The Effect of Turbulence in Hydropower Dam Fish Passageways on Pacific Lamprey Passage

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THE EFFECT OF TURBULENCE IN HYDROPOWER DAM FISH PASSAGEWAYS ON PACIFIC LAMPREY PASSAGE

Syms, Channing; Caudill, Christopher; Kirk, Mark; Tonina, Daniele; Budwig, Ralph
SERPENTINE WEIR PASSAGE

- Lamprey passage is very low through serpentine weirs. (25-30%)
- Turbulence or Distance through slots.
- Flume designed as a representation of serpentine.
LAMPREY OBSTACLES

- Salmonids are subcarangiform swimmers and move quickly through turbulent conditions.
- Anguilliform swimmers may be more affected by turbulence.
- In high flow/turbulence conditions, Lamprey go into burst and attach mode.
**FLUME SETUP**

### FLUME CONTROL TREATMENT

<table>
<thead>
<tr>
<th>Flow Setting</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Flow</td>
<td>2.4</td>
</tr>
<tr>
<td>Medium Flow</td>
<td>1.8</td>
</tr>
<tr>
<td>Low Flow</td>
<td>1.2</td>
</tr>
</tbody>
</table>
SAMPLING

- Developed Robot for precise measurements within the flume.
- Sontek Micro ADV used for measurements.
- Measurements taken at 3 elevations (0 cm, 30cm, and 65 cm)
- Control Treatment
  - Assumed symmetry within flume.
  - Took 17 measurements per elevation for ½ of the flume
- Turbulence treatment – 33 measurements per elevation
- 4000 samples per measurement
VELOCITY AND TURBULENCE

- Average Velocity is computed as the magnitude of the resultant of the three average velocity components.
- The root-mean-square error of the turbulent velocity fluctuations about the mean velocity are computed for use in determining turbulence intensities and levels of turbulent kinetic energy.

\[
\text{RMS}[V'_x] = \sqrt{(V'_x)^2} = \sqrt{\frac{\sum V_x^2 - \left(\sum V_x\right)^2}{n}}
\]

\[
\text{RMS}[V'_y] = \sqrt{(V'_y)^2} = \sqrt{\frac{\sum V_y^2 - \left(\sum V_y\right)^2}{n}}
\]

\[
\text{RMS}[V'_z] = \sqrt{(V'_z)^2} = \sqrt{\frac{\sum V_z^2 - \left(\sum V_z\right)^2}{n}}
\]

- Turbulence is temporal not spatial.
- Turbulence is then normalized by the average velocity of the slot to calculate intensity. (COV)
- Velocity at high flow is 2x velocity at low flow. Intensity will be 2 standard deviations different.
ROBOT FLUME MEASUREMENTS

Go link below for video of flume.

http://youtu.be/xXxp-E4nmj4
Go link below for GoPro video underwater.

http://youtu.be/KX8Ldo9VPGg
Average Velocity at Floor with Control Treatment

- **Flow**
  - 1 Weir
  - 2 Weirs
  - 3 Weirs

- **Low Flow (1.2 m/s)**: Lower Velocity on Edge
- **Medium Flow (1.8 m/s)**: Higher Velocity in Center
- **High Flow (2.4 m/s)**
Average Velocity at Floor with Turbulence Treatment

Flow

1 Weir

Low Flow (1.2 m/s)

2 Weirs

Medium Flow (1.8 m/s)

3 Weirs

High Flow (2.4 m/s)
Normalized Turbulence X at Floor with Control Treatment

Low Flow (1.2 m/s)  Medium Flow (1.8 m/s)  High Flow (2.4 m/s)

1 Weir

2 Weirs

3 Weirs

X-Axis

Higher Turbulence on Edge

Lower Turbulence in Center

Flow
Normalized Turbulence X at Floor with Turbulence Treatment

Flow

Low Flow (1.2 m/s)  Medium Flow (1.8 m/s)  High Flow (2.4 m/s)

X-Axis

1 Weir

2 Weirs

3 Weirs
Normalized Turbulence Z at Floor with Control Treatment

Flow

1 Weir

2 Weirs

3 Weirs

Low Flow (1.2 m/s) Medium Flow (1.8 m/s) High Flow (2.4 m/s)

Hydraulic Jump
Results

- Flows are more turbulent in the control treatment near the walls due to shear.
- Turbulence treatment creates vortices similar to serpentine weirs.
- Higher flows intensify turbulence in all cases.
- Number of Weirs and Discharge do not affect velocity at bottom.
- Heterogeneous flow in turbulence treatment.
- Z-axis turbulence may cause detachment of fish.
- Velocity is lowered by introducing structures that increase turbulence.
What’s Next?

• Monitoring Lamprey behavior in flume.
• 1/3 of Experiments Complete
• Appear to be no differences observed in success across all weir and flow conditions for turbulence treatment.
• Preliminary results show Lamprey are holding attachment much longer with the turbulence treatment.
Video of Lamprey swimming in Control Treatment

http://youtu.be/mHDXdJfjU1c
TURBULENCE

Video of Lamprey swimming in Turbulence Treatment

http://youtu.be/gvWRCPlwbCU
Normalized Turbulence $Y$ at Floor with Control Treatment

Flow

1 Weir

2 Weirs

3 Weirs

Low Flow (1.2 m/s)  Medium Flow (1.8 m/s)  High Flow (2.4 m/s)
Normalized Turbulence Y at Floor with Turbulence Treatment

Flow

1 Weir

2 Weirs

3 Weirs

Low Flow (1.2 m/s)  Medium Flow (1.8 m/s)  High Flow (2.4 m/s)