Regional Patterns in Spring/Summer Chinook Salmon and Steelhead Juvenile Survival Relative to Smolt-to-Adult Return Rates

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Key Questions:

What are the spatial and temporal patterns in survival?

What factors are associated with the patterns in survival?

Can management efforts help achieve regional survival goals?

NPCC Goal: Smolt-to-Adult survival rates averaging 4%

Minimize Smolt-to-Adult survival rates < 1%
What are the spatial and temporal patterns in survival?

Species?
- Wild spring/summer (yearling) Chinook salmon
- Wild steelhead

Timeframe?
- Juvenile outmigration years 2000-2012

Tools?
- Mark-recapture methods using PIT tags
- 330K steelhead, 1.1 million Chinook salmon tags
Freshwater survival

**steelhead**

Mean: 85% >> 57% > 48%

**Chinook salmon**

Mean: 81% >> 60% > 54%
Fish Travel Time

Mean: 1.8 << 6.6 << 12.5

Mean: 4.1 << 9.9 << 19.1
Ocean survival

Mean: 10.2% > 7.0% >> 3.8%

Mean: 6.0% ≈ 5.4% >> 2.5%
Smolt-to-Adult survival

Mean: 5.6% ≈ 5.6% >> 2.1%

Mean: 4.4% ≈ 3.7% >> 1.4%
Instantaneous mortality rates

- Steelhead Chinook salmon: 8% mortality/day
- Chinook salmon: 4% mortality/day

Freshwater Survival vs. Fish Travel Time
Correlations between freshwater and ocean survival

\[ \log_e \left( \text{Ocean survival} \right) \]

\[ \log_e \left( \text{Freshwater survival} \right) \]
Variable environmental conditions
Variable environmental conditions

Freshwater

Water Transit Time

Powerhouse Passages
Variable environmental conditions

Winter Icthyoplankton

Pacific Decadal Oscillation
Variable environmental conditions

**Freshwater**

- Water Transit Time

**Marine**

- Winter Icthyoplankton

- Powerhouse Passages

- Pacific Decadal Oscillation
Variable environmental conditions

\[ \log_e \left( \text{Smolt-to-Adult survival} \right) \]

- **Steelhead**: Powerhouses vs. Water Transit Time vs. Winter Ichthyoplankton
- **Chinook salmon**: Powerhouses vs. Water Transit Time vs. Winter Ichthyoplankton
What factors are associated with the patterns in survival?

Multiple regression with multi-model inference

Migration year as random effect

<table>
<thead>
<tr>
<th>Variables</th>
<th>Freshwater survival</th>
<th>Ocean survival</th>
<th>Smolt-to-Adult survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Transit Time</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Powerhouse passages</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Average dissolved gas Stock</td>
<td>✓</td>
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<tr>
<td>Winter Ichthyoplankton</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Pacific Decadal Oscillation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Fitted freshwater survival

steelhead $R^2 = 0.85$

Chinook salmon $R^2 = 0.60$
Fitted ocean survival

steelhead  \( R^2 = 0.70 \)

Chinook salmon  \( R^2 = 0.87 \)
Fitted Smolt-to-Adult survival

steelhead \( R^2 = 0.79 \)

Chinook salmon \( R^2 = 0.90 \)
Relative Variable Importance

Freshwater survival

Ocean survival

Smolt-to-Adult survival

steelhead

Chinook salmon
Can management efforts help achieve regional survival goals?

Use model-averaged coefficients to forecast Smolt-to-Adult survival rates.

Considered two management scenarios:
- Current Biological Opinion spill levels
- Spill to 125% dissolved gas limits

Account for variable freshwater and ocean conditions:
- High, average, low flow years
- Winter Ichthyoplankton, Pacific Decadal Oscillation
Predicted Smolt-to-Adult survival rates: Chinook salmon

Prob. (< 1% SAR): 38% 5%

[Box plots showing survival rates for different locations and scenarios.]
Predicted Smolt-to-Adult survival rates: steelhead

Prob. (< 1% SAR):   26%     0%
Conclusions

Models captured high degree of spatial and temporal patterns in variation

**Freshwater:** Powerhouses + Water Transit Time

**Ocean:** Powerhouses + Water Transit Time + Ichthyoplankton + PDO

**Smolt-to-Adult:** Powerhouses + Water Transit Time + Ichthyoplankton + PDO

**Snake:** 230% - 250% improvement in Smolt-to-Adult survival with increased spill

**Yakima:** 50% - 60% improvement

**John Day:** 30% - 50% improvement

**Adaptive Management Experiment:**
Ongoing tagging efforts provides framework for monitoring