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

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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
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

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 mean $RRS = 0.534$ (0.538 without steelhead)

Christie et al. 2014
Causes of fitness loss – genetic effects

multi-generation effect?

Hood River steelhead: Araki et al., 2009 Biology Letters
Causes of fitness loss – genetic effects

multi-generation effect?

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?

\[ H_{HN} < H_{NN} \]

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

Thompson and Blouin. 2015. CJFAS
Domestication mechanism hypothesis

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

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

\[
\text{Selection intensity} = \frac{\text{FL}_{\text{adults}} - \text{FL}_{\text{smolts}}}{\text{SD}}
\]

the number of phenotypic standard deviations above the mean trait value that the surviving fish are at release from the hatchery
<table>
<thead>
<tr>
<th>Smolt Year</th>
<th>Fish Origin</th>
<th>Watershed</th>
<th>Selection intensity fork length</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>Natural</td>
<td>Keough River, BC</td>
<td>0.73</td>
<td>Ward and Slaney 1988, Ward et al. 1989</td>
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<td>1978</td>
<td>Natural</td>
<td>Keough River, BC</td>
<td>1.00</td>
<td>Ward and Slaney 1988, Ward et al. 1989</td>
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<tr>
<td>1979</td>
<td>Natural</td>
<td>Keough River, BC</td>
<td>0.54</td>
<td>Ward and Slaney 1988, Ward et al. 1989</td>
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<tr>
<td>1981</td>
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<td>Keough River, BC</td>
<td>0.47</td>
<td>Ward and Slaney 1988, Ward et al. 1989</td>
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<td>1982</td>
<td>Natural</td>
<td>Keough River, BC</td>
<td>0.44</td>
<td>Ward and Slaney 1988, Ward et al. 1989</td>
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<tr>
<td>2003</td>
<td>Hatchery</td>
<td>Scott Creek, CA</td>
<td>0.66</td>
<td>Bond et al. 2008</td>
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<tr>
<td>1998</td>
<td>Hatchery</td>
<td>Hood River, OR</td>
<td>1.80</td>
<td>Thompson et al. This study</td>
</tr>
<tr>
<td>2010</td>
<td>Hatchery</td>
<td>Hood River, OR</td>
<td>0.30</td>
<td>Thompson et al. This study</td>
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</tbody>
</table>
Domestication mechanism: Family effects before release
Domestication mechanism: Size-biased survival post-release