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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

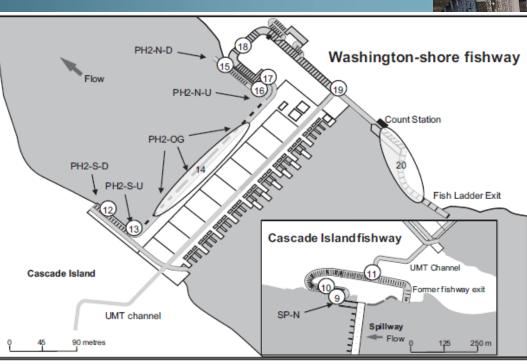
Syms, Channing; Caudill, Christopher; Kirk, Mark; Tonina, Daniele; Budwig, Ralph

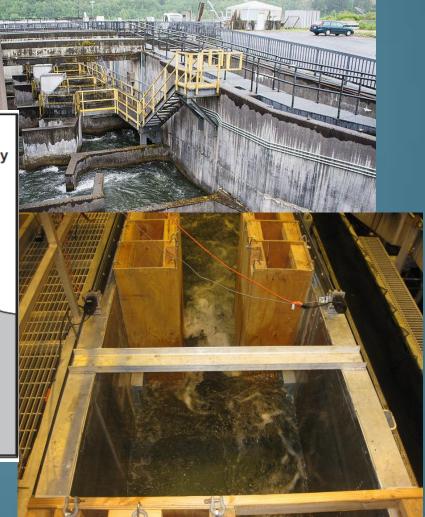




SERPENTINE WEIR PASSAGE

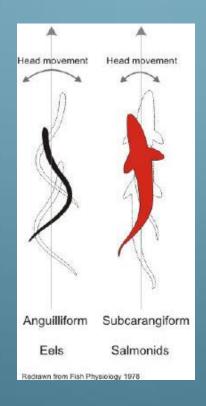
- Lamprey passage is very low through serpentine weirs.
 (25-30%)
- Turbulence or Distance through slots.
- Flume designed as a representation of serpentine.



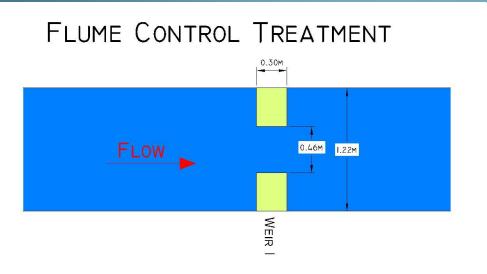


LAMPREY OBSTACLES

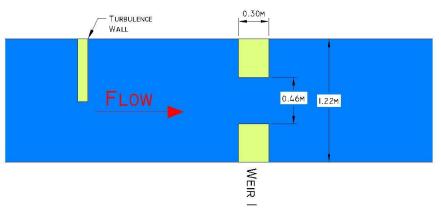
- Salmonids are subcarangiform swimmers and move quickly through turbulent conditions.
- Anguilliform swimmers may be more affected by turbulence.
- In high flow/ turbulence conditions, Lamprey go into burst and attach mode.



FLUME SETUP



FLUME TURBULENCE TREATMENT

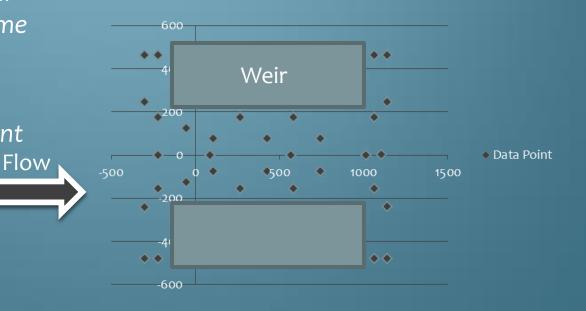


Flow Setting	Velocity (m/s)
High Flow	2.4
Medium Flow	1.8
Low Flow	1.2

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







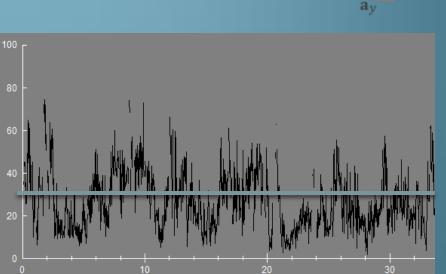
VELOCITY AND TURBULENCE

- 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.

•
$$RMS[V'_{x}] = \sqrt{(V'_{x})^{2}} = \sqrt{\frac{\sum V_{x}^{2} - \frac{(\sum V_{x})^{2}}{n}}{n-1}}$$

•
$$RMS[V_y'] = \sqrt{(V_y')^2} = \sqrt{\frac{\sum V_y^2 - \frac{(\sum V_y)^2}{n}}{n-1}}$$

•
$$RMS[V_{z}'] = \sqrt{(V_{z}')^{2}} = \sqrt{\frac{\sum V_{z}^{2} - \frac{(\sum V_{z})^{2}}{n}}{n-1}}$$



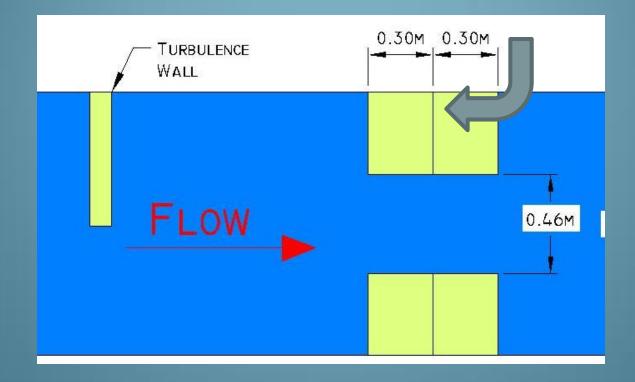
- Turbulence is temporal not spatial.
- Turbulence is then normalized by the average velocity of the slot to calculate intensity. (COV)
- Velocity at high flow is 2x velocity at low flow. Intensity will be 2 standard deviations different.

ROBOT FLUME MEASUREMENTS

Go link below for video of flume.

http://youtu.be/xXxp-E4nmj4

LAMPREY VIEW IN FLUME



LAMPREY VIEW IN FLUME

Go link below for GoPro video underwater.

http://youtu.be/KX8Ldo9VPGg

Average Velocity at Floor with Control Treatment

3 Weirs

2 Weirs

1 Weir

Flow

-200

-300

-400

400

300

200

-100

-200

-300

-400

-200 0 200 400 600

Average Velocity @ 0cm (cm/s)

800 1000

800 1000 400

300

200

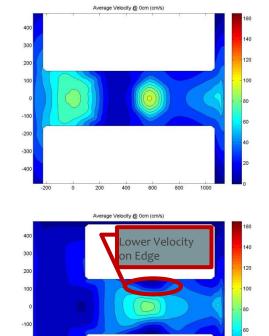
-200

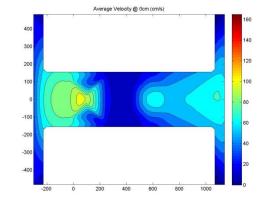
-200

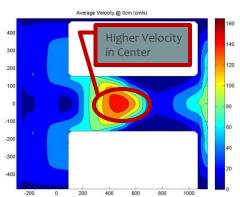
0

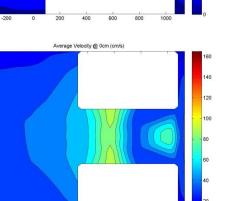
200 400

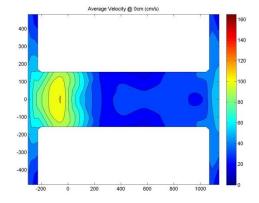
120



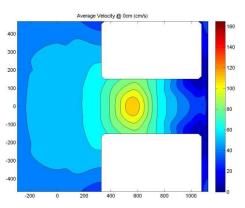








Average Velocity @ 0cm (cm/s) 400 300 120 200 -100 -200 -300 -400 800 -200 0 200 400 600 1000



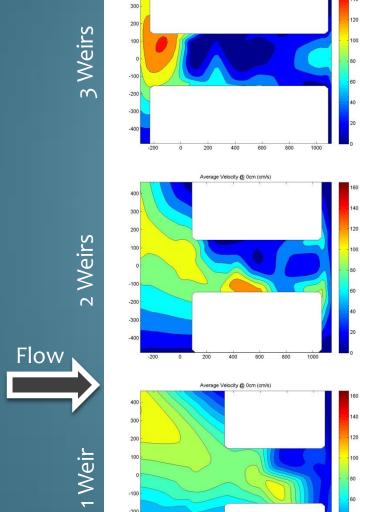
-200 200 400 600 0 Low Flow (1.2 m/s)

Medium Flow (1.8 m/s)

600

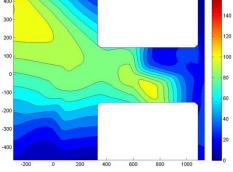
800 1000

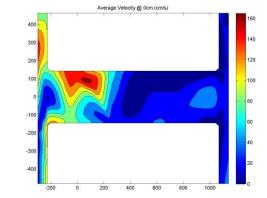
Average Velocity at Floor with Turbulence Treatment

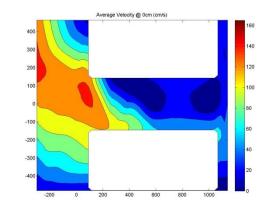


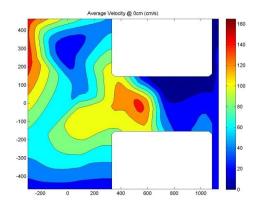
400

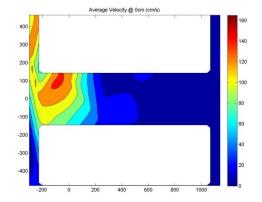
Average Velocity @ 0cm (cm/s)

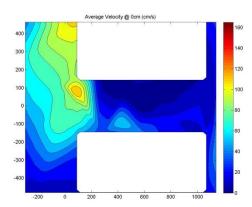


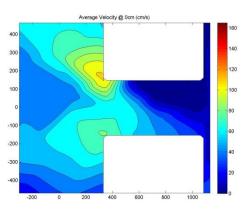








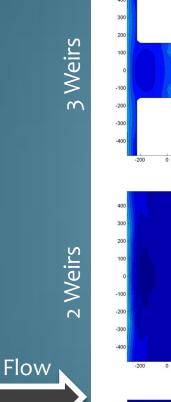




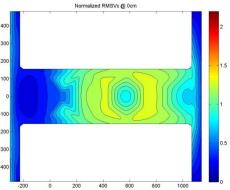
Low Flow (1.2 m/s)

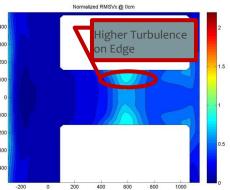
Medium Flow (1.8 m/s)

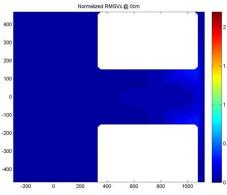
Normalized Turbulence X at Floor with Control Treatment

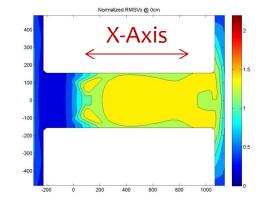


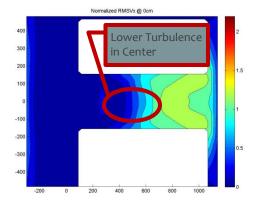
1 Weir

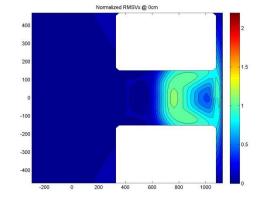


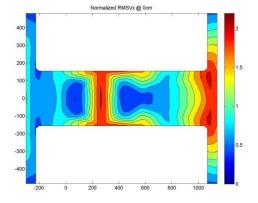


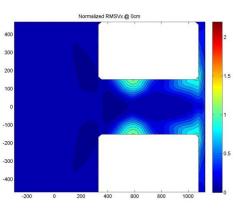








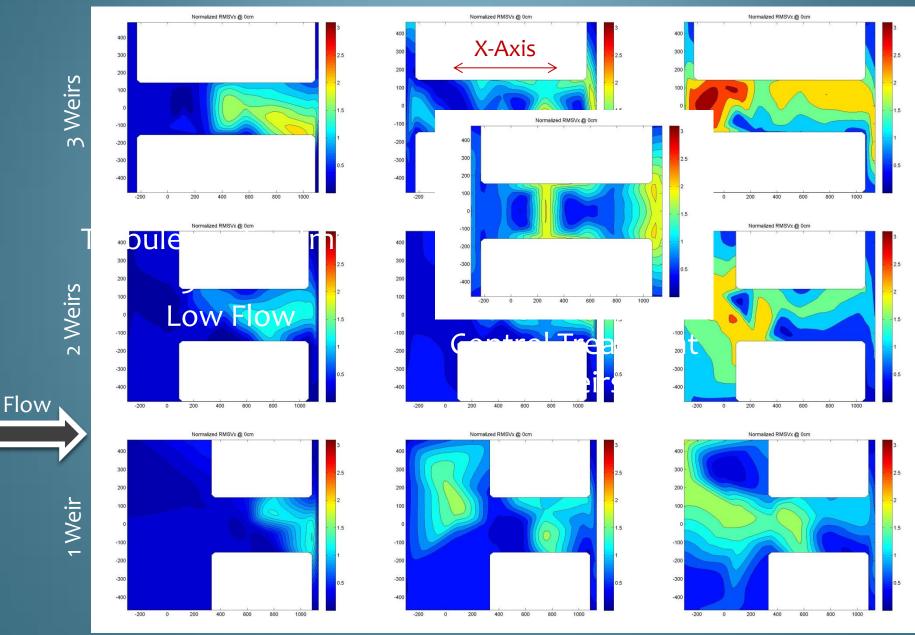




Low Flow (1.2 m/s)

Medium Flow (1.8 m/s)

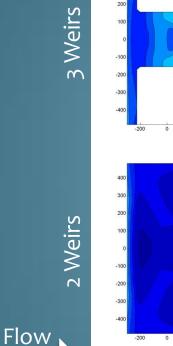
Normalized Turbulence X at Floor with Turbulence Treatment



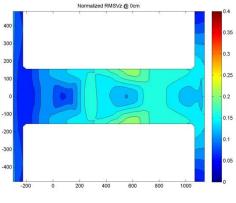
Low Flow (1.2 m/s)

Medium Flow (1.8 m/s)

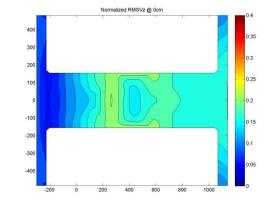
Normalized Turbulence Z at Floor with Control Treatment



1 Weir



Normalized RMSVz @ 0cm



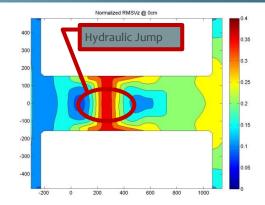
Normalized RMSVz @ 0cm

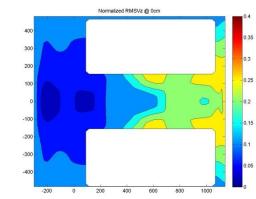
0.25

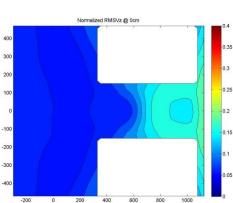
0 15

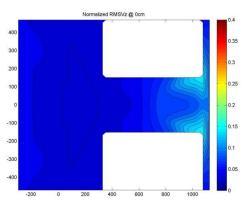
400

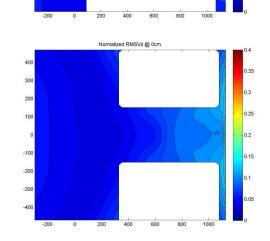
300







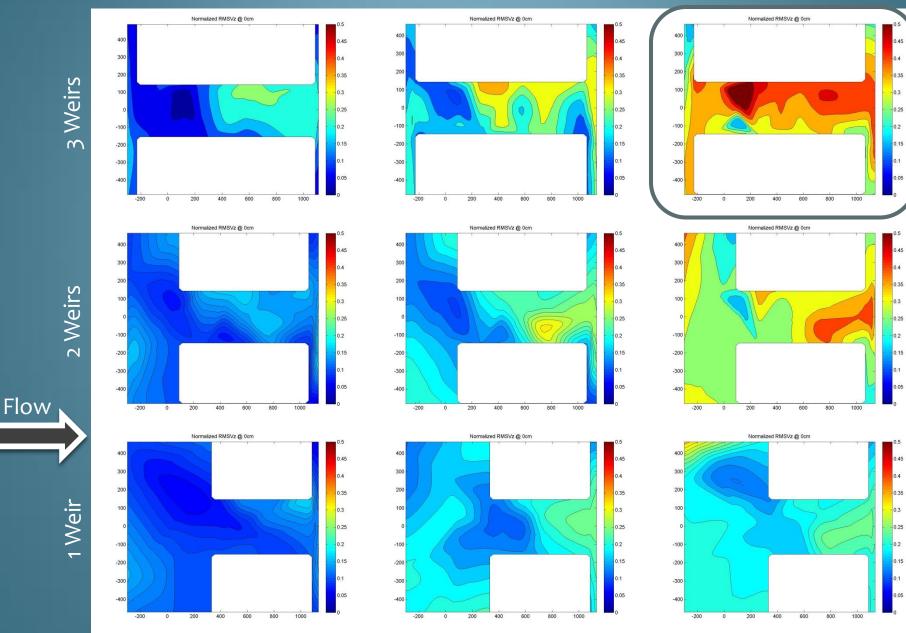




Low Flow (1.2 m/s)

Medium Flow (1.8 m/s)

Normalized Turbulence Z at Floor with Turbulence Treatment



Low Flow (1.2 m/s)

Medium Flow (1.8 m/s)

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

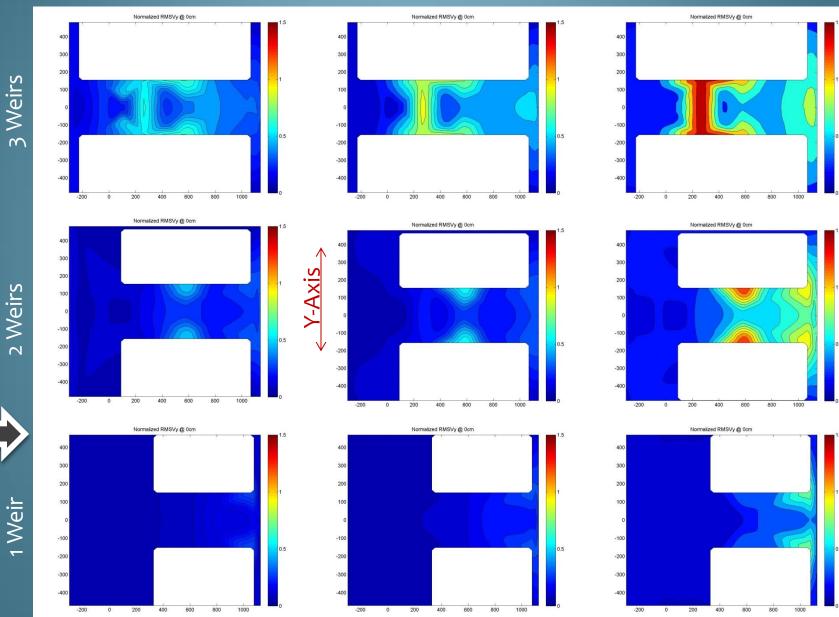


Video of Lamprey swimming in Turbulence Treatment

http://youtu.be/gvWRCPIwbCU



Normalized Turbulence Y at Floor with Control Treatment

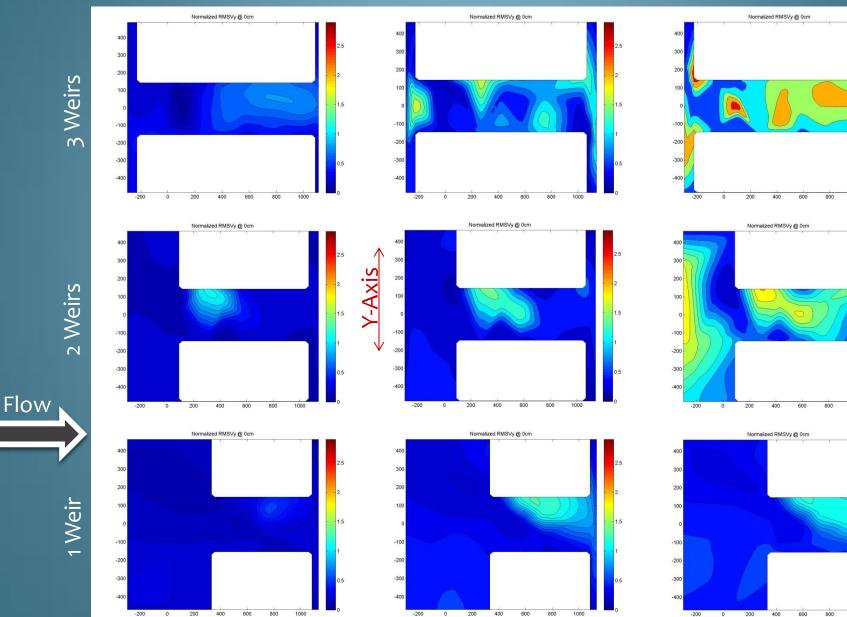


Low Flow (1.2 m/s)

Flow

Medium Flow (1.8 m/s)

Normalized Turbulence Y at Floor with Turbulence Treatment



Low Flow (1.2 m/s)

Medium Flow (1.8 m/s)

High Flow (2.4 m/s)

100

1000

1000

-15