
1977	Natural	Keough River, BC	0.73	Ward and Slaney 1988, Ward et al. 1989
1978	Natural	Keough River, BC	1.00	Ward and Slaney 1988, Ward et al. 1989
1979	Natural	Keough River, BC	0.54	Ward and Slaney 1988, Ward et al. 1989
1980	Natural	Keough River, BC	1.47	Ward and Slaney 1988, Ward et al. 1989
1981	Natural	Keough River, BC	0.47	Ward and Slaney 1988, Ward et al. 1989
1982	Natural	Keough River, BC	0.44	Ward and Slaney 1988, Ward et al. 1989
2003	Hatchery	Scott Creek, CA	0.66	Bond et al. 2008
1998	Hatchery	Hood River, OR	1.80	Thompson et al. This study
2010	Hatchery	Hood River, OR	0.30	Thompson et al. This study

Domestication mechanism: Family effects before release



Domestication mechanism: Size-biased survival post-release