Laboratory Evaluation of the Effects of Turbine Noise on Fish

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Recent Developments in Research on the Environmental Effects of MHK Technologies
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Components of Underwater Noise

Sound energy can cause damage based on:
- Frequency
- Intensity
- Spectrum

Two components of any sound wave:
- Pressure
- Particle motion

Near field (pressure & particle motion)
Far field (mostly pressure, but some motion)
- All fish can acoustically detect particle motion
- Some fish are acoustically sensitive to pressure

- Marine energy development raises concerns about noise impacts on fish:
- Typical assessments to determine harm include:
  - Auditory – hearing shift
  - Barotrauma – tissue/organ damage
Auditory

- Changes in hearing threshold
- Masking

Salmon: Halvorsen et al., 2009; Bass: Holt et al., 2010; Dab: Chapman & Sand 1973; Karl von Frisch - ear
Barotrauma is tissue injury caused by rapid pressure changes

**Impulsive Sounds**
- Pile driving
- Seismic exploration
- Explosions

**Intermittent and Continuous Sounds**
- Low- and mid-frequency sonar
- Shipping
- Wave energy converters
- Tidal turbines
Underwater Noise Effects - Barotrauma

- Swim bladder
  - Contracts and expands
  - Rupture
  - Damages surrounding tissues

- Dissolved blood gasses come out of solution
  - Bubbles form in blood and tissues
  - Damages tissues, vessels, organs

- Equilibration state of animal is important
  - Neutrally buoyant fish
  - Tissue-gas equilibration with surrounding water
  - Physiological state of fish at exposure is critical (mimic state of wild fish)
Testing Methods

Salmon and Bass

Tidal Turbine Noise Exposure 24 hours

Barotrauma → Detailed External Exam → Necropsy → Detailed Internal Exam

Auditory Evoked Potential - AEP → Hearing Test → Changes in threshold sensitivity

Salmon only
Noise from OpenHydro tidal turbine

- Turbine spectrogram
  - Measured at EMEC
- Laboratory experiments
  - Continuous noise exposure
  - Physiological response of fish to sound exposure
Tidal Turbine Noise and Fish Audiograms
Tidal Turbine - Hearing Tests

- Respiration reservoir
- Hydrophone holder
- Respiration tube
- Electrode wires
- Fish holder
- AEP tank

Hearing test
Brain activity - synchronized to the sound wave

Synchronized Brain activity disappeared = no detection

Outcome for juvenile salmon:

NSS difference between test and control exposures @ 158-162dB
Barotrauma Exposure and Effects Response Model

Barotrauma
- Used panel of 72 injuries to assess biological effects
- Purpose “Quantify a qualitative assessment”
- Focused on physiological ‘meaning’ of observed injuries

Fish Index Trauma - FIT
- List of 72 injuries
- Physiological Rank
- 3 Injury classes
- Weight

Response Weighted Index (RWI)
\[ RWI = \sum (W \times T_i) \]

<table>
<thead>
<tr>
<th>Mortal Injury</th>
<th>Wt</th>
<th>Moderate Injury</th>
<th>Wt</th>
<th>Mild Injury</th>
<th>Wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead within 1 hr</td>
<td>5</td>
<td>Hemorrhage: intestine</td>
<td>3</td>
<td>Hematoma : vent</td>
<td>1</td>
</tr>
<tr>
<td>Hemorrhage: heart</td>
<td>5</td>
<td>Hemorrhage: wall capillaries</td>
<td>3</td>
<td>Hematoma: dorsal fin</td>
<td>1</td>
</tr>
</tbody>
</table>
Fish Physiology Groups

**Physostomous**
- Connection between gut and swim bladder
- Gulp or burp air
- Need access to air to increase swim bladder volume

**Physoclistous**
- Closed swim bladder
- Small organ for gas exchange to fill or empty swim bladder
- Need time – several hours to change swim bladder volume

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*SALMON*  
*Micropterus salmoides* Largemouth Bass (juvenile)  
Photo by: Brian Zimmerman

*BASS*  
*Micropterus salmoides* Largemouth Bass (juvenile)  
Photo by: Brian Zimmerman
Results - Barotrauma

Salmon

Largemouth Bass

Proportion of injury occurrence (unweighted)

- CONTROL SALMON
- EXPOSED SALMON

Proportion of injury occurrence (unweighted)

- CONTROL BASS
- EXPOSED BASS

Micropterus salmoides Largemouth Bass (juvenile)
Photo by: Brian Zimmerman
Salmon and bass showed low levels of hemorrhages in their tissues, considered to be recoverable.

Both species have deflated their swimbladders, probably due to combination of:
- Stress
- Active management

Bass actively empty their swim bladder over time.

Salmon quickly empty swim bladder with a burp, then refill with gulps of air.
Effects of Tidal Turbine Sound on Fish

- “Worst case” levels of noise for one turbine (OH)
  - Tested juvenile salmon and largemouth bass (surrogate for rockfish)
  - Noise equivalent to placing fish next to turbine, no avoidance
  - Exposure for up to 24 hours (continuous, longer than tidal cycle)
- Barotrauma appears to be minor, recoverable as fish moves away
- Hearing shift for salmon not significant

BUT need more info on:

- Hearing shift in other fish groups
- Effects in barotrauma and hearing shift on elasmobranchs
- Sound from other turbine types
- Effects of arrays of turbines (additive, multiplicative) at commercial buildout
Thank you!

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