Asking the Fish: Using Acoustic Telemetry Data (2008-2012) to Identify Safest Operating Conditions for Juvenile Salmonid Passage at Bonneville Dam

MARK WEILAND¹, CHRISTA WOODLEY², JINA KIM¹, BISHES RAYAMAJHI¹, JON RERECICH³ AND BRAD EPPARD³

¹Pacific Northwest National Laboratory
²U.S. Army Engineering Research and Development Center, Vicksburg, MS
³U.S. Army Corps of Engineers, Portland District, Portland, OR
Bonneville Dam (rkm 234)

- **Powerhouse 1 (B1)**
  - 10 minimum gap runner turbines
  - Sluiceway
  - No in-turbine screens

- **Spillway**
  - 18 spillbays
    - Bays 1-3, 16-18 modified deflectors
    - Bays 4-15 unmodified deflectors

- **Powerhouse 2 (B2)**
  - 8 turbine units
  - Corner collector
  - Submerged traveling screens
Current Operations

- **B2 operates at low to mid range of 1% peak efficiency**
  - Improve conditions for guided fish in the gatewell
    - May result in unfavorable conditions for turbine passed fish

- **B1 increase flow to offset reduced discharge at B2**
  - Compare survival within to above the 1% operating range
    - Need to operate outside of upper 1% operating range

- **Spillway 85,000-120,000 cfs (variable survival)**
  - Erosion of stilling basin and ogees in several spill bays and accumulation of rock may be affecting survival
Background

- Survival studies using the Juvenile Salmon Acoustic Telemetry System (JSATS) were conducted at Bonneville Dam to evaluate passage and survival.

- Between 2008 and 2012, 73,549 juvenile Chinook salmon and steelhead were surgically implanted with JSATS acoustic micro-transmitters and released upstream of Bonneville Dam.

- Bonneville Dam was equipped with JSATS cabled receiver arrays for detection and route of passage determination.

- Autonomous receivers were deployed downstream for estimating survival rates.
Objectives

- Analyze 2008-2012 JSATS and operations data to examine survival rates for juvenile salmonids at BON

- B2 Turbine Survival Comparison:
  - Examine survival for fish passing turbines operating across the 1% peak efficiency range

- B1 Turbine Survival Comparison:
  - Examine survival for fish passing turbines operating within the 1% peak efficiency range and above the upper limit of the 1% operating range

- Bonneville Spillway:
  - Examine spillway survival by spillbay with focus on those bays where erosion of the ogee or stilling basin immediately downstream had occurred
Methods

- **B1 turbines**
  - Lower quarter of 1% efficiency (Q1)
  - Lower middle quarter of 1% efficiency (Q2)
  - Upper middle quarter of 1% efficiency (Q3)
  - 1% of peak efficiency (Q4)
  - Best operating point/range (BOP)
  - Above best operating point to generator limit (ABOP)

- **B2 turbines**
  - Lower quarter of 1% efficiency (Q1)
  - Lower middle quarter of 1% efficiency (Q2)
  - Upper middle quarter of 1% efficiency (Q3)
  - 1% of peak efficiency (Q4)

- **BON spillway**
  - By bay
  - Group bays
Methods: B1 and B2 Binned Operating Ranges

B1 Turbine Operating Range
- Best Op Point
- UL_Q4 = UL_1%
- UL_Q3
- UL_Q2
- UL_Q1
- LL_Q1 = LL_1%

Above BOP

B2 Turbine Operating Range (w/STS)
- UL_Q4 = UL_1%
- UL_Q3
- UL_Q2
- UL_Q1
- LL_Q1 = LL_1%
Analyses: BON
B1 CH1 Passage Distribution

Discharge (cfs)

HEAD (ft)

Above BOR

Best Op Range
UL_Q4 = UL_1%
UL_Q3
UL_Q2
UL_Q1
LL_Q1 = LL_1%

2010
2011
2012

2010
2011
2012
Analyses: BON
B1 CH1 Survival by Operating Condition

![Bar chart showing survival rates for different conditions.](image)
Analyses: BON
B1 STH Passage Distribution

Discharge (cfs)

Above BOR

Best Op Range
UL_Q4 = UL_1%
UL_Q3
UL_Q2
UL_Q1
LL_Q1 = LL_1%

HEAD (ft)

2010
2011
2012
Analyses: BON
B1 CH0 Passage Distribution

Discharge (cfs)

HEAD (ft)

Best Op Range
UL_Q4 = UL_1%
UL_Q3
UL_Q2
UL_Q1
LL_Q1 = LL_1%

Above BOR

Best Op Range
Q4
Q3
Q2
Q1

2010
2011
2012
Analyses: BON
B1 CH0 Survival by Operating Condition

Survival

<table>
<thead>
<tr>
<th>Condition</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>BOR</th>
<th>ABOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>47</td>
<td>57</td>
<td>116</td>
<td>1187</td>
<td>380</td>
<td></td>
</tr>
<tr>
<td>Survival</td>
<td>0.70</td>
<td>0.80</td>
<td>0.90</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operating Condition</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LL to UL</td>
<td>1407</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LL to BOP</td>
<td>1787</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UL to BOP</td>
<td>380</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABOP</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Survival
Analyses: BON
B2 CH1 Passage by Quartile

Discharge (cfs) vs. HEAD (ft)

- UL_Q4 = UL_1%
- UL_Q3
- UL_Q2
- UL_Q1
- LL_Q1 = LL_1%

Data for the years 2008 to 2012 is represented with different markers:
- 2008: Red square
- 2009: Yellow circle
- 2010: Orange triangle
- 2011: Green diamond
- 2012: Brown star

The graph illustrates the relationship between discharge and head for different quartiles across the years.
Analyses: BON
B2 CH1 Survival by Operating Condition

Survival

Q1  Q2  Q3  Q4
759  574  267  469
Analyses: BON
B2 STH Passage Distribution

Discharge (cfs) vs. HEAD (ft)

Legend:
- **UL_Q4 = UL_1%**
- **UL_Q3**
- **UL_Q2**
- **UL_Q1**
- **LL_Q1 = LL_1%**

Year Legend:
- **2008**
- **2009**
- **2010**
- **2011**
- **2012**

Q4, Q3, Q2, Q1
Analyses: BON
B2 STH Survival by Operating Condition

Survival

Q1  Q2  Q3  Q4

541  346  146  202
Analyses: BON
B2 CH0 Survival by Operating Condition

Survival

Q1  Q2  Q3  Q4
298  501  384  1444

0.70  0.80  0.90  1.00
Analyses: BON Spillway CH1 and STH Survival by Bay

Yearling Chinook

Survival

Steelhead

Survival
Analyses: BON Spillway Ch0 Survival by Bay

Subyearling Chinook

<table>
<thead>
<tr>
<th>Bay</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay01</td>
<td>0.85</td>
</tr>
<tr>
<td>Bay02</td>
<td>0.90</td>
</tr>
<tr>
<td>Bay03</td>
<td>0.95</td>
</tr>
<tr>
<td>Bay04</td>
<td>1.00</td>
</tr>
<tr>
<td>Bay05</td>
<td>0.95</td>
</tr>
<tr>
<td>Bay06</td>
<td>0.90</td>
</tr>
<tr>
<td>Bay07</td>
<td>0.85</td>
</tr>
<tr>
<td>Bay08</td>
<td>0.95</td>
</tr>
<tr>
<td>Bay09</td>
<td>0.90</td>
</tr>
<tr>
<td>Bay10</td>
<td>0.85</td>
</tr>
<tr>
<td>Bay11</td>
<td>0.95</td>
</tr>
<tr>
<td>Bay12</td>
<td>0.90</td>
</tr>
<tr>
<td>Bay13</td>
<td>0.85</td>
</tr>
<tr>
<td>Bay14</td>
<td>0.95</td>
</tr>
<tr>
<td>Bay15</td>
<td>0.90</td>
</tr>
<tr>
<td>Bay16</td>
<td>0.85</td>
</tr>
<tr>
<td>Bay17</td>
<td>0.95</td>
</tr>
<tr>
<td>Bay18</td>
<td>0.90</td>
</tr>
</tbody>
</table>
Analyses: BON
Spillway Survival, Grouped Bays

Yearling Chinook

<table>
<thead>
<tr>
<th>Bay</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-03</td>
<td>0.85</td>
</tr>
<tr>
<td>04-07</td>
<td>0.90</td>
</tr>
<tr>
<td>08-12</td>
<td>0.95</td>
</tr>
<tr>
<td>13-15</td>
<td>1.00</td>
</tr>
<tr>
<td>16-18</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Steelhead

<table>
<thead>
<tr>
<th>Bay</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-03</td>
<td>0.85</td>
</tr>
<tr>
<td>04-07</td>
<td>0.90</td>
</tr>
<tr>
<td>08-12</td>
<td>0.95</td>
</tr>
<tr>
<td>13-15</td>
<td>1.00</td>
</tr>
<tr>
<td>16-18</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Sub-Yearling Chinook

<table>
<thead>
<tr>
<th>Bay</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-03</td>
<td>0.85</td>
</tr>
<tr>
<td>04-07</td>
<td>0.90</td>
</tr>
<tr>
<td>08-12</td>
<td>0.95</td>
</tr>
<tr>
<td>13-15</td>
<td>1.00</td>
</tr>
<tr>
<td>16-18</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Analyses: BON Spillway CH1 and STH Survival by Discharge

Yearling Chinook

Steelhead
Analyses: BON
Spillway CH0 Survival by Discharge

\[ y = 0.0004x + 0.8979 \]
\[ R^2 = 0.6299 \]
Conclusions: BON

- **B1**
  - There was not a difference in survival for salmonids passing within the 1% of peak operating efficiency and salmonids passing at operations above the upper 1% operating efficiency

- **B2**
  - No difference in survival across operating range

- **Spillway**
  - No obvious bay affect
  - Lower survival of CH1 and STH above 290 kcfs discharge
  - Trend of lower survival for CH0 at low discharge levels
Acknowledgements


**Cascade Aquatics**: B James, P James, J Jorgensen, K Prather, E Anderson, C Green, E Green, J Herdman, K Martin, H Watson

**USACE**: M Langeslay, John Day Dam (M. Zyndol, T. Hurd), Bonneville Dams (J. Rerecich, B. Hausmann, A. Traylor, I Royer, K Welch).

**UW**: J Skalski, J Lady, A Seaburg, R Townsend, and P Westhagen.