International Conference on Engineering and Ecohydrology for Fish Passage

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Session B1 - Using Fish Morphological Characteristics to Re-design Hydroelectric Turbines

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Using Fish Morphological Characteristics to Re-Design Hydroelectric Turbines

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National Conference on Engineering & Ecohydrology for Fish Passage
(Fish Passage 2012)

Amherst, MA
June 6, 2012
Turbine Passage Injury Mechanisms

Photos from Dixon (2010)
Environmentally Advanced Turbines

Voith Minimum Gap Runner (modification of Kaplan turbine)

94-98% survival in field studies

Alden Turbine (1/3-scale pilot turbine)

Predicted survival in full-sized turbine of 97-100%
- 7 fish species have been tested in advanced turbines
- 30 fish species in the U.S. tested in conventional turbines

However, there are
- 900 species of freshwater fish in the United States and
- 14,000 species of freshwater fish globally

Can turbine passage survival be predicted for untested fish species in conventional and advanced turbines?

How will differential turbine-passage mortality alter the downstream fish community?
Traits-Based Assessment (TBA)

- Traits – Measureable properties of an organism
  - Ecological traits – environmental preferences, behaviors
  - Biological traits – body size, shape, physiology, life history characteristics
- Similar traits may lead to similar risk of turbine passage and similar turbine passage survival
- Traits may be more useful than taxonomy for predicting turbine passage survival
Traits that Influence the Vulnerability of a Fish Population to Reservoir-Passage and Turbine-Passage Losses

- Exposure to Turbine Passage
  - Migratory
  - Habitat Choice
  - Behavior

- Sensitivity to Turbine Passage Stressors
  - Size
  - Swim Bladder Morphology
  - Integument

- Population Sustainability
  - Demography
  - Ability to re-colonize
  - Endemism

- Population Vulnerability
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Population Vulnerability
Ecological Traits Influence Susceptibility to Turbine Passage

Diagram:
1. Tailwaters
2. Powerhouse
3. Spillbay
4. Fishway
5. Main Channel
6. Tributary
7. Anabranch
8. Floodplain Pool
9. Connected Lagoon
Ecological Traits Influence Susceptibility to Turbine Passage

- Resident Tributary
- Resident Shallow Water
- Diadromous/Potadromous

Legend:
1. Tailwaters
2. Powerhouse
3. Spillbay
4. Fishway
5. Main Channel
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- Population Vulnerability
Fish Size

- All strike mortality models incorporate length as a variable.
- Large (long) fish are more likely than small fish to be struck while passing through the space between the rotor blades.
- Length more important than taxonomy when considering fish strike?
Rapid decompression that occurs downstream from the turbine runner may cause damaging expansion of the swim bladder unless the expanding gases can be vented through the pneumatic duct.

Physostomous fish are more resistant to pressure changes than physoclistous fish.

<table>
<thead>
<tr>
<th>Physostomous fish</th>
<th>Physoclistous fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tested</td>
<td>Untested</td>
</tr>
<tr>
<td>Rainbow trout and Chinook salmon</td>
<td>All other salmon and trout species</td>
</tr>
<tr>
<td>White sturgeon</td>
<td>All other sturgeons</td>
</tr>
<tr>
<td>Alewife</td>
<td>All other clupeids (herrings and shads)</td>
</tr>
</tbody>
</table>
Integument

- Abrasion from contact with hard structures or fluid forces (shear stresses) can cause loss of protective mucous coating, descaling, or damage to the skin
- Type of scales and integument are useful for grouping fish when considering abrasion and shear stresses
Information Needed to Improve Turbine Design

- Better understanding of the turbine environment *(in situ* measurements and modeling)
- Better understanding of fish responses to turbine passage stressors *(bioassays of small number of species)*
- Categorize untested fish species *(e.g., cluster analysis of database information)*
- Predict effects on individuals or populations *(comparisons of above information)*
Changes in water pressure during turbine passage, predicted by CFD
Bioassays of Turbine Passage Stressors

Fish Length=250 mm; Blade thickness=10 mm; Velocity=7.3 m/s

Fish Length=150 mm; Blade thickness=150 mm; Velocity=7.3 m/s
Example of Fish Trait Categorization – 94 Species and 9 Traits

- **Environmental traits**
  - Habitat
    - Lowland
    - Upland
    - Montane
  - Water column position
  - River order
  - Current velocity
    - Slow
    - Moderate
    - Fast
  - Life history
    - Resident
    - Diadromous/Potadromous

- **Biological traits**
  - Longevity
    - > 10 years,
    - < 5 years
    - < 2 years
  - Age at maturity
    - > 5 years
    - > 2 years
    - 1 year
  - Size
  - Swim bladder type
  - Integument
- Longevity > 10 years
  - Maturity > 5 years
  - Slow currents

- Typical large river species
  - Longevity 5-10 years
  - Maturity 3-5 years
  - Slow to moderate currents

- Lifespan 3-5 years
  - Maturity 2 years
  - Slow to moderate currents

- Short life span < 3 years
  - Early maturity 1-1.5 years
  - Slow to moderate currents
  - Smaller rivers
Summary

- Traits-based assessment (TBA) considers environmental, biological, behavioral, and life history characteristics of fish
  - Identification of species most susceptible to turbine passage
  - Identification of species sharing similar sensitivities to turbine passage stressors
  - Evaluation of population sustainability in event of downstream passage losses
- Approach is transferable to fish communities from different biogeographic regions
- TBA is useful for assessing impacts of new hydropower development, developing mitigation measures, and identifying representative test species
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http://www1.eere.energy.gov/windandhydro/

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