Size at Release of Imnaha River Smolts: Does Size Matter?

Joseph Feldhaus
Tim Hoffnagle
Richard Carmichael

Northeast-Central Oregon Research & Monitoring
Oregon Department of Fish and Wildlife
203 Badgley Hall
Eastern Oregon University
La Grande, OR

This project was funded by the
Lower Snake River Compensation Plan
United States Fish and Wildlife Service
1. Prevent extinction of Imnaha River Chinook Salmon populations.


3. Meet mitigation goal of 3,210 hatchery adults returning to the Imnaha Basin.

4. Re-establish historic tribal and recreational fisheries.

5. Minimize impacts of hatchery programs on resident fish populations.
Imnaha River Spring Chinook Salmon LSRCP Program Objectives

1. Prevent extinction of Imnaha River Chinook Salmon populations.


3. Meet mitigation goal of 3,210 hatchery adults returning to the Imnaha Basin.

4. Re-establish historic tribal and recreational fisheries.

5. Minimize impacts of hatchery programs on resident fish populations.

6. Operate hatchery program so that the genetic and life history characteristics of hatchery salmon mimic those of wild salmon, while achieving mitigation goals.
Research & Monitoring Objectives

• Compare life history characteristics of hatchery and natural origin Chinook Salmon.
  • Juvenile/adult migration survival
  • Adult run timing
  • Age and size of maturity

• Identify optimum rearing and release strategies that will produce maximum survival to adulthood for hatchery-produced Chinook Salmon smolts.
  • Smolt-to-adult return (SAR) and survival (SAS) rates
  • Production Efficiency - number of mature salmon produced per 10 kg of smolts released
The Problem: Age Structure Differences

Imnaha River 1982-1987 Brood Year returns:

- Age 3: H > N
- Age 4: H < N
- Age 5: H < N

Hatchery

- Age 3: 43%
- Age 4: 41%
- Age 5: 16%

Natural

- Age 3: 13%
- Age 4: 51%
- Age 5: 36%
Lookingglass Fish Hatchery and Imnaha River Acclimation Site
### Study Design

(BY 1991 had BKD and was not included)

<table>
<thead>
<tr>
<th><strong>Large Smolts</strong></th>
<th><strong>Small Smolts</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target:</strong> 30-38 g (15-12 fpp)</td>
<td><strong>Target:</strong> 18-23 g (25-20 fpp)</td>
</tr>
<tr>
<td><strong>Actual:</strong> 26-41 g (17.5-11.1 fpp)</td>
<td><strong>Actual:</strong> 18-25 g (25.2-18.2 fpp)</td>
</tr>
</tbody>
</table>
Dependent Variables

- Juvenile survival to Lower Granite Dam (PIT tags in BY 1992-1998)
- Age composition
- Length at maturity
- Harvest, stray, and smolt-to-adult return (SAR) and survival (SAS) rates
- Production efficiency: returns/10 kg of smolts released
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Hypothesis

There is no difference between large and small smolts.
Smolt Size and Survival

Survival

Smolt weight (g)
Overall Smolt Survival to Lower Granite Dam (LGD) BY 1992-1998

Percent survival to LGD (+ STD)

P = 0.045

Smolt size group
Age Composition

Age at maturity

Percent survival to LGD (+ STD)

- Age 3: P = 0.182
- Age 4: P = 0.474
- Age 5: P = 0.871
Length at Maturity

Age at maturity

Mean length (mm ± STD)

P = 0.767
P = 0.738
P = 0.197
# Harvest, Stray, SAR and SAS Rates

<table>
<thead>
<tr>
<th></th>
<th>Large Smolts</th>
<th>Small Smolts</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Harvest</strong></td>
<td>0.022%</td>
<td>0.028%</td>
<td>0.035</td>
</tr>
<tr>
<td><strong>Stray</strong></td>
<td>0.012%</td>
<td>0.007%</td>
<td>0.184</td>
</tr>
<tr>
<td><strong>SAR</strong></td>
<td>0.846%</td>
<td>0.920%</td>
<td>0.282</td>
</tr>
<tr>
<td><strong>SAS</strong></td>
<td>0.881%</td>
<td>0.955%</td>
<td>0.287</td>
</tr>
</tbody>
</table>

- Large Smolts: (30 g)
- Small Smolts: (21 g)
Production Efficiency

P = 0.218

Smolt Size Group

Large
Small

Adults/10 kg of smolts released

0
2
4
6
8
10
12
Study Design: Size Group and Density

High Density
44,346 - 85,796 smolts / rcwy
BY 1988-1993

Low Density
6,613 – 26,796 smolts / rcwy
BY 1994-1998

Large Smolts
26-41 g

Small Smolts
18-25 g

Large Smolts
26-33 g

Small Smolts
19-23 g

Dependent Variables

• Juvenile survival to Lower Granite Dam (PIT tags in BY 1992-1998)
• Age composition
• Harvest, stray, and smolt-to-adult return (SAR) and survival (SAS) rates
• Production efficiency: returns/10 kg of smolts released
Smolt Survival to Lower Granite Dam

- Large smolts
- Small smolts


**Percent survival to LGD (+ STD):**

- High Density: $P = 0.012$
- Low Density: $P = 0.105$
Age Composition
High Density (BY 1988-1993)

Age 3

Age 4

Age 5

Percentage (+ STDEV)

P = 0.127

P = 0.457

P = 0.914

Large

Small

High Density (BY 1988-1993)
Age Composition
Low Density (BY 1994-1998)

- Age 3
  - Percentage (+ STDEV)
  - Large: P = 0.594
  - Small: P = 0.594

- Age 4
  - Percentage (+ STDEV)
  - Large: P = 0.665
  - Small: P = 0.665

- Age 5
  - Percentage (+ STDEV)
  - Large: P = 0.747
  - Small: P = 0.747
Smolt-to-Adult Survival (SAS)

P = 0.528

P = 0.393
SAS variation between brood years

P < 0.0001

High Density
1988 - 1993

Low Density
1994 - 1998

Percent SAS survival (± STDEV)

Brood Year

Large Small

No data
# Harvest, Stray, SAR, and SAS Rates

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td><strong>Harvest</strong></td>
<td>&lt;0.001%</td>
<td>0.001%</td>
<td>0.197</td>
<td><strong>Low Density</strong></td>
<td>0.038%</td>
<td>0.048%</td>
<td>0.035</td>
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<tr>
<td><strong>Stray</strong></td>
<td>0.007%</td>
<td>0.004%</td>
<td>0.299</td>
<td></td>
<td>0.016%</td>
<td>0.009%</td>
<td>0.278</td>
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<tr>
<td><strong>SAR</strong></td>
<td>0.264%</td>
<td>0.273%</td>
<td>0.376</td>
<td></td>
<td>1.249%</td>
<td>1.417%</td>
<td>0.537</td>
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<td><strong>SAS</strong></td>
<td>0.271%</td>
<td>0.279%</td>
<td>0.393</td>
<td></td>
<td>1.302%</td>
<td>1.475%</td>
<td>0.528</td>
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**High Density** (1988-1993)  
**Low Density** (1994-1998)
Production Efficiency

P = 0.343
P = 0.448

Smolt Density
High 1988-1993
Low 1994-1998

Adults/10 kg of smolts released

Large
Small

High 1988-1993
Low 1994-1998
Smolt Density
Evaluation Summary

• Large smolts survived better to LGD during high density years.

• Smolt size did not affect age composition, or harvest, stray, SAR, or SAS rates.

• Imnaha River spring Chinook Salmon have a very low stray rate.

• Brood year/migration year variation is more important than smolt size.

• Small smolts produced twice the number of returning mature salmon as large smolts.
Smolt Size and Survival

Graph showing the relationship between Smolt weight (g) and SAS (Survival and Success). The graph indicates a peak survival rate around a certain weight, which decreases as the weight deviates from this optimal value.
Smolt Size and Survival

SAS

Smolt weight (g)
**Production Efficiency**

1,700 kg smolts / raceway

**Large Smolts**
- 34 g / smolt
- 37,000 smolts

Mean SAS = 0.881%

**Small Smolts**
- 20 g / smolt
- 65,000 smolts

Mean SAS = 0.955%
# Production Efficiency

- 1,700 kg smolts / raceway

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Mean SAS = 0.881%  
Mean SAS = 0.955%

- 326 mature salmon:
  - Age 3: 80
  - Age 4: 207
  - Age 5: 40

- 621 mature salmon:
  - Age 3: 135
  - Age 4: 389
  - Age 5: 96
# Production Efficiency

1,700 kg smolts / raceway

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326 mature salmon:  
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Small smolts produce **295** (nearly 2X) more mature salmon than large smolts:
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621 mature salmon:
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- Age 4: 389
- Age 5: 96

Small smolts produce 295 (nearly 2X) more mature salmon than large smolts: 56 age 3, 183 age 4, and 56 age 5.
Smolt Size and Survival

Production Efficiency
(# of adults / 10 kg smolts)

Smolt weight (g)
Management Implications

• The yearly environmental challenges encountered during migration are more important than smolt size (i.e. brood year effect).

• In a space-poor and egg-rich environment (e.g., most hatcheries), to maximize the number of adult returns consider releasing smaller smolts.

• This study occurred with brood years experiencing “Max Transportation.” With changing operations in the Columbia River Hydrosystem (e.g., barged vs. in-river, & flow requirements), a new pattern may emerge!
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• Spread the risk: release both large and small smolts?
Lookingglass Fish Hatchery

Source: USGS
Source: NASA, NGA, USGS
Imnaha River Weir and Acclimation Ponds

Acclimation Ponds

Adult Weir
## Smolt-to-Adult Survival (SAS)

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<td>0.18%</td>
<td>0.25%</td>
<td>0.968</td>
</tr>
<tr>
<td>Age 4</td>
<td>0.56%</td>
<td>0.70%</td>
<td>0.701</td>
</tr>
<tr>
<td>Age 5</td>
<td>0.08%</td>
<td>0.23%</td>
<td>0.165</td>
</tr>
<tr>
<td>Total SAS</td>
<td>0.82%</td>
<td>1.17%</td>
<td>0.287</td>
</tr>
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Survival to LGD BY 1992-1998

Percent survival to LGD (± STDEV)

High 1992-1993

Low 1994-1998

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SAS variation between brood years

P < 0.0001

Percent SAS survival (± STDEV)

Brood Year

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Oregon Fish & Wildlife