The effects of high rearing density on the potential for domestication selection in hatchery culture of steelhead (*Oncorhynchus mykiss*)

Neil Thompson, Michael Blouin

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OSU Oregon State University

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1. F1 vs. natural-origin RRS
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3. Drivers of domestication in captivity
4. Novel hypothesis - density influencing domestication

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ARTICLE

The effects of high rearing density on the potential for domestication selection in hatchery culture of steelhead (*Oncorhynchus mykiss*)

Neil F. Thompson and Michael S. Blouin

Abstract: Hatchery-reared steelhead (*Oncorhynchus mykiss*) often have lower fitness than natural-origin fish when spawning in the wild. Fitness loss in hatcheries is partly due to genetic adaptation to captivity (domestication), but the underlying selection pressures driving adaptation remain unknown. Circumstantial evidence suggests that adaptation to hatcheries is accelerated when fish are reared at high density. We hypothesized two mechanisms by which high rearing densities could accelerate adaptation to the hatchery. First, high density could increase the among-family component of variation in fork length, which could increase the opportunity for selection after release. Second, a growth trade-off in fork length among families could occur across densities (family-by-environment interaction). We raised the same set of families, in replicate, at each of two densities. We found main effects of density (high density reduced body size) and family (accounted for 33%–53% of variance in size at release) on juvenile fork length. However, high density did not increase the percentage of variance in fork length among families, and there was weak evidence for a family-by-environment interaction. We propose an alternate model of how increased density might exacerbate domestication selection. The relationship between size at release and probability of survival is strongly nonlinear (almost truncational) for steelhead. Because high density decreases the fork lengths of all families approximately equally, high density could simply reduce the number of families that are above a threshold for high survival, resulting in strong among-family selection after release from the hatchery.

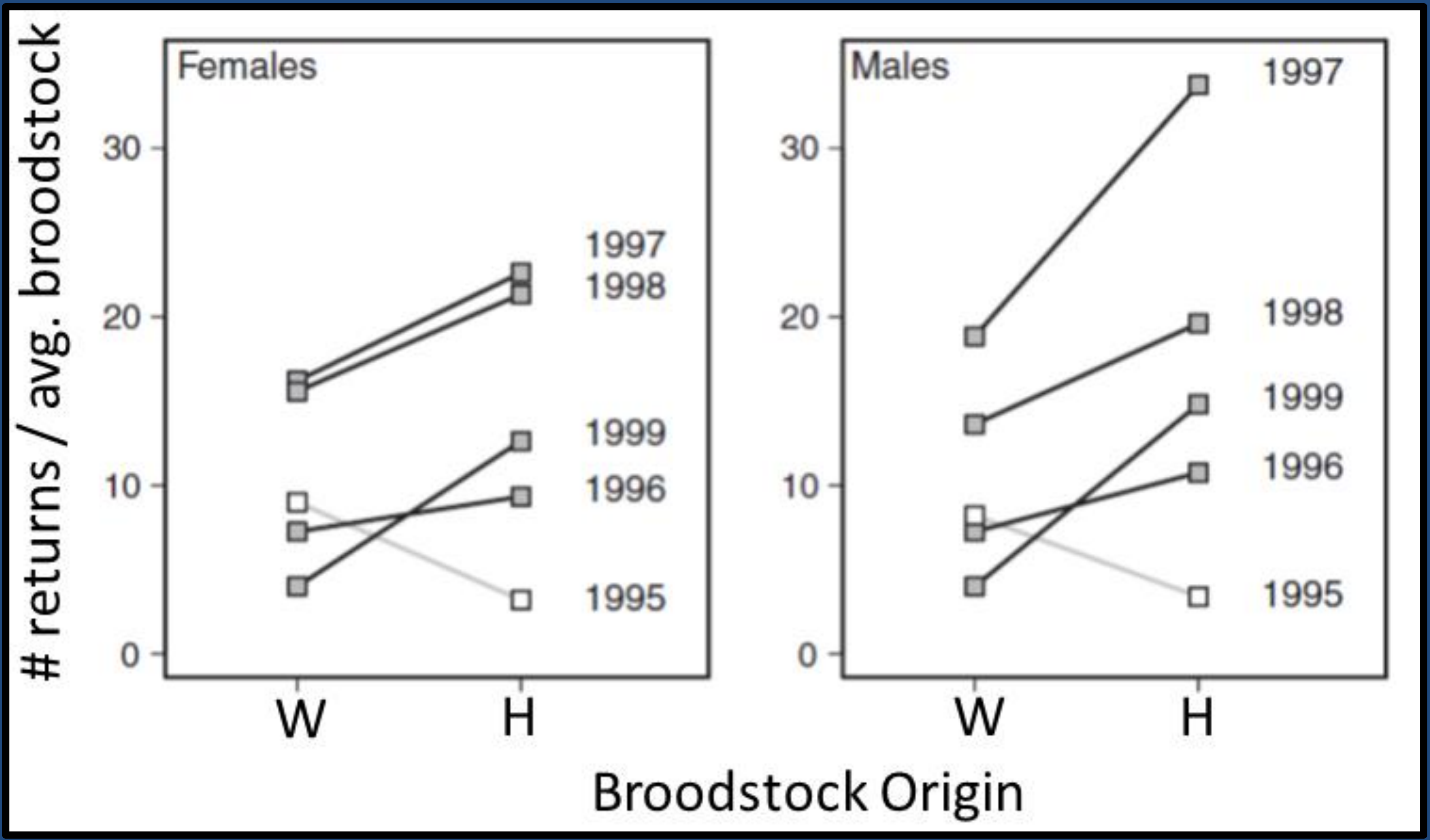
1: Early-generation hatchery fish have lower fitness than wild fish

51 point estimates

Weighted geometric mean **RRS = 0.534**

Christie *et al*. 2014

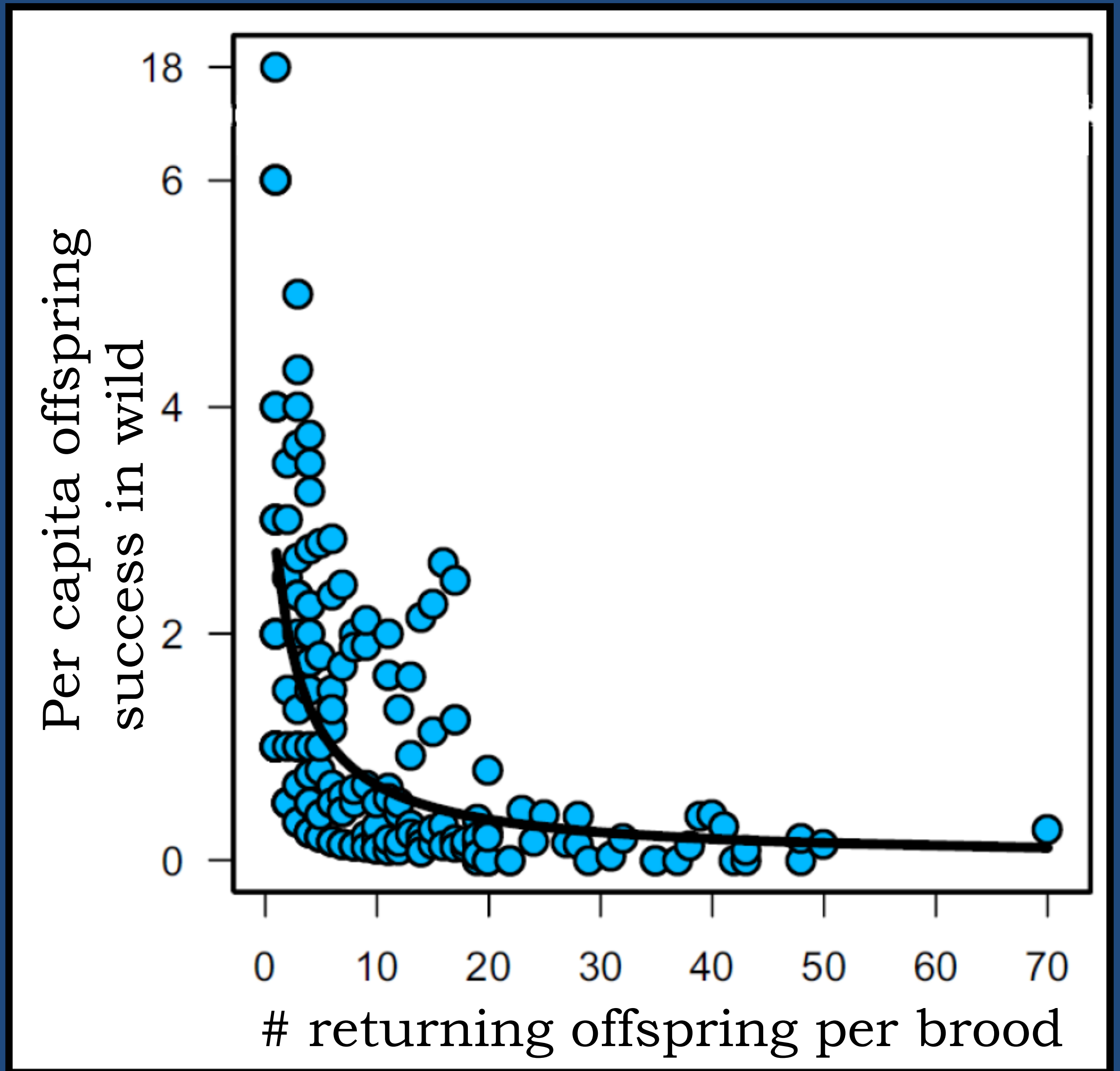
2. Genetic effects – adaptation to captivity in *mykiss* broodstock performance in the hatchery



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

2. Genetic effects - adaptation to captivity in *mykiss*

Fitness tradeoff across environments



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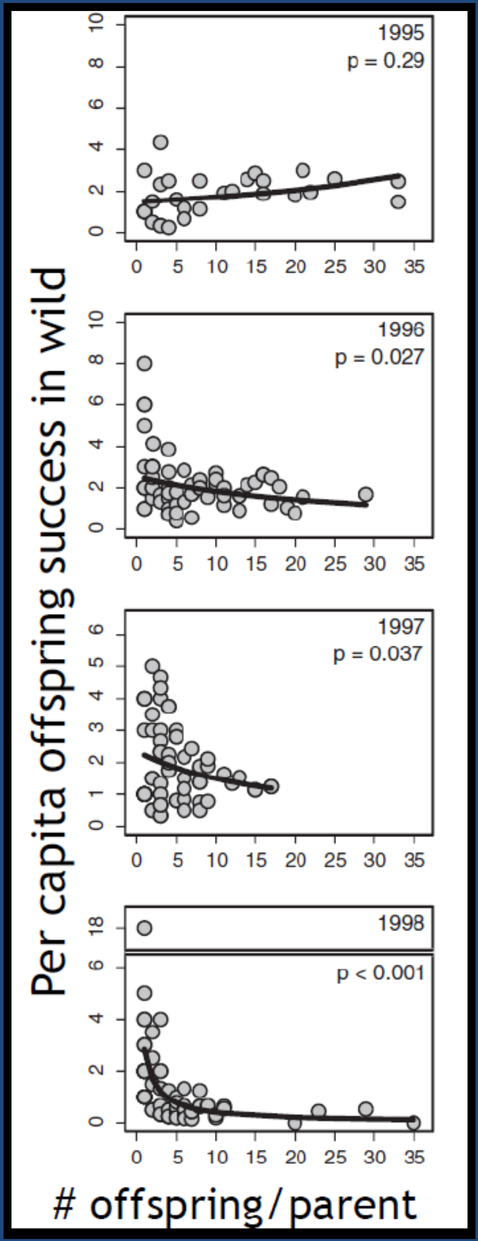
3. Drivers of domestication in captivity



fish reared

5,000

26,000

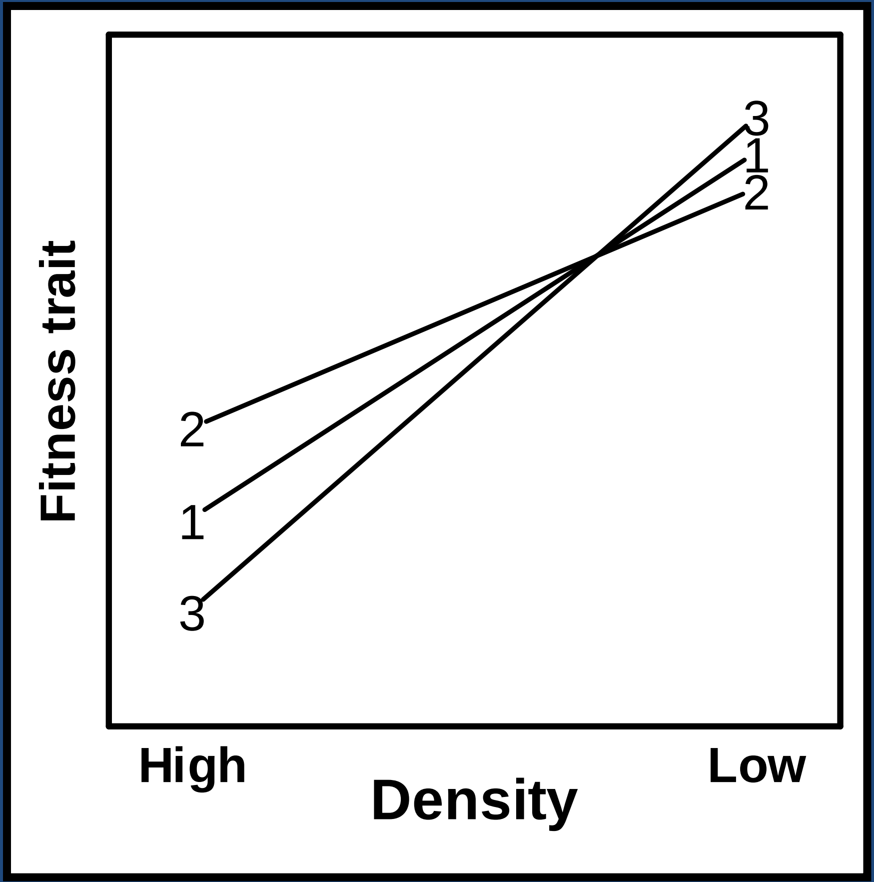
48,000

57,000

Christie *et al*. 2012 PNAS

Rearing density hypotheses

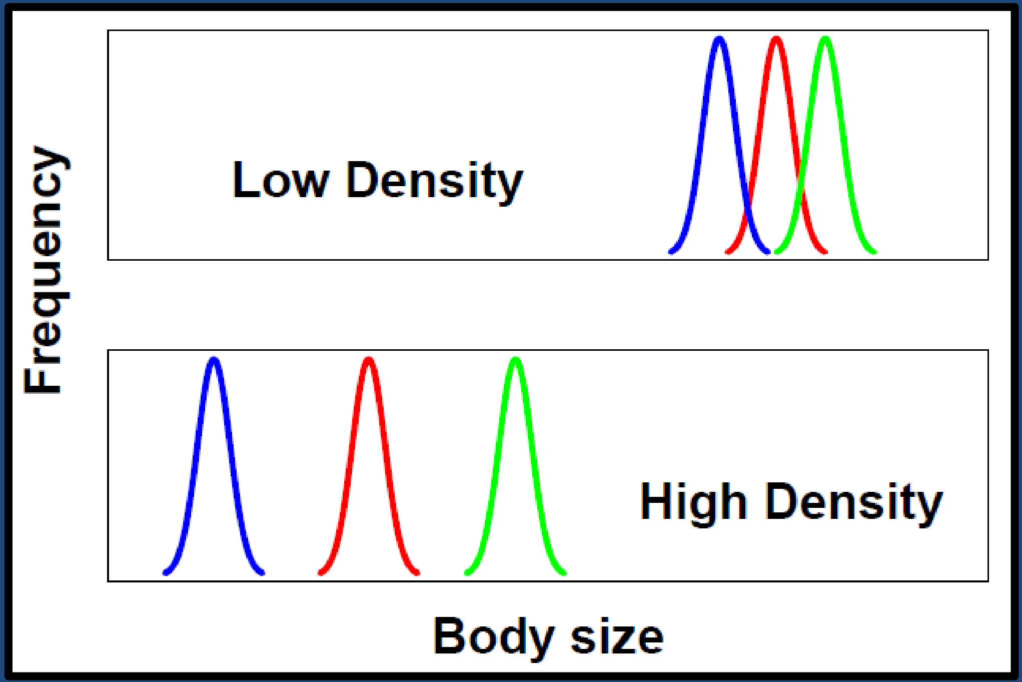
1. Increased rearing density causes performance tradeoffs



Rearing density hypotheses

1. Increased rearing density causes performance tradeoffs
2. High rearing density increases opportunity for selection

$$ICC = \frac{V_A}{V_A + V_W}$$



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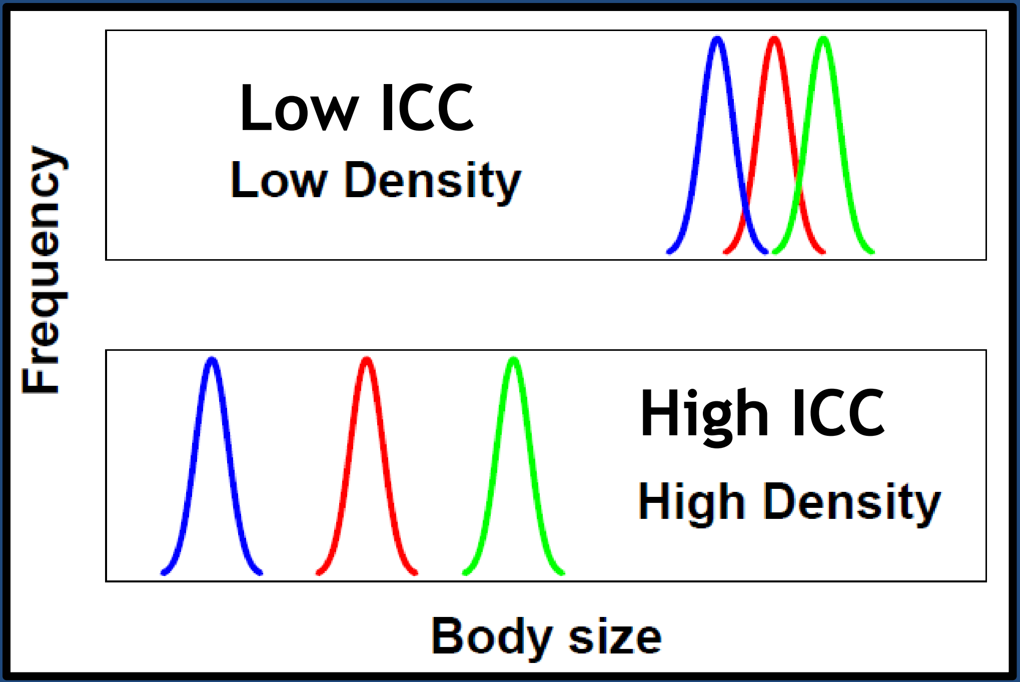
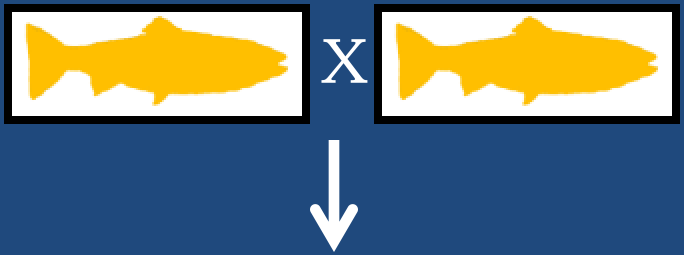


Experimental methods

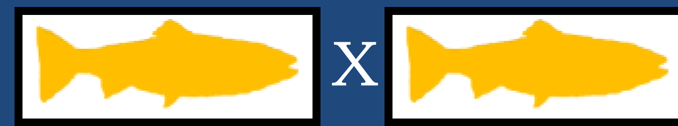


1 family

Not comparing H vs W

ORECON HATCHERY RESEARCH CENTER

Experimental methods



1 family

Two treatments

high/low density

OREGON HATCHERY
RESEARCH CENTER

Experimental methods

Replicated twice

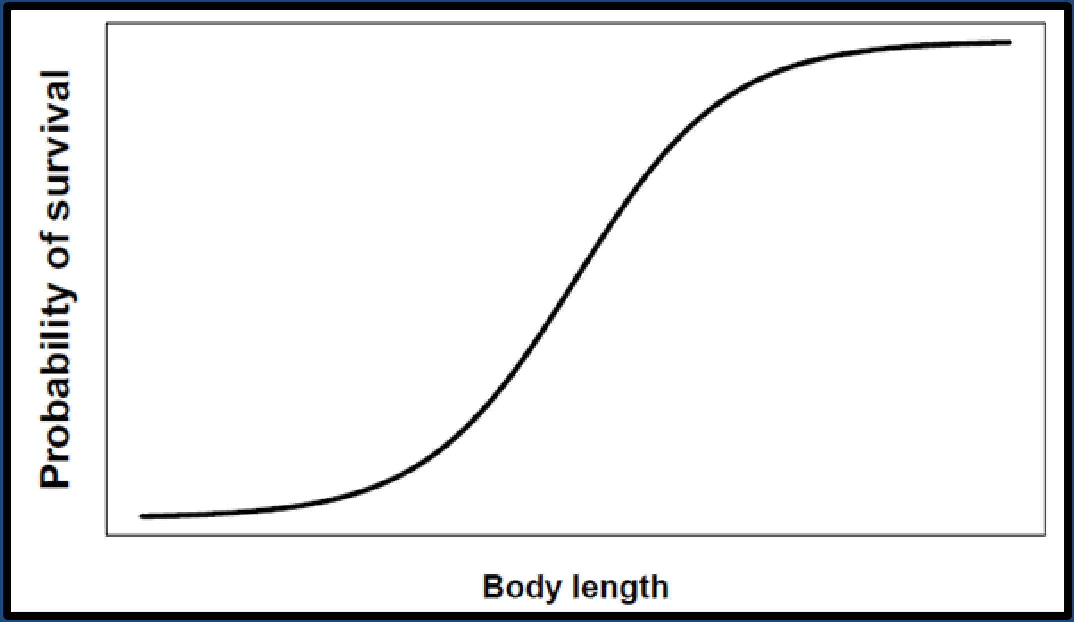
2012: 6 months

6 families, n = 4 tanks

2013: 12 months

10 families, n = 6 tanks

Response = fork length



Large size = higher survival in hatchery *mykiss*

(Tipping 1997; Reisenbichler *et al.* 2004; Bond *et al.* 2008; Clarke *et al.* 2014; Osterback *et al.* 2014)

Sampling

Measure FL

Fin tissue

Genetic parentage analysis - SOLOMON

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Statistical analysis

Family-by-density interaction

Average family fork length = density + family + density*family + tank (random)

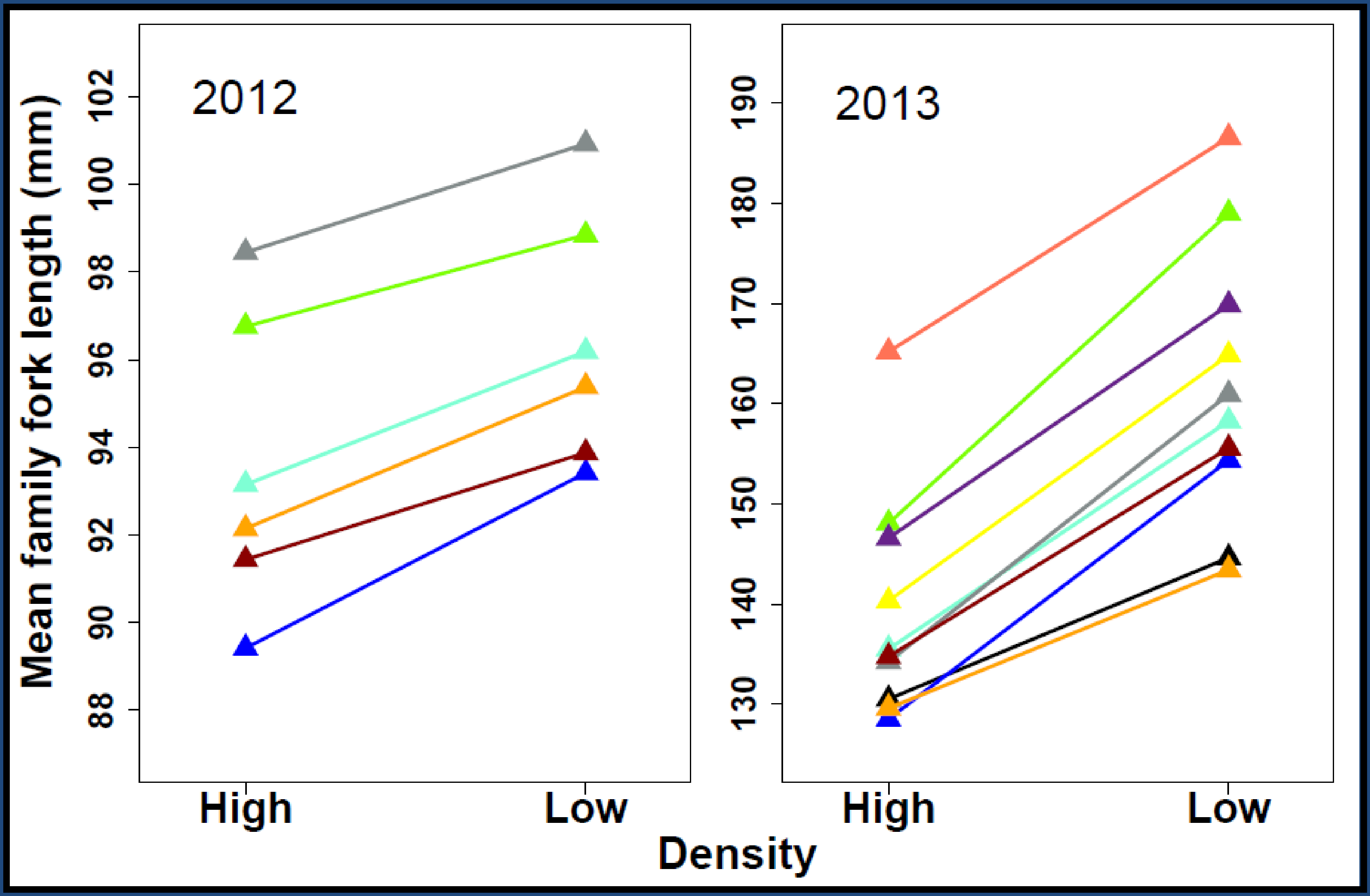
Statistical analysis

Family-by-density interaction

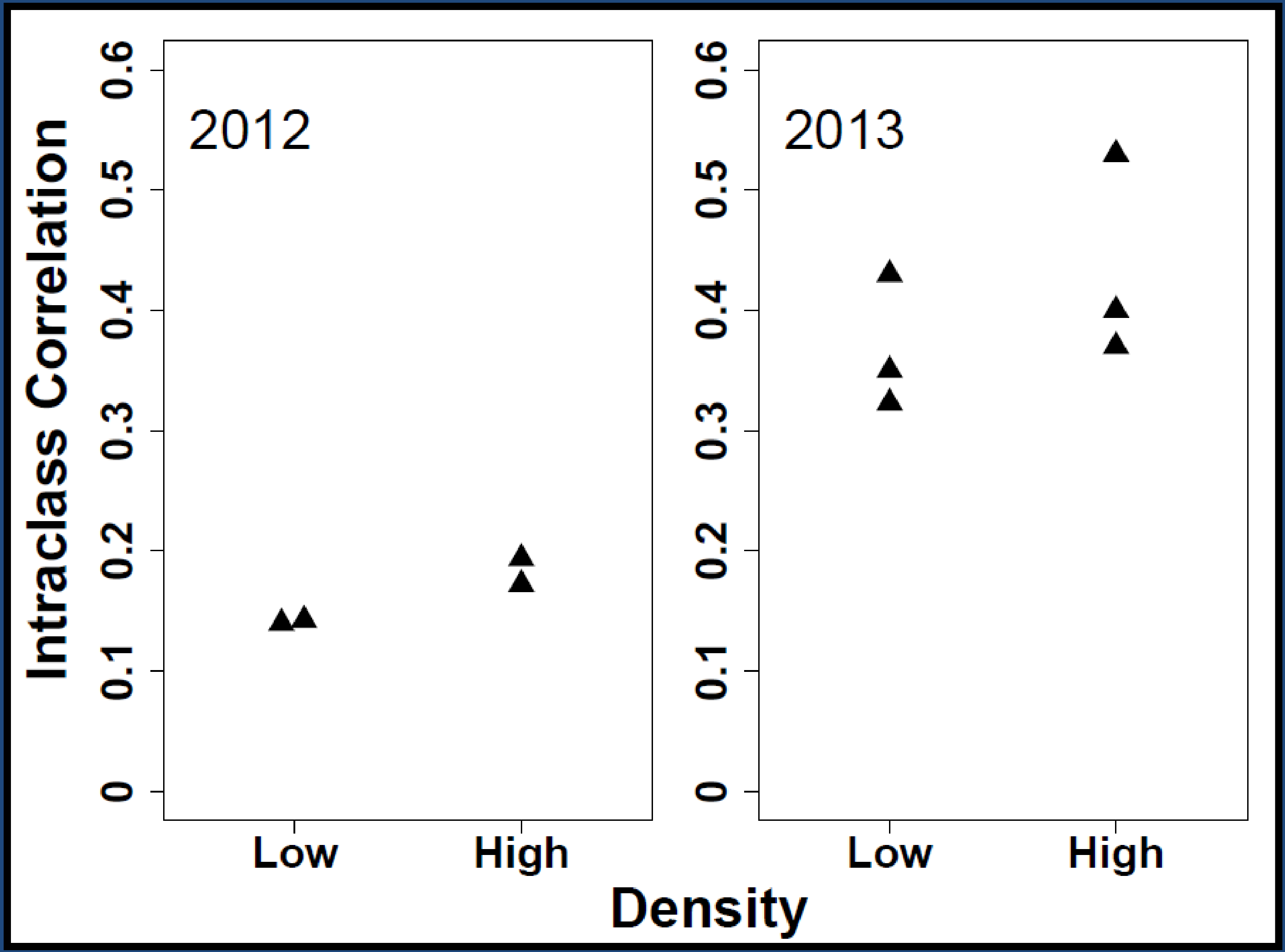
Average family fork length = density + family
+ density*family + tank (random)

Opportunity for selection –
Welch's t-test on ICC values

Results – Performance tradeoff

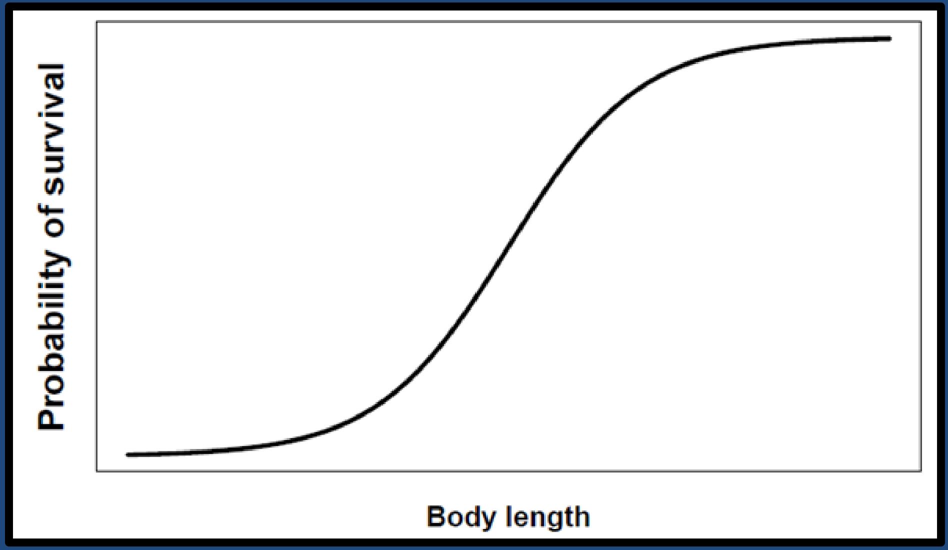


Results – Opportunity for selection higher in high density?



4. Novel hypothesis:

How might density influence domestication?



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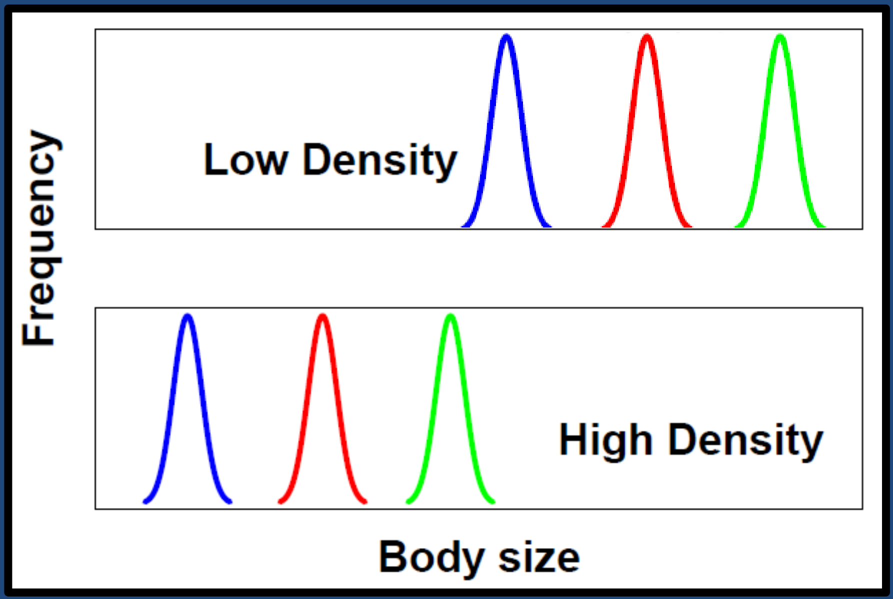

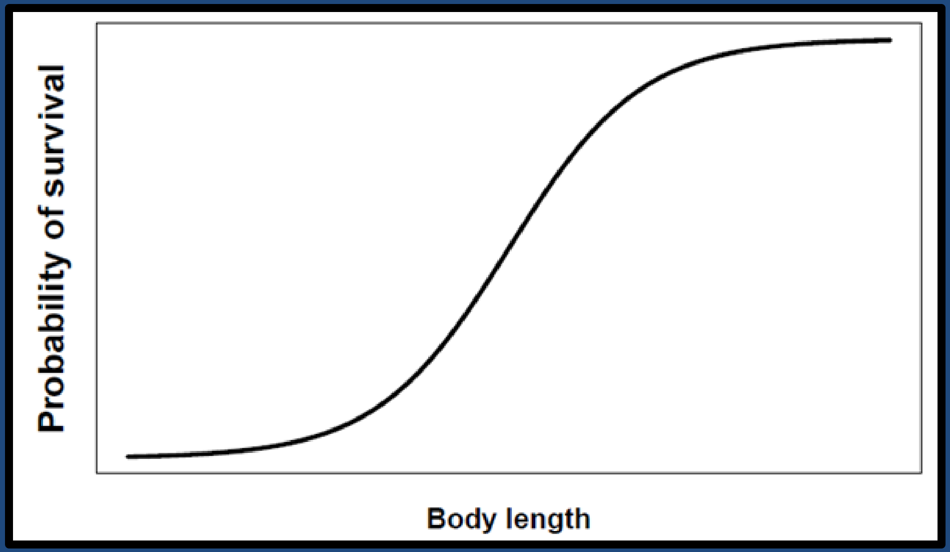

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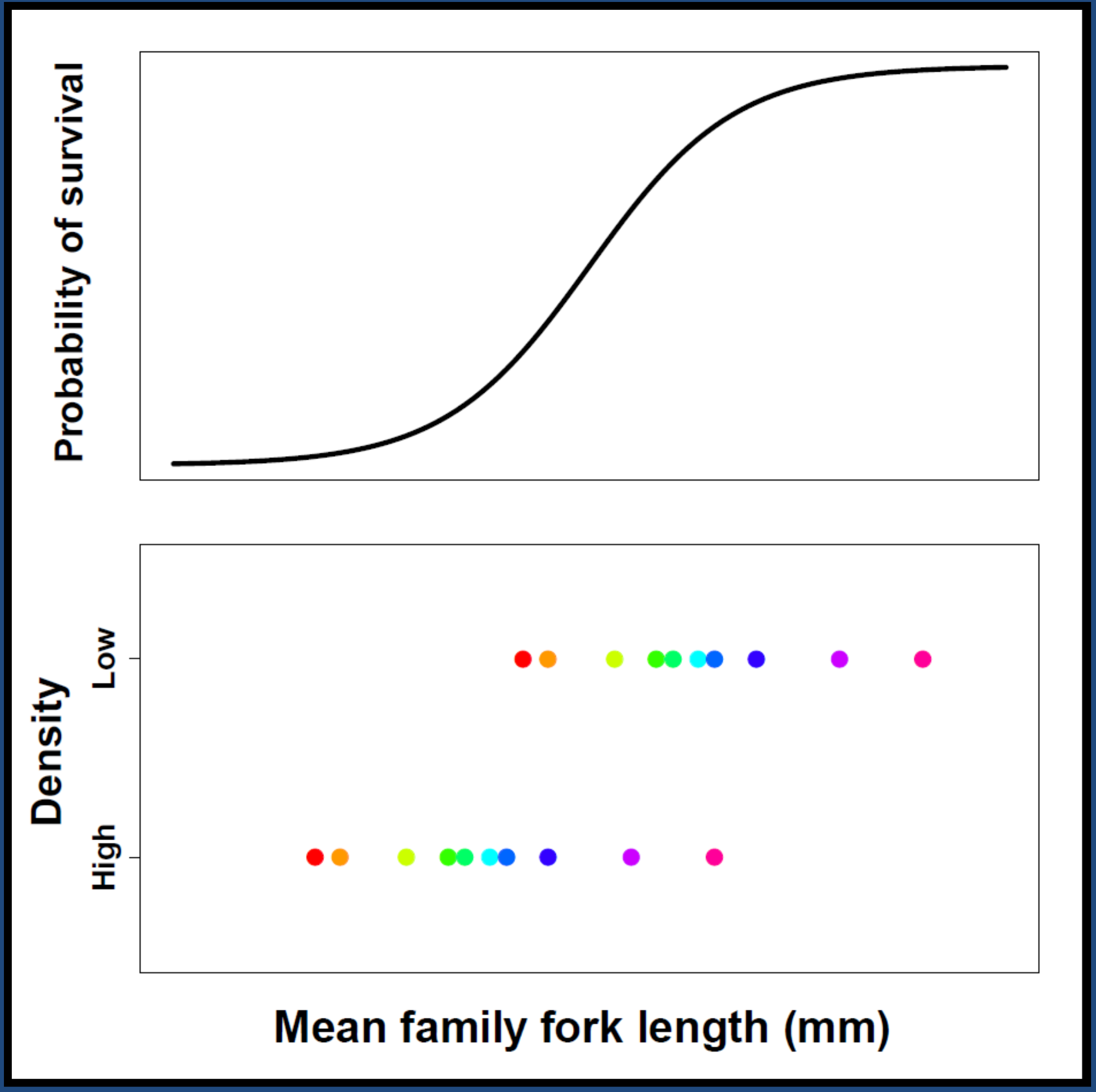

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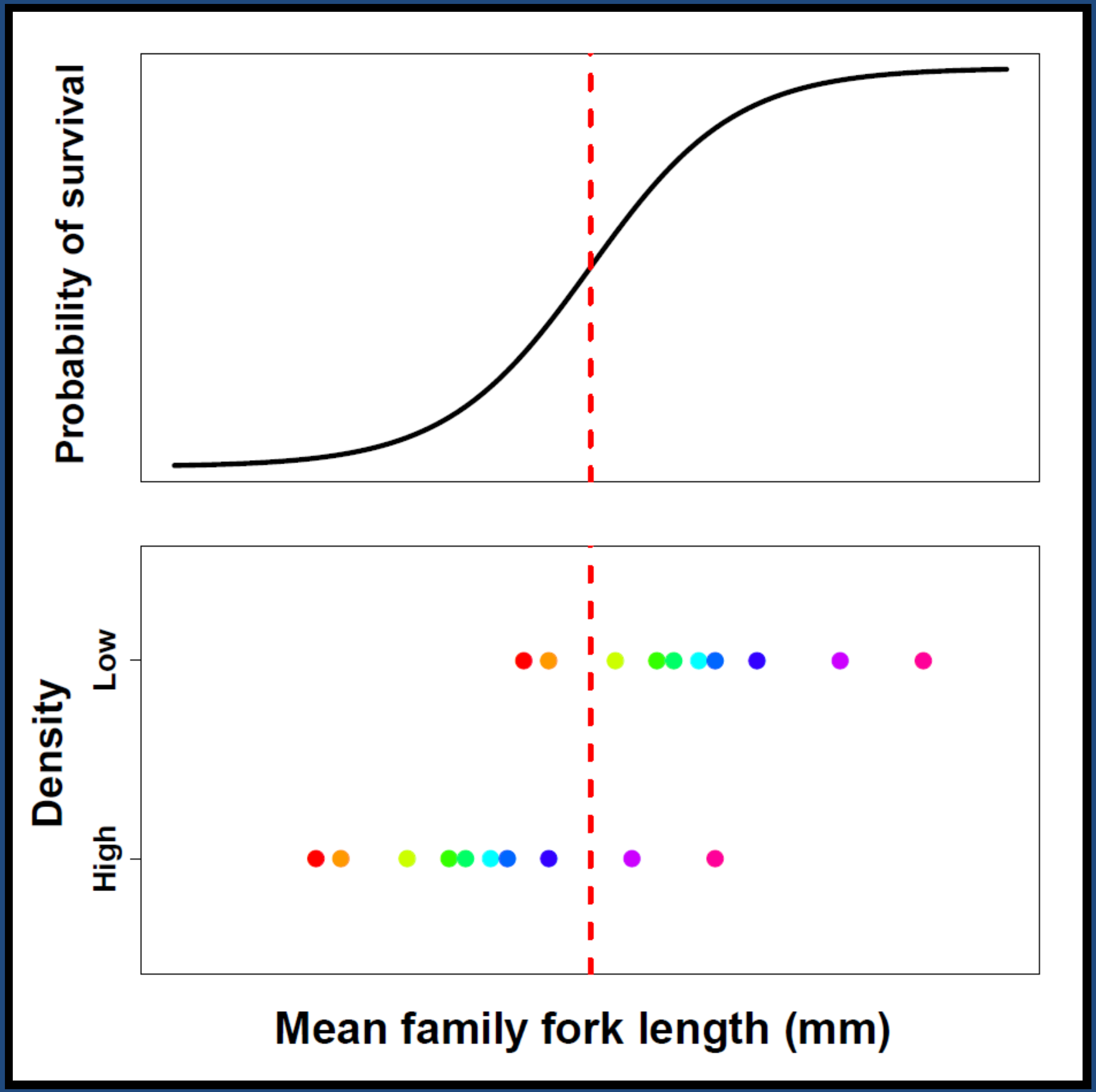

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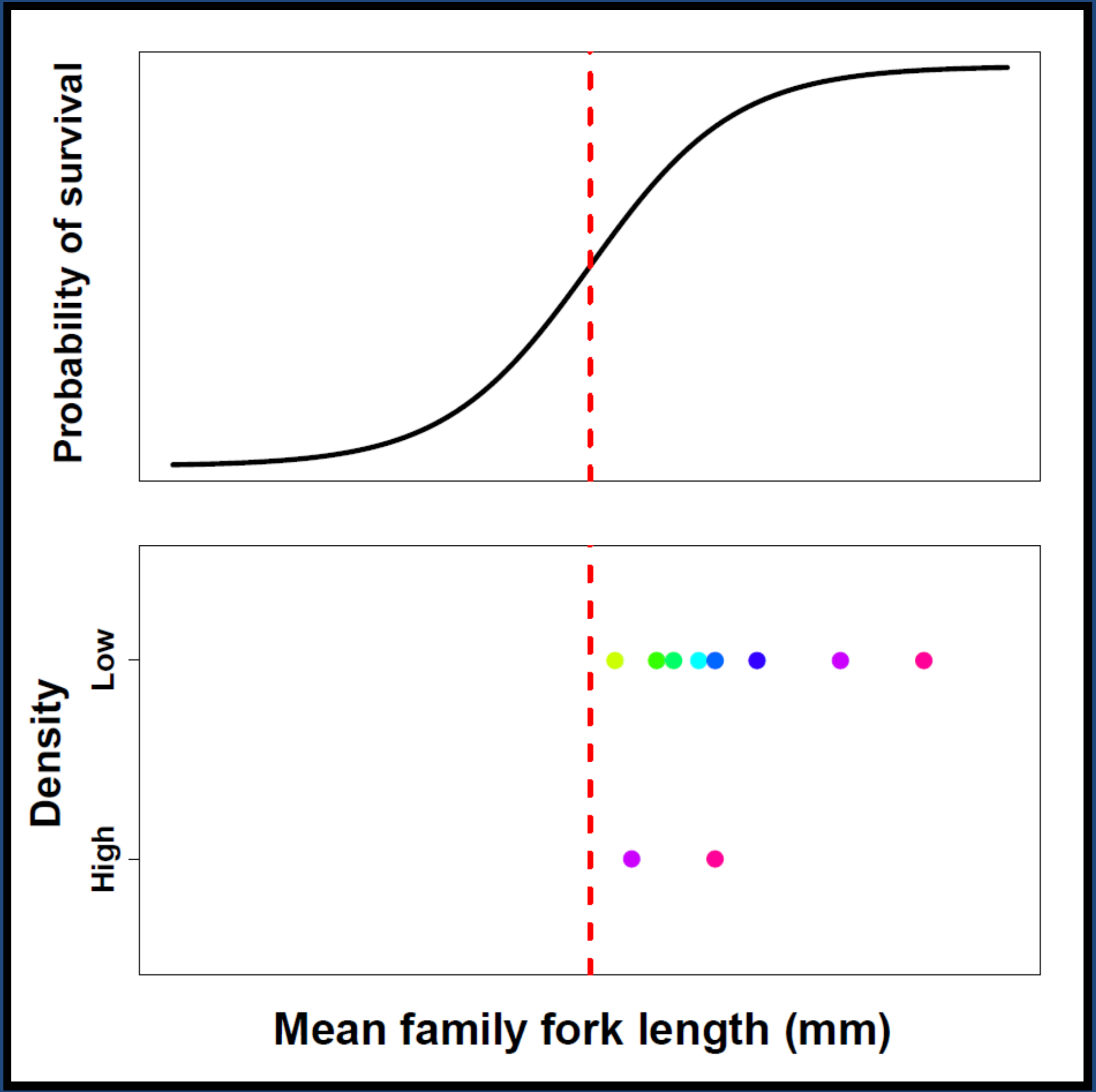
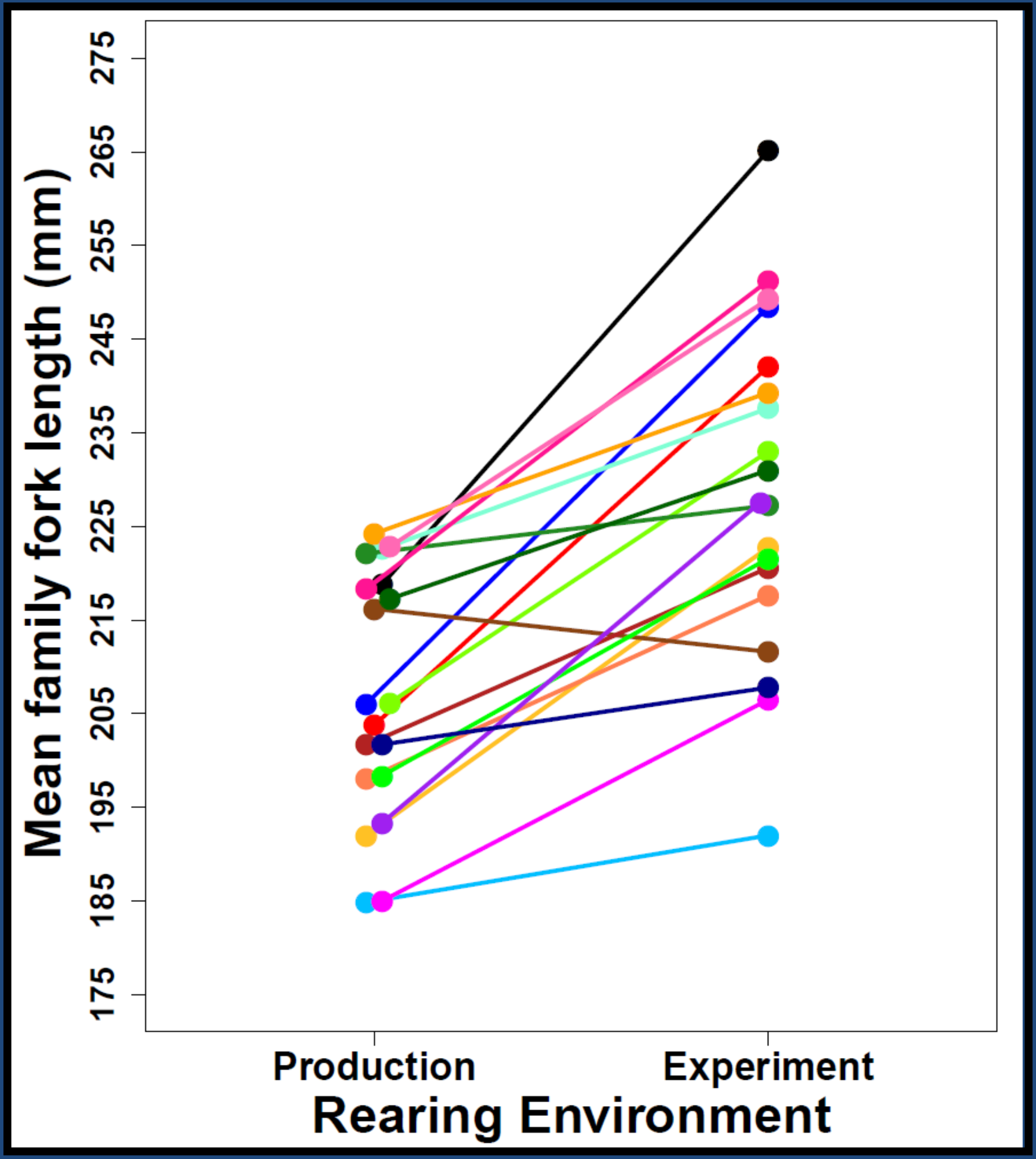


Unpublished Hood River data



Acknowledgments

- ODFW
- OHRC
- Alsea River hatchery
- Oak Springs hatchery

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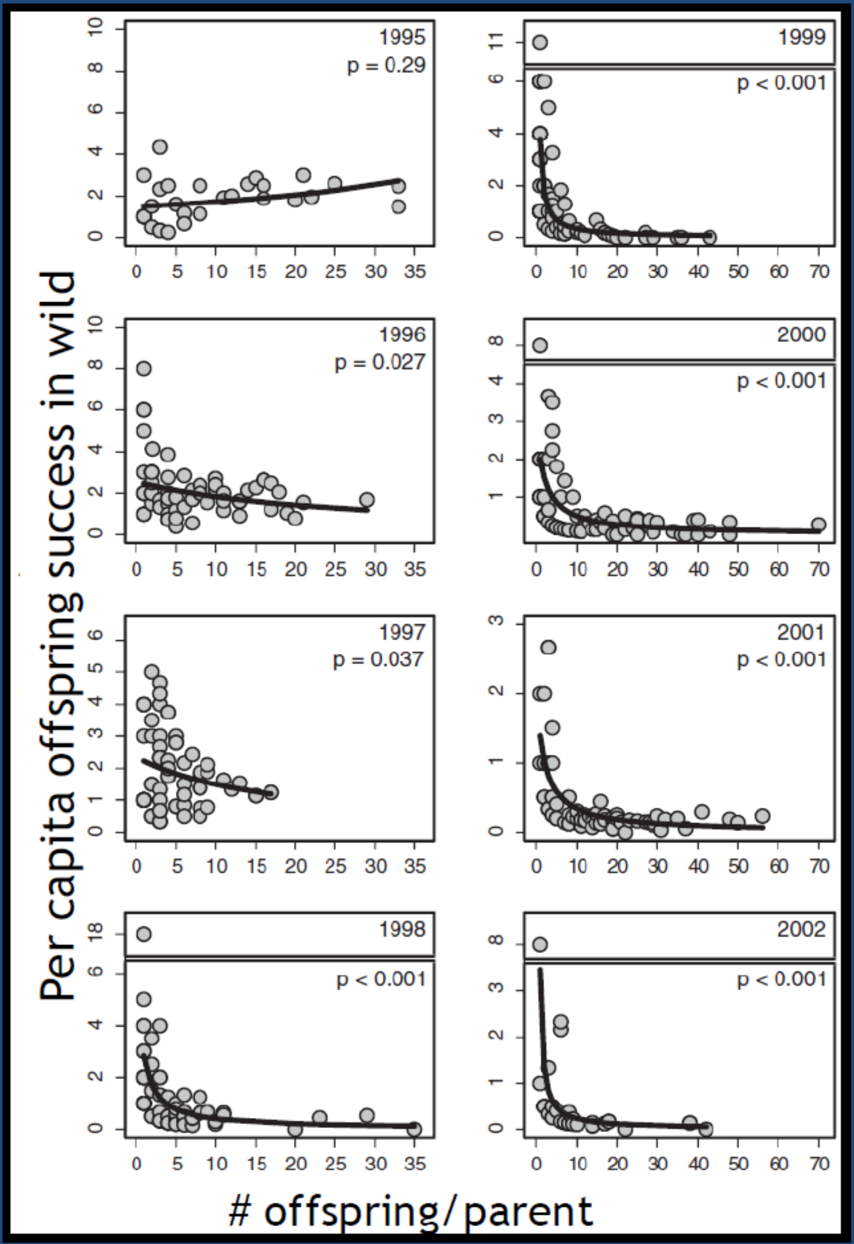

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51 point estimates

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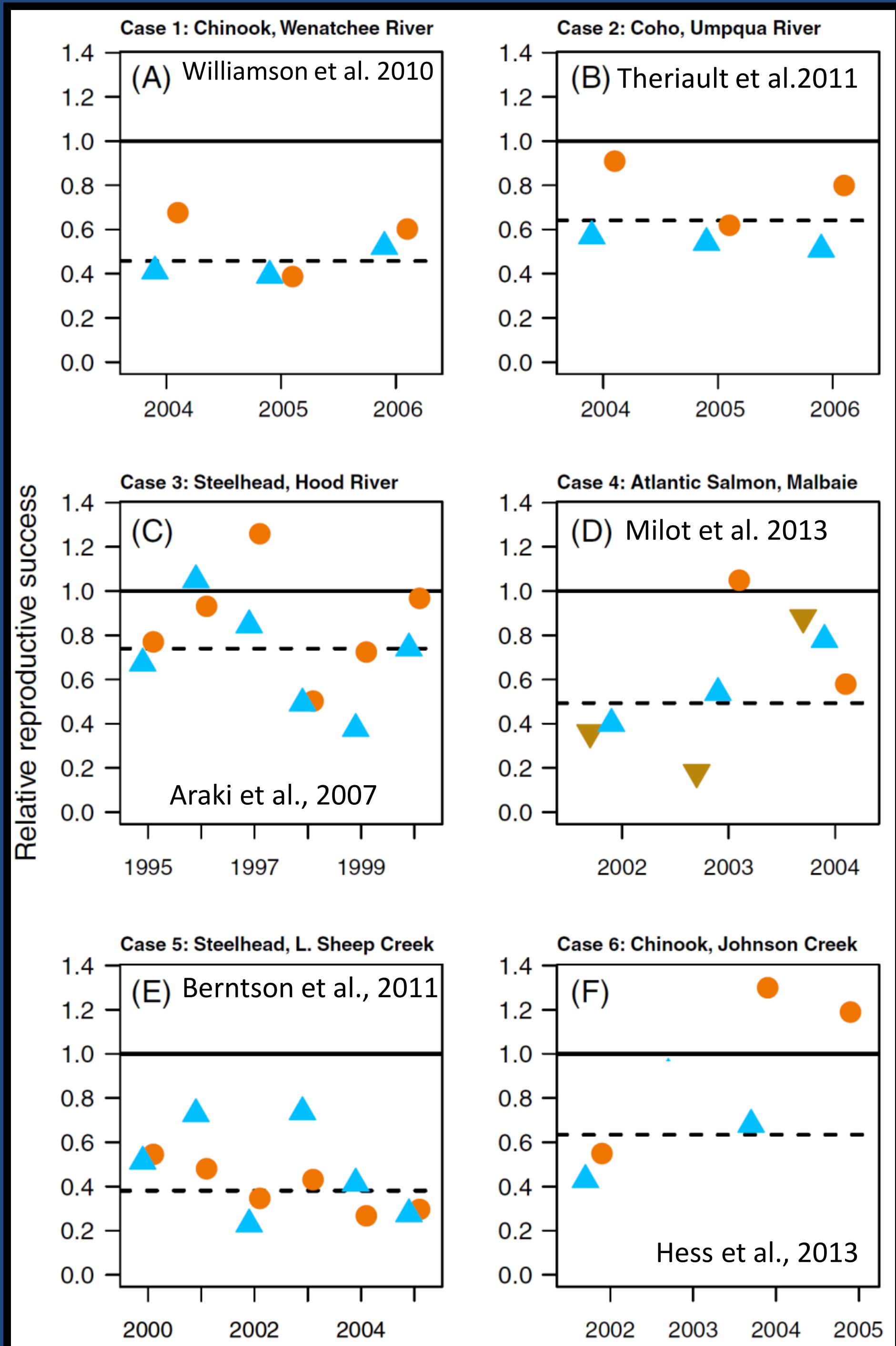
= 0.534

Without mykiss

RRS = 0.538

Christie *et al.* 2014



51 point estimates

Weighted geometric mean **RRS= 0.534**

(0.538 without steelhead)

Christie *et al.* 2014

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

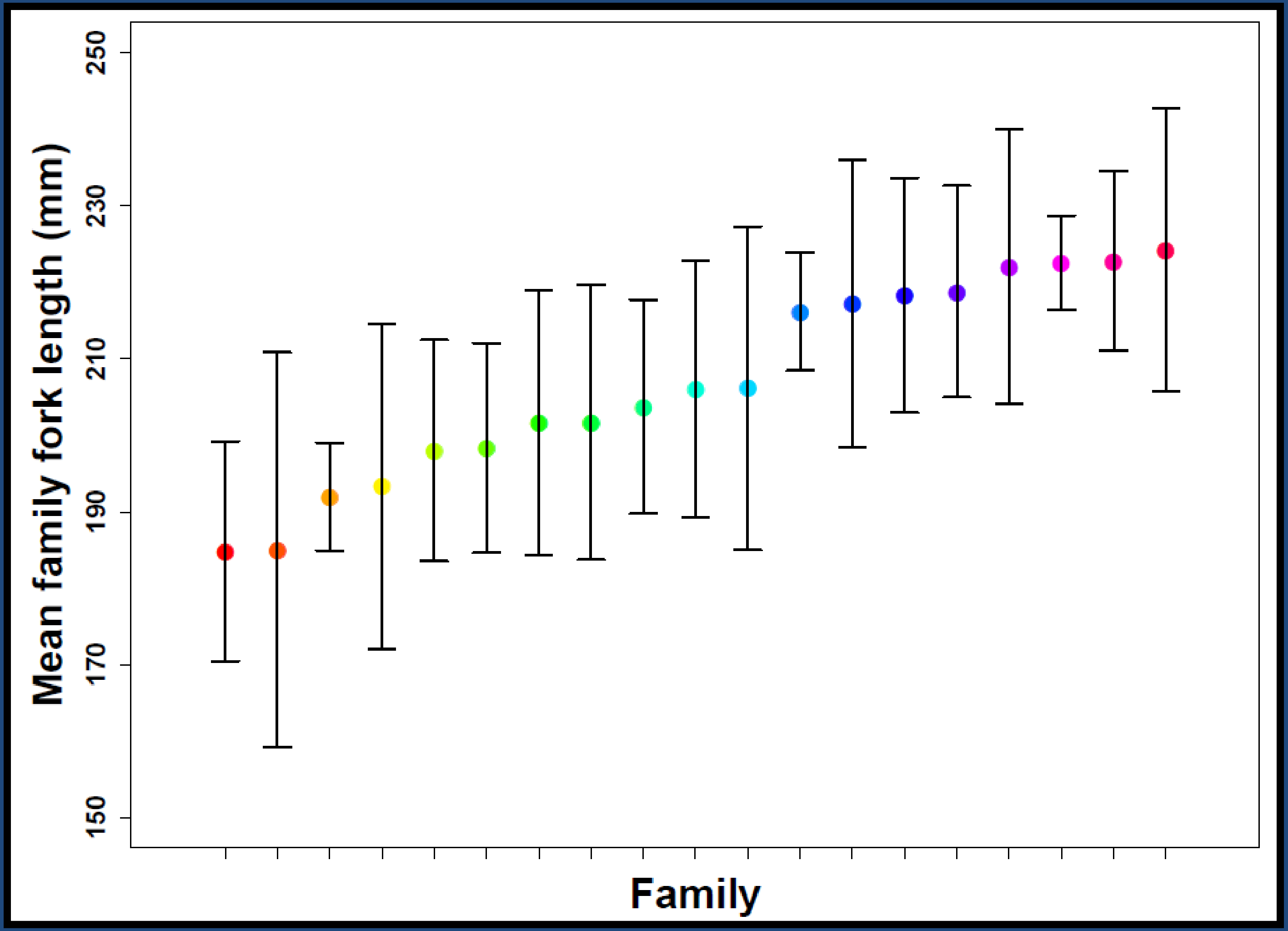
- local origin broodstock – integrated program
- offspring evaluated in river of origin
- relatively “wild” population

Table 1. Details for each of the six case studies. We report the number of F1 run years evaluated (years), the life stage at which F2 fish were collected, the hypothesis testing methods employed, and any features unique to the study. Four species from six populations are represented.

Case	Common name	Species	Years	F2 life stage	Hypothesis testing	Unique features	References
1	Chinook	*O. tshawytscha*	3	Adult, juvenile	*t*-tests, linear models, GLM	Identified spawning location	Ford et al. (2013)
2	Coho	*O. kisutch*	3	Adult	Randomization tests, ANOVA	Unfed fry, different broodstock crosses	Thériault et al. (2011)
3	Steelhead	*O. mykiss*	6	Adult	Randomization tests	Different broodstock crosses	Araki et al. (2007a,b)
4	Atlantic salmon	*S. salar*	3	Juvenile	Bootstrapping, GLM	Only Atlantic Ocean study to date	Milot et al. (2013)
5	Steelhead	*O. mykiss*	6	Adult, juvenile	GLM	Integrated broodstock program	Berntson et al. (2011)
6	Chinook	*O. tshawytscha*	4	Adult	Randomization tests	No prior hatchery intervention	Hess et al. (2012)

Christie *et al.* 2014

Hood River production data



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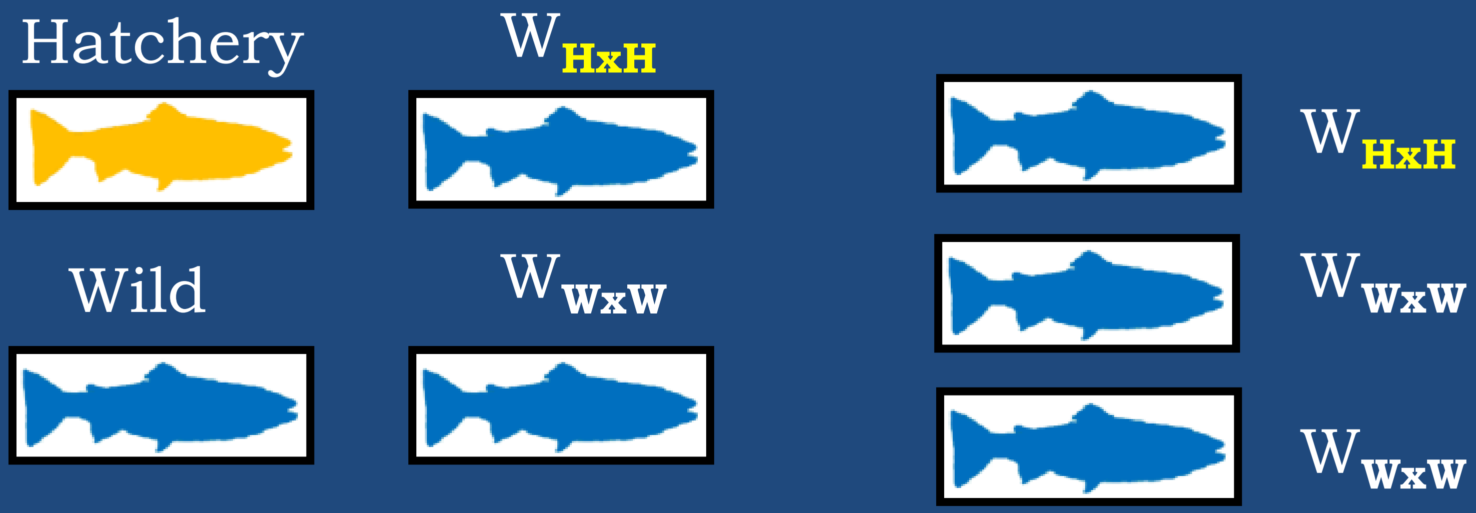
multi-generation effect?



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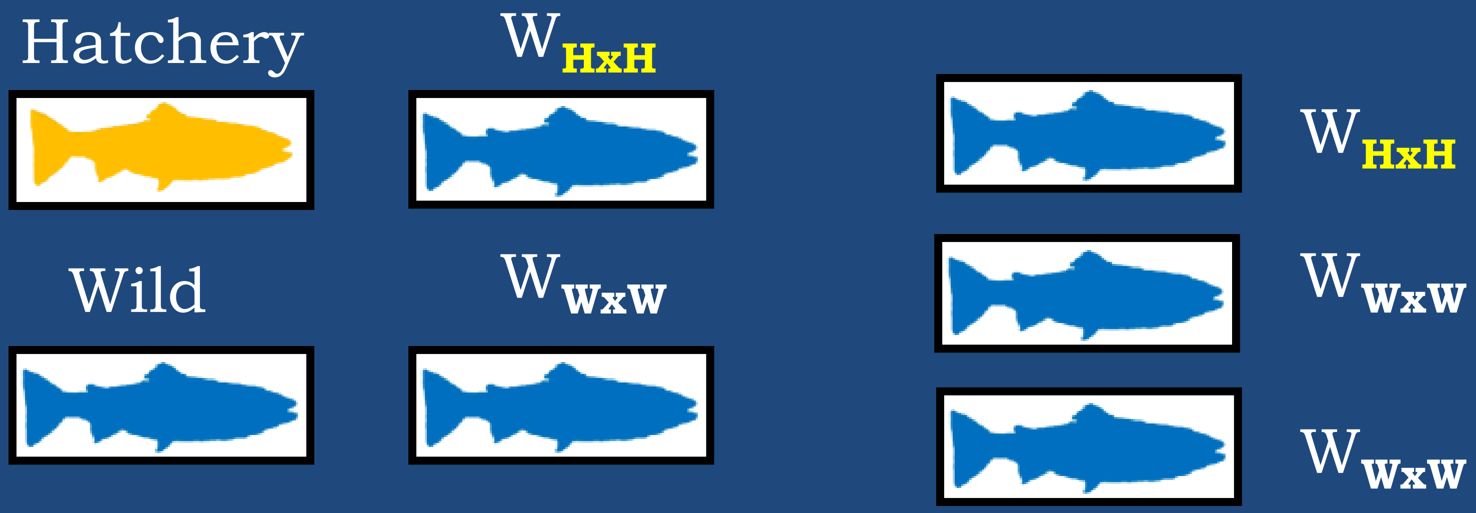

W_{HxH} RRS = 0.3 - 0.4 compared to W_{WxW}

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

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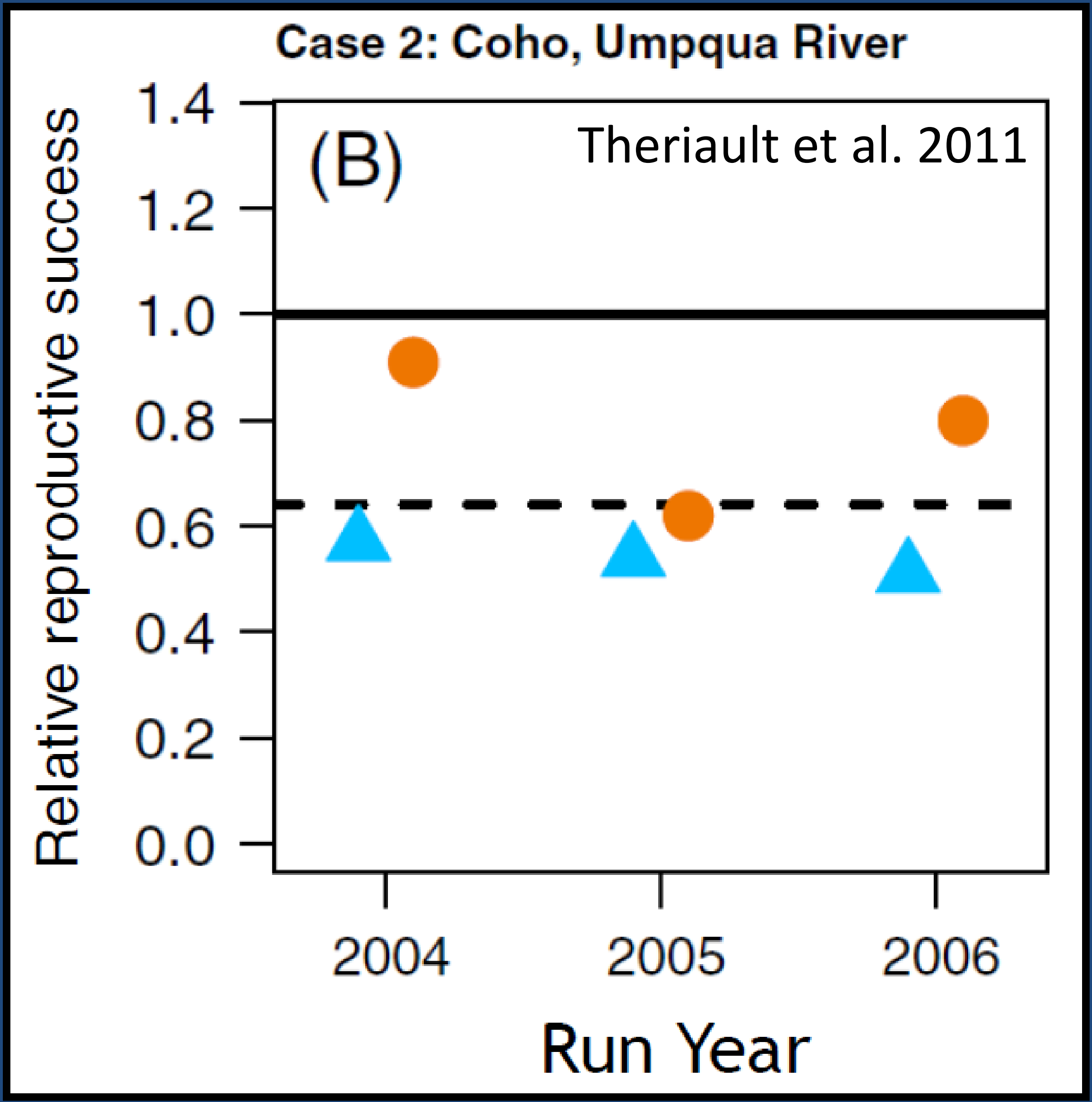
Christie *et al.* 2014



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