Jun 22nd, 11:15 AM - 11:30 AM

Eels III: Assessment of Three Sonars to Evaluate the Downstream Migration of American Eels in the St. Lawrence River

Christopher W.D. Gurshin
Normandeau Associates

David J. Coughlan
Normandeau Associates

Anna-Maria Mueller
Aquacoustics, Inc.

Donald Degan
Aquacoustics, Inc.

Paul T. Jacobson
Electric Power Research Institute

Follow this and additional works at: http://scholarworks.umass.edu/fishpassage_conference

Gurshin, Christopher W.D.; Coughlan, David J.; Mueller, Anna-Maria; Degan, Donald; and Jacobson, Paul T., "Eels III: Assessment of Three Sonars to Evaluate the Downstream Migration of American Eels in the St. Lawrence River" (2016). International Conference on Engineering and Ecohydrology for Fish Passage. 14.
http://scholarworks.umass.edu/fishpassage_conference/2016/June22/14

This Event is brought to you for free and open access by the The Fish Passage Community at UMass Amherst at ScholarWorks@UMass Amherst. It has been accepted for inclusion in International Conference on Engineering and Ecohydrology for Fish Passage by an authorized administrator of ScholarWorks@UMass Amherst. For more information, please contact scholarworks@library.umass.edu.
Assessment of Three Sonars to Evaluate the Downstream Migration of American Eels in the St. Lawrence River

Christopher W.D. Gurshin, Ph.D.
David J. Coughlan
Normandeau Associates, Inc.

Anna-Maria Mueller, Ph.D.
Donald Degan
Aquacoacoustics, Inc.

Paul T. Jacobson, Ph.D.
Electric Power Research Institute
BACKGROUND

- Electric Power Research Institute (EPRI) facilitated the collaboratively funded Eel Passage Research Center (EPRC)
- To provide effective downstream passage of out-migrating adult American eels at hydroelectric facilities on St. Lawrence R.
- EPRC strategy: trap-and-transport eels downstream
- Need a sampling technique to evaluate guidance systems and monitor abundance/distribution
- What about sonar? → This Study
OBJECTIVES
Sonar Mount System on Iroquois Dam Pier Nose

• Can sonar be used to:
  1. Estimate relative abundance of out-migrating eels,
  2. Determine their distribution, and
  3. Describe their approach behavior?

• Test 3 Sonars
  - **EK60**: Simrad EK60 Split-beam Echosounder (120 kHz)
  - **ARIS**: Sound Metrics ARIS Explorer Multibeam Sonar (1100/1800 kHz)
  - **M3**: Mesotech M3 Multi-mode Multibeam Sonar (500 kHz)
MULTI-PHASE APPROACH
3 Phases of Sonar Evaluation

• **Phase 1** – Installation and testing multiple sampling configurations

• **Phase 2** – Sonar measurements of known number and size of live eels tethered to surface floats and released at known locations/depths.
  1. Develop tether-and-release methods
  2. Test detectability at multiple ranges
  3. Randomized, single-blind target classification test
  4. Test acoustic vs. batch release counts

• **Phase 3** – Continuous monitoring of “wild” out-migrating eels
PHASE 1 - SUMMARY
Optimal System Design & Sampling Configurations

- Absorption loss too high at 1800 kHz
- ARIS Spreader lens doubles sampling volume & eels still visible
- Eel targets seen in M3 & ARIS at expected sampling coverage
- Tracking > 20 m possible, but ID unlikely
- Near-surface deployment too noisy
- Near-bottom has blind zones & shadows
- Motion artifact of long, fast moving targets can mimic “anguilliform” echo patterns
MOTION ARTIFACT
Example of a 130-cm stick in ARIS movie

- Motion artifacts distorts image to resemble anguilliform “squiggle” that makes interpretation difficult
  - Alters echo shape over time
- A long, fast moving, rigid object mimics the changing shape of an eel in typical anguilliform swimming motion
  - Leads to false positives
- Factors:
  - Target speed within a single frame
  - Target orientation relative to the trajectory
  - Maximum range (affects cycle period, i.e. ping rate within a frame)
MOTION ARTIFACT EXAMPLE
Ping & Echo Pattern Within Frame from Fast-moving Oblong Target

Image Credit: A.M. Mueller, Aquacoustics
PHASE 2: EXPERIMENTATION WITH TEST EELS
Developed method to release live eels tethered with surface float

- 30 eels
- 70-91 cm TL
- 1.3-2.4 kg
**PHASE 2 : TARGET CLASSIFICATION TEST**  
Randomized, Single-Blind Classification of ARIS Data

<table>
<thead>
<tr>
<th>ARIS Setting</th>
<th>Total Valid Releases</th>
<th>Eel</th>
<th>Fish</th>
<th>Eel Lure</th>
<th>PVC Pipe</th>
<th>Stick</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 48 beams, r = 2-18 m, -13° Tilt</td>
<td>13</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1 perch lure, 1 pike)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. 96 beams, r = 2-12 m, -13° Tilt</td>
<td>15</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(2 perch lure, 1 pike)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. 48 beams, r = 10-36 m, -32° Tilt</td>
<td>9</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

- **Eel Lure (97 cm)**
- **Perch Lure (23 cm)**
- **PVC Pipe (1 m)**
- **Northern Pike (65-67 cm)**
- **Sticks (80-130 cm)**
MANUAL EEL CLASSIFICATION OF ARIS DATA
Visual Inspection & Quality Score for Eel Identification

Eel ID Confidence

Score Classification
Q1 Highly confident eel ID Eel shape & anguilliform motion
Q2 Reasonably confident eel ID; shape and/or anguilliform motion ambiguity
Q3 Uncertain; ambiguity in shape/motion
Q4 Reasonably confident non-eel ID
Q5 Highly confident non-eel ID

How accurate is Q1-Q2 vs Q1-Q3?
• Balancing Missed Detections vs False Positives
• Classification Experiment with Known Targets
EEL ID SCORE = Q1
76-cm live eel (ID 901) released at 6 m
EEL ID SCORE = Q3
130-cm stick released at r=10 m
EEL ID SCORE = Q5
1-m PVC Pipe
# CLASSIFICATION TEST: EEL (Q1-Q3) ERROR RATE

Confusion Tables for Eel IDs Among Randomized Target Releases

**Initial Classification Scheme:**

\[ Q1 + Q2 + Q3 = \text{EEL}, \quad Q4 - Q5, \quad \text{Missed} = \text{NOT EEL} \]

### Eel ID Confidence

<table>
<thead>
<tr>
<th>Score</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIGH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Eel ID

- **78-cm Eel**
- **80-cm Eel**
- **Base of Pier Nose 9**

### Settings

1. **Setting 1**
   - 48 beams/2-18 m range
   - -13° Down

2. **Setting 2**
   - 96 beams/2-12 m range
   - -13° Down

3. **Setting 3**
   - 48 beams
   - -32° Down

### Eel ID Confidence

<table>
<thead>
<tr>
<th><strong>EEL ID</strong></th>
<th><strong>CONFIDENCE</strong></th>
<th><strong>LOW</strong></th>
<th><strong>HIGH</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1-Q3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRUE (+)</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>FALSE (+)</td>
<td>1</td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td>FALSE (-)</td>
<td>0</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>TRUE (-)</td>
<td>7</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Q4-Q5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRUE (+)</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>FALSE (+)</td>
<td>1</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>FALSE (-)</td>
<td>1</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>TRUE (-)</td>
<td>8</td>
<td>89%</td>
<td></td>
</tr>
</tbody>
</table>

### Non-Eel ID Confidence

<table>
<thead>
<tr>
<th><strong>NON-EEL ID</strong></th>
<th><strong>CONFIDENCE</strong></th>
<th><strong>LOW</strong></th>
<th><strong>HIGH</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1-Q3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRUE (+)</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>FALSE (+)</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>FALSE (-)</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>TRUE (-)</td>
<td>4</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>
CLASSIFICATION TEST: EEL (Q1-Q2) ERROR RATE

Confusion Tables for Eel IDs Among Randomized Target Releases

<table>
<thead>
<tr>
<th>Score</th>
<th>TRUE EEL</th>
<th>TRUE NON-EEL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TRUE (+)</td>
<td>FALSE (+)</td>
</tr>
<tr>
<td>Q1</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>80%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Q2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>33%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Q3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Q4</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>67%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Q5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>100%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

PREFERRED CLASSIFICATION SCHEME:
Q1+Q2 = EEL, Q3-Q5, Missed = NOT EEL
M3 EXAMPLE OF AN EEL
83-cm Eel (ID 931) at 9 m on 18 Sep 2015 (~12:13)
EXAMPLE OF EK60 ECHOGRAMS
Matched to known range and time
PHASE 2: RANGE TEST
Released live tethered eels into beams at 5 range intervals

- 80-cm eel released at 5 m
- Detected at 9 m in 3 sonars

NOTE: Eel TL = 70-89 cm, tether lengths = 3-7 m
PHASE 2: RANGE TEST SUMMARY

• Targets were detected by all sonars at multiple ranges
• ARIS sonar identified eels:
  – 30% at 5 m
  – 50% at 10 m
• Accepting more uncertainty eels, 25% at 25 m were identified as eels
• M3 and EK60 sonars detected targets, ID was only possible with the knowledge of the range and time of tethered eel release
PHASE 3: RESULTS OF SONAR MONITORING
Continuous Monitoring of Out-migrating Eels at Iroquois Dam

• No eels in 15-22 July 2015
• 2 eels in 17-19 September
  1. ID Quality Score 1: 18Sep 2015 01:06 (after midnight)
  2. ID Quality Score 2: 18Sep 2015 04:16 (pre-dawn)
• Estimated lengths of 95 cm & 64 cm
CONCLUSIONS
Sampling Limitations & Sonar Performance

• St. Lawrence River is challenging
  – 1.7 to 2 m/s flow
  – Orders of magnitude higher abundance of debris and fish
  – Potential impact of high false positive error

• Motion artifacts decreases eel ID certainty, especially at increasing ranges

• Important to classify targets conservatively to avoid false positives

• 15-22 July: no eels

• 17-19 September: 2 eels @ night

• EK60 can detect eels, but eel ID difficult

• ARIS can provide ID at range < 18-20 m

• M3 has merit for tracking behavior, but not ID
ACKNOWLEDGEMENTS

• Field staff
• Ecological Specialties for I-beam fabrication
• Hunt Underwater Specialties
• Ontario Power Generation
• New York Power Authority
• EPRC Members
• USFWS & NYSDEC
• Simrad, Kongsberg, & Sound Metrics
EXAMPLE OF M3 AND ARIS AT >20 M RANGE
Released 79-cm eel with 4-m tether at nominal 25-m interval

(detected 21 m range)
EEL ID SCORE = Q2
80-cm live eel (ID 930) released at 7 m
EEL ID SCORE = Q4
1-m PVC Pipe released, motion artifact present