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

Neil Thompson, Michael Blouin
1. F1 vs. natural-origin RRS
   – Christie et al. 2014 Evol Apps.

2. Causes of fitness loss in *mykiss*
   – Christie et al. 2012 PNAS
1. F1 vs. natural-origin RRS
   – Christie et al. 2014 Evol Apps.
2. Causes of fitness loss in *mykiss*
   – Christie et al. 2012 PNAS
3. Drivers of domestication in captivity
4. Novel hypothesis - density influencing domestication

CJFAS 72:1829-1834
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

Christie *et al.* 2012 *PNAS*
Hood River steelhead
3. Drivers of domestication in captivity

# fish reared

1995

\[ p = 0.29 \]

5,000

1996

\[ p = 0.027 \]

26,000

1997

\[ p = 0.037 \]

48,000

1998

\[ p < 0.001 \]

57,000

Christie et al. 2012 PNAS
Rearing density hypotheses

1. Increased rearing density causes performance tradeoffs

![Graph showing fitness traits at different densities](image-url)
Rearing density hypotheses

1. Increased rearing density causes performance tradeoffs

2. High rearing density increases opportunity for selection

\[ ICC = \frac{V_A}{V_A + V_W} \]
Rearing density hypotheses

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

\[
ICC = \frac{V_A}{V_A + V_W}
\]
Experimental methods

Not comparing H vs W

1 family
Experimental methods

Two treatments
high/low density

1 family
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
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?
4. Novel hypothesis:

How might density influence domestication?
How might density influence selection?
How might density influence selection?
How might density influence selection?
Unpublished Hood River data
Acknowledgments

• ODFW
• OHRC
• Alsea River hatchery
• Oak Springs hatchery
3. Drivers of domestication in captivity

Christie et al. 2012 PNAS
1: Early-generation hatchery fish have lower fitness than wild fish

51 point estimates

Geometric RRS = 0.534

Without mykiss

RRS = 0.538

Christie et al. 2014
51 point estimates

Weighted geometric mean \( \text{RRS} = 0.534 \) (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

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**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.

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

Christie et al. 2014
Hood River production data
2. Causes of fitness loss in *mykiss* – genetic effects

multi-generation effect?
2. Causes of fitness loss in *mykiss* – genetic effects

multi-generation effect?

Hatchery

\[ W_{HxH} \]

Wild

\[ W_{WxW} \]

\[ W_{HxH} \]

\[ W_{HxH} \]

\[ W_{WxW} \]

\[ W_{WxW} \]

\[ W_{WxW} \]

\[ W_{HxH} \]

\[ W_{WxW} \]

\[ W_{HxH} \]

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

Christie et al. 2014
Case 2: Coho, Umpqua River

(B) Theriault et al. 2011

Relative reproductive success

Run Year

Christie et al. 2014