Alternative steelhead smolt rearing strategies for locally derived broodstocks

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Steelhead program at WNFH

• Location: Winthrop, WA on Methow River
  • 54 miles from Columbia confluence
  • 524 miles from Pacific Ocean
  • Nine Columbia River dams
• Purpose
  • Mitigation for Grand Coulee Dam
  • Recover threatened upper Columbia River steelhead
Recovery actions for Upper Columbia steelhead

- Past program: Wells yearling smolts (S1)
- Switch to local Methow River broodstock
  - Requires change to the culture regime
    - Late spawn timing of Methow broodstock
      - Shortens growth window
    - Cold water temperatures at Winthrop NFH
      - Lower growth rates
  - Two year smolt rearing (S2)
- Compare S1 and S2 strategies to determine viability of switching exclusively to local broodstock.
Winthrop NFH steelhead smolt size at release

2010

S1 Mean = 194 mm
S2 Mean = 214 mm

2011

S1 Mean = 159 mm
S2 Mean = 187 mm
Evaluation of S1 and S2 steelhead smolts

- Outmigration (PIT tag detections)
  - Survival
  - Travel time
- Residualism
  - Precocious male maturation
  - Too small to smolt
- Prerelease subsampling
  - FL, WT, Sex, Smolt Index, tissues for physiological & genetic analyses
## Outmigration Survival Data: SURPH

<table>
<thead>
<tr>
<th>RELEASE YEAR</th>
<th>GROUP</th>
<th># PIT TAGS RELEASED</th>
<th>SURVIVAL RELEASE-RR</th>
<th>SURVIVAL RR-MCN</th>
<th>OVERALL (JOHN DAY)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forced</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>S1</td>
<td>14,841</td>
<td>73.7 (2.4)</td>
<td>55.4 (10.1)</td>
<td>40.8 (7.3)</td>
</tr>
<tr>
<td></td>
<td>S2</td>
<td>14,756</td>
<td>81.5 (3.0)</td>
<td>64.9 (12.7)</td>
<td>52.9 (10.2)</td>
</tr>
<tr>
<td>2011</td>
<td>S1</td>
<td>14,907</td>
<td>45.8 (1.8)</td>
<td>55.9 (5.3)</td>
<td>25.6 (2.2)</td>
</tr>
<tr>
<td></td>
<td>S2</td>
<td>14,945</td>
<td>69.5 (2.1)</td>
<td>57.4 (4.3)</td>
<td>39.9 (2.7)</td>
</tr>
<tr>
<td><strong>Volitional</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>S1</td>
<td>14,917</td>
<td>64.5 (2.1)</td>
<td>55.5 (4.3)</td>
<td>28.5 (2.2)</td>
</tr>
<tr>
<td></td>
<td>S2</td>
<td>14,892</td>
<td>62.2 (2.3)</td>
<td>56.8 (4.8)</td>
<td>28.0 (2.4)</td>
</tr>
<tr>
<td>2013</td>
<td>S1</td>
<td>14,543</td>
<td>69.3 (2.2)</td>
<td>67.5 (10.1)</td>
<td>42.3 (5.9)</td>
</tr>
<tr>
<td></td>
<td>S2</td>
<td>14,477</td>
<td>58.9 (1.7)</td>
<td>61.8 (6.9)</td>
<td>45.3 (5.6)</td>
</tr>
</tbody>
</table>
Outmigration Survival

Apparent Survival ($\psi$) vs. Year:

- **2010**
  - For forced migration:
    - S1 and S2 survival rates shown.
  - For volitional migration:
    - S1 and S2 survival rates shown.

- **2011**
  - Similar pattern as 2010.

- **2012**
  - Similar pattern as 2010.

- **2013**
  - Similar pattern as 2010.

Survival rates are indicated by the size of the circles, with larger circles representing higher survival rates.
Selection on body size after release

- 2011 S1
  - Migrant fish: 158, 182
  - Released fish:...

- 2011 S2
  - Migrant fish: 186, 193
  - Released fish:...

- 2012 S1
  - Migrant fish: 172, 184
  - Released fish:...

- 2012 S2
  - Migrant fish: 185, 192
  - Released fish:...

- 2013 S1
  - Migrant fish: 195, 198
  - Released fish:...

- 2013 S2
  - Migrant fish: 194, 197
  - Released fish:...
Final smolt size affects survival to Columbia
Inter-annual variability of S1 smolt size

![Graph showing inter-annual variability of S1 smolt size.](image)

- **Apparent Survival (Φ) to Rocky Reach**
- **Fork Length at Release (mm)**
- **Wells S1 Fork Length**
- **Methow S2 average release fork length**

Data points and lines illustrate the variability in fork length and apparent survival over different release years.
Travel time by reach

Forced

- **ROCKY REACH**
- **MCNARY**
- **BONNEVILLE**

Travel Time (days)
0
3
6
9
12
15
18
21
24
27

S1 smolts
S2 smolts

Volitional

- **ROCKY REACH**
- **MCNARY**
- **BONNEVILLE**

Travel Time (days)
0
3
6
9
12
15
18
21
24
27

* Volitional

2010
2011
2012
2013
Puberty in male steelhead

- Initiation of maturation occurs 1 year before maturation
- Before development of secondary sexual characteristics
- Small differences in GSI between initiating males and immature males
- Large differences in GSI for between mature and immature males
- Develop indicators and verify with histology of testis

GnRH = gonadotropin releasing hormone  
FSH = follicle stimulating hormone  
LH = lutenizing hormone  
11KT = 11-ketotestosterone  
amh = anti mullerian hormone (in sertoli cells)  
igf3 = insulin like growth factor 3 – a gonad specific IGF found in sertoli cells of teleost fish
Reproductive Stages based on Histology

Gonadosomatic Index

Stage 0
- Single type A gonad
- Paired type A gonad

Stage I
- Single type A gonad
- Paired type A gonad
- Early B gonad

Stage II
- Early B gonad

Stage III
- Primary spermatocytes
- Secondary spermatocytes
- Spermatids

Stage V
- Spermatozoa
- Spermatozoa

Mature

Initiating

Immature

Initiating
Indicators of male maturation status

Pituitary & Testis mRNAs

Pituitary FSH

Pituitary LH

Testis size and hormones

GSI

Testis AMH

Testis IGF-3

Plasma 11-KT
Male steelhead reproductive state at release

- Mature
- Initiating
- Immature

N = 300
S1 and S2 males each release year
Residualism

- PIT tag data
  - Compare size of released and detected S1 & S2 populations

- Annual field sampling (August and September)
  - Electrofishing, seining, angling
  - Spring Creek outfall of WNFH
  - Downstream reference reach of Methow River
Proportional representation of S1 & S2 residuals

Forced release
- 2010: 0.16%
- 2011: 0.42%
- 2012: 0.13%
- 2013: 0.10%

Volitional release
- 2010: 0.02%
- 2011: 0.27%
- 2012: 0.26%
- 2013: 0.15%
Size at release and residualism

Mean Fork Length at Release (mm)
150 160 170 180 190 200 210 220
Residuals (% of fish released)
0.0
0.1
0.2
0.3
0.4
0.5
S1, \( r^2 = 0.95 \)
S2, \( r^2 = 0.72 \)

2010
2011
2012
2013

NOAA Fisheries
Percent residual steelhead by sex

Forced release

Volitional release

<table>
<thead>
<tr>
<th>Year</th>
<th>S1</th>
<th>S2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>113</td>
<td>7</td>
</tr>
<tr>
<td>2011</td>
<td>200</td>
<td>35</td>
</tr>
<tr>
<td>2012</td>
<td>53</td>
<td>91</td>
</tr>
<tr>
<td>2013</td>
<td>47</td>
<td>83</td>
</tr>
</tbody>
</table>
Reproductive status of male residuals

<table>
<thead>
<tr>
<th>Year</th>
<th>Immature (S1)</th>
<th>Maturing (S2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>62</td>
<td>0%</td>
</tr>
<tr>
<td>2012</td>
<td>29</td>
<td>30%</td>
</tr>
<tr>
<td>2013</td>
<td>21</td>
<td>55%</td>
</tr>
</tbody>
</table>
Conclusions: Survival and Travel Time

- WNFH can raise steelhead from a locally-sourced broodstock (S2)
  - Survival: S2 ≥ S1
  - Travel time: S2 < S1
- Survival of S1 (co-mingled Wells stock) is
  - More variable than S2s and is contingent on rearing practices that maximize size at release
- Detections of migrating steelhead are inversely related to residualism
Conclusions: Residualism

- S1 & S2 residual populations are male biased
  - Regardless of release strategy
  - Most male residuals are maturing
- Residualism rates appear to be inversely related to size at release for S1 and S2 steelhead
- S1 residualism is likely due to growth rates insufficient to induce smoltification in 1 year
- S2 residualism is likely due to increased rates of precocial maturation
Costs? Benefits? Appropriateness?

• Costs?
  • Maybe 1 year production (S1→S2)
  • Natural broodstock collection – angling
  • ↑ risk in culture (hold fish for 2 years)
  • Slight increase in feed and labor

• Benefits?
  • Preserve life history variation
  • Larger smolts and fewer residuals
  • Natural age of smoltification
  • Reduce size selection
  • Higher SAR?
  • Reduce hatchery/wild ecological interactions

• When to use?
  • Transition to locally-derived broodstock
  • Late spawn timing
  • Cold hatchery water sources
  • Short hatchery culture season
  • Recovery of ESA listed populations
Acknowledgements

• Collaborators
  • USFWS – staff of WNFH and Mid Columbia FRO
  • NOAA/NWFSC - Manchester and Montlake
  • UW
  • USGS
  • WDFW

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Two more reasons to care about residuals

S1 residual collected in Methow River 14 Sept. 2011

Maturing Testes - Bad

Yellow Jackets - Good

Chinook eggs - Bad
Males with high GSI were a mixture of males that had matured the previous spring, or were maturing for the following spring.