Factors associated with the regional patterns of steelhead survival in the Columbia River Basin

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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?

Stocks?
Wild steelhead from Snake, Entiat & Methow, Yakima, and John Day rivers

Timeframe?
Juvenile outmigration years 2000-2017

Tools?
Mark-recapture methods using PIT tags (~500K tagged steelhead)
Regression and multi-model inference
Study Area

Yakima R
Snake R
John Day R

1-3 years

Columbia R
Willamette R

Methow R
Entiat R

Snake R
Salmon R

John Day R
What are the spatial and temporal patterns in survival?

**Freshwater survival**

![Graph showing freshwater survival with data points for EM, SNK, YAK, and JDA]
What are the spatial and temporal patterns in survival?

Estuary-Ocean survival
What are the spatial and temporal patterns in survival?

Smolt-to-Adult Return (SAR)

SARs < 1%: 14% 33% 0% 0%

NPCC Goal: 4% avg.
What are the factors that influence survival?

How do reservoirs affect the currents that fish rely on?

Current velocity = 7 miles/hour
What are the factors that influence survival?

How do reservoirs affect the currents that fish rely on?
What are the factors that influence survival?

How do reservoirs affect the currents that fish rely on?
Water Transit Time (WTT)

Estimate of the number of days required for average water particle to transit a reservoir (volume/flow)
Long-term changes in Lewiston-BON WTT

Migration Year

WTT

~2 days
Long-term changes in Lewiston-BON WTT

Migration Year

WTT

dam construction

~2 days

Long-term changes in Lewiston-BON WTT

Migration Year

WTT

~2 days

dam construction

~20 days
Long-term changes in Lewiston-BON WTT

Migration Year

WTT

4 days

32 days

26

27 days
Water transit times by stock and year

Water Transit Time (d)

Characterizing effects of spill, flow, and spillway surface passage

PowerHouse passage experiences (PITPH)

Incorporates spill proportion, flow, and spillway surface passage

Powerhouse = Turbines + collection/bypass system

Spillway = 1 - Powerhouse
Freshwater influences on life-stage survival

Freshwater survival

Estuary-Ocean survival

Smolt-to-Adult survival

Logit Survival

Water Transit Time (d)

Powerhouses

Logit Survival

Water Transit Time (d)

Powerhouses

Water Transit Time (d)

Powerhouses

Logit Survival

Freshwater influences on life-stage survival

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Water Transit Time (d)

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Water Transit Time (d)

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Water Transit Time (d)

Powerhouses

Logit Survival
Ocean influences on life-stage survival

Estuary-Ocean survival

Smolt-to-Adult survival

Logit Survival

Icthyoplankton Biomass

Upwelling (Apr-May)
What factors are associated with the patterns in survival?

**Multiple regression with multi-model inference**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Freshwater survival</th>
<th>Est.-Ocean survival</th>
<th>Smolt-to-Adult survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Transit Time</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Powerhouse passages Stock</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Winter Ichthyoplankton Upwelling (Apr-May)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Freshwater survival

$R^2 = 0.77$

Relative variable importance

Stock: NA
PH: 1
WTT: NA
Ichthy. Upwell: NA
Estuary-Ocean survival

$R^2 = 0.66$

Relative variable importance

Stock  | PH  | WTT  | Ichthy. Upwell.

0.00 0.05 0.10 0.15 0.20 0.25
J J J J J J

0.00 0.05 0.10 0.15 0.20 0.25
S S S S S S
Smolt-to-Adult survival

$R^2 = 0.70$

Relative variable importance

<table>
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<tr>
<th>Stock</th>
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<th>Ichthy. Upwell.</th>
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<tr>
<td>1</td>
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Graphs showing trends in survival rates from 2000 to 2015.
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% Total Dissolved Gas limits

Account for variable freshwater and ocean conditions:
  High, average, low flow years
  Winter Ichthyoplankton, Pacific Decadal Oscillation
Probability of low SARs (< 1%)
Average SARs

Average SAR

- Snake
- Ent.-Met.
- Yakima
- John Day

Colors:
- Red: 2000-2014
- Yellow: BIOP spill
- Blue: 125% TDG spill
Conclusions

Models captured high degree of spatial and temporal patterns in variation

**Freshwater:**  Stock + Powerhouses + Water Transit Time

**Estuary-Ocean:**  Stock + Water Transit Time + Ichthyo. + Upwelling

**Smolt-to-Adult:**  Stock + Powerhouses + Water Transit Time + Ichthyo. + Upwelling

**Snake:**  175% improvement in SARs with increased spill

**Ent.-Met.:**  128% improvement

**Yakima:**  125% improvement

**John Day:**  120% improvement

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