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

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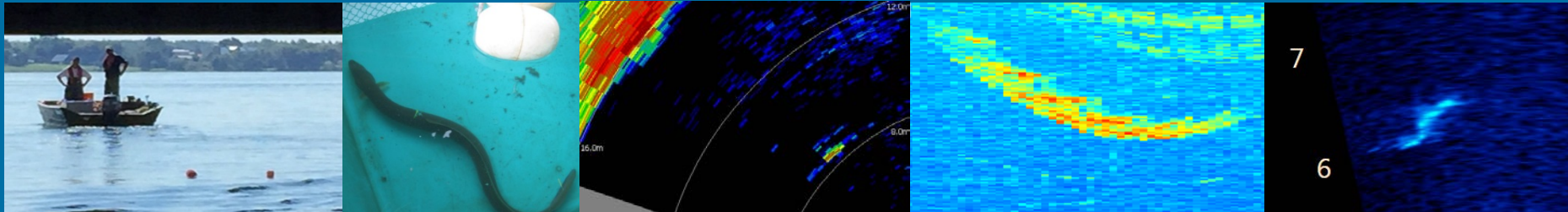
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Assessment of Three Sonars to Evaluate the Downstream Migration of American Eels in the St. Lawrence River



Wednesday, 22 June 2016

2016 International Conference on River Connectivity

Campus Center 168C, University of Massachusetts, Amherst MA USA



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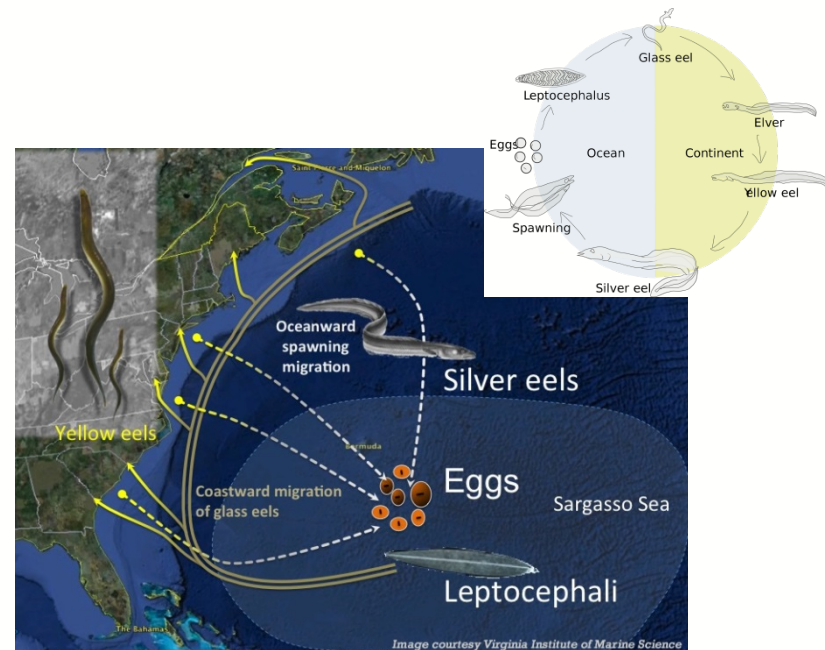
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BACKGROUND

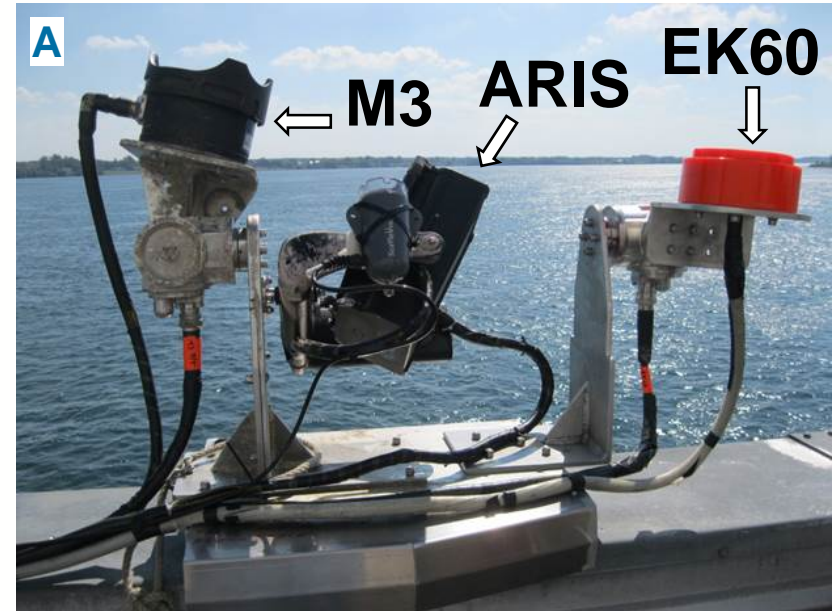
- Electric Power Research Institute (EPRI) facilitated the collaboratively funded Eel Passage Research Center (EPRC) 
- To provide effective downstream passage of out-migrating adult American eels at hydroelectric facilities on St. Lawrence R.
- EPRC strategy: trap-and-transport eels downstream
- Need 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

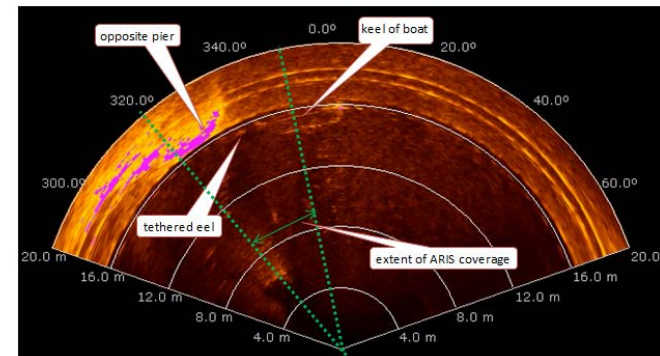
3 Phases of Sonar Evaluation

- **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

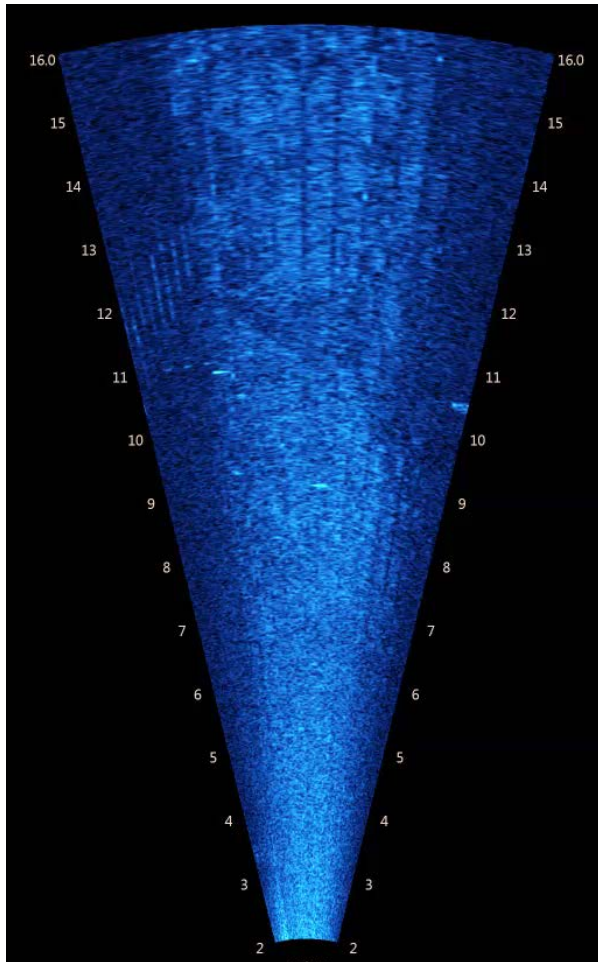
Optimal System Design & Sampling Configurations

- 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 distort 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

ping 1
transmit/receive on
beams 0,6,12 ... 90

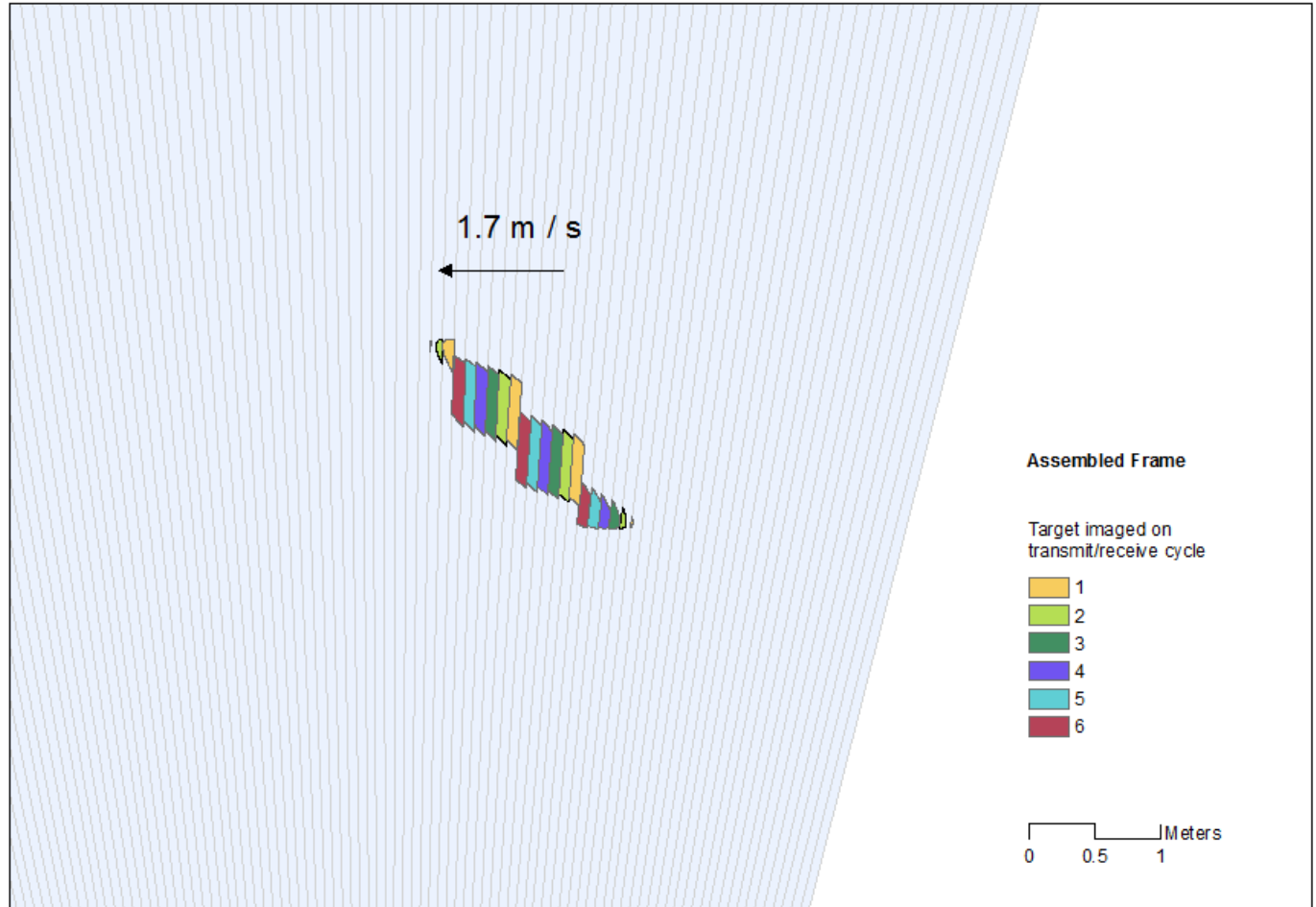
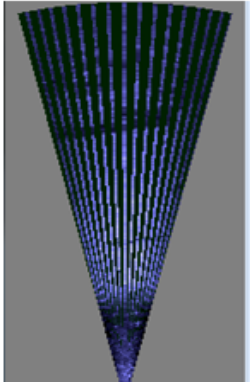
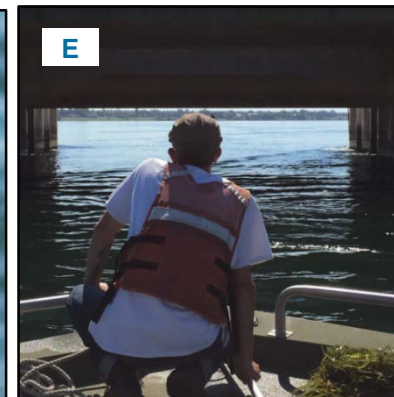


Image Credit: A.M. Mueller, Aquacoustics

PHASE 2: EXPERIMENTATION WITH TEST EELS

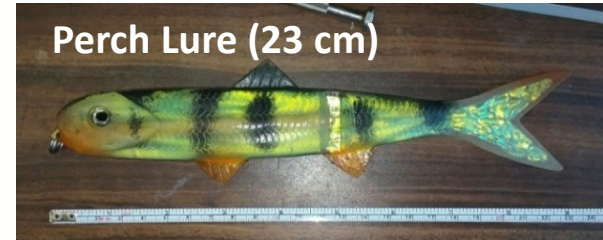
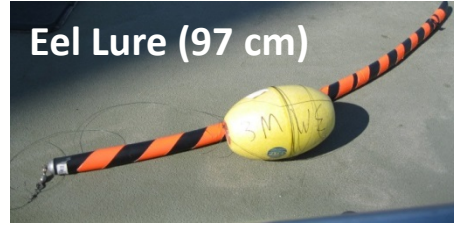
Developed method to release live eels tethered with surface float

- 30 eels
- 70-91 cm TL
- 1.3-2.4 kg

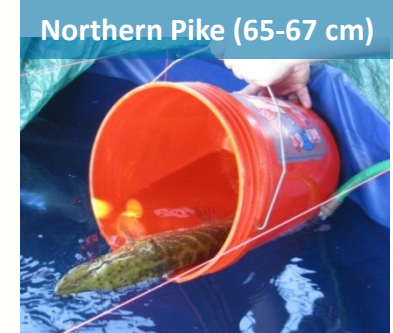


PHASE 2 : TARGET CLASSIFICATION TEST

Randomized, Single-Blind Classification of ARIS Data

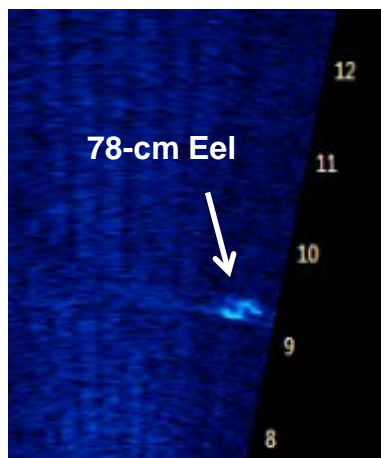


ARIS Setting	Total Valid Releases	Eel	Fish	Eel Lure	PVC Pipe	Stick
1. 48 beams, r = 2-18 m, -13° Tilt	13	5	2 (1 perch lure, 1 pike)	4	1	1
2. 96 beams, r = 2-12 m, -13° Tilt	15	6	3 (2 perch lure, 1 pike)	2	3	1
3. 48 beams, r = 10-36 m, -32° Tilt	9	5	0	1	2	1



MANUAL EEL CLASSIFICATION OF ARIS DATA

Visual Inspection & Quality Score for Eel Identification



Eel ID Confidence

HIGH



LOW

LOW



HIGH

Non-Eel ID Confidence

Score Classification

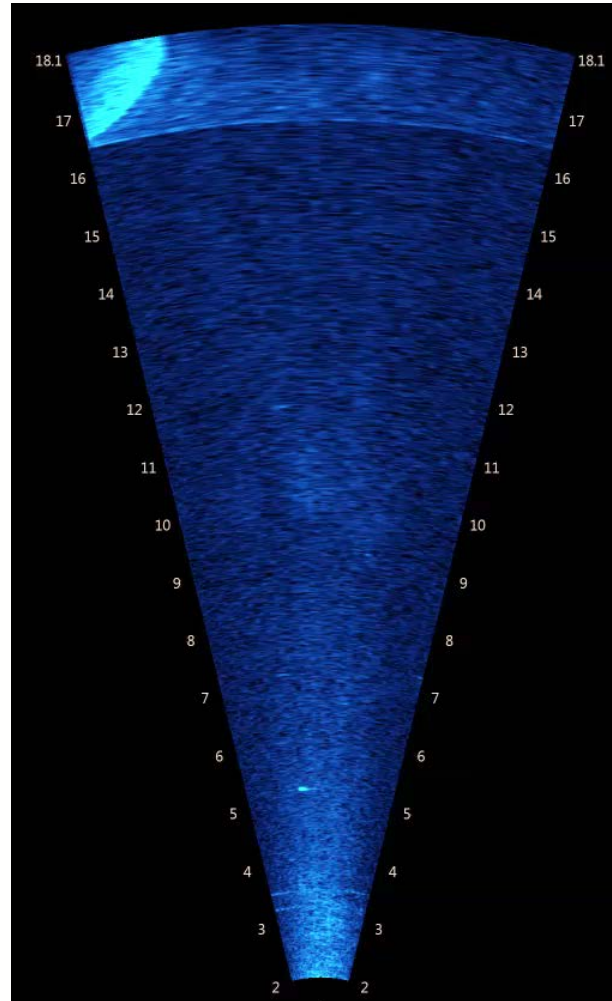
- | | |
|----|---|
| Q1 | Highly confident eel ID Eel shape & anguilliform motion |
| Q2 | Reasonably confident eel ID; shape and/or anguilliform motion ambiguity |
| Q3 | Uncertain; ambiguity in shape/motion |
| Q4 | Reasonably confident non-eel ID |
| Q5 | Highly confident non-eel ID |

How accurate is Q1-Q2 vs Q1-Q3?

- Balancing Missed Detections vs False Positives
- Classification Experiment with Known Targets

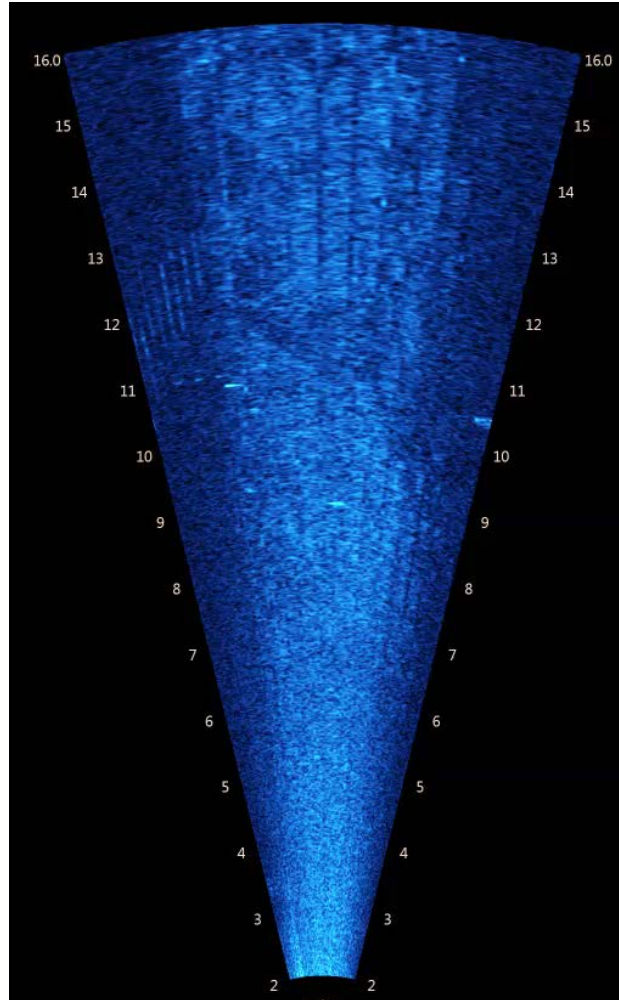
EEL ID SCORE = Q1

76-cm live eel (ID 901) released at 6 m



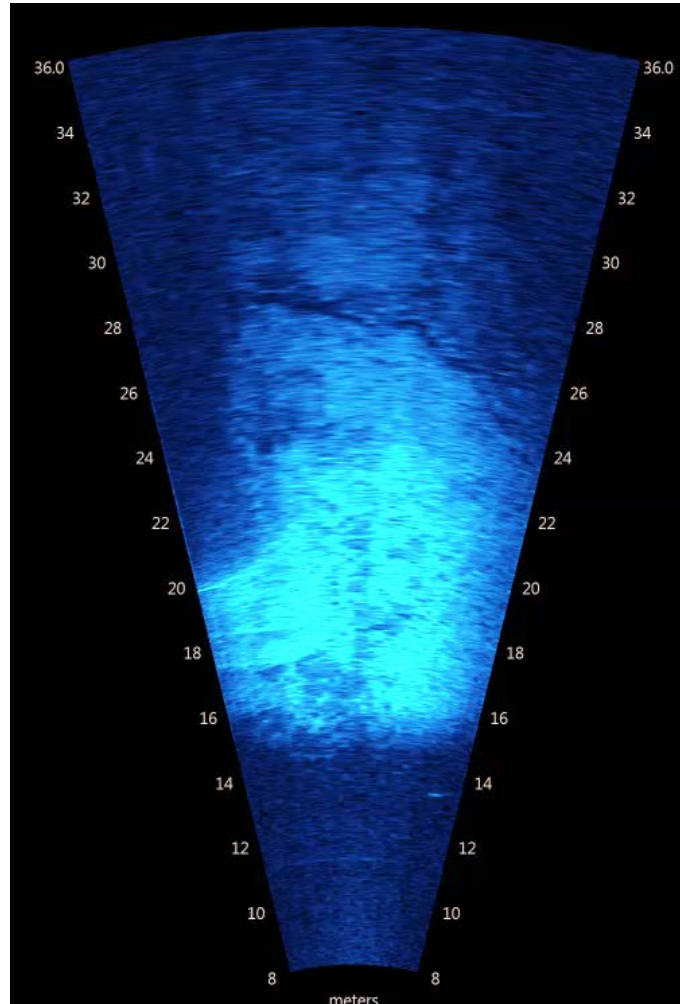
EEL ID SCORE = Q3

130-cm stick released at r=10 m



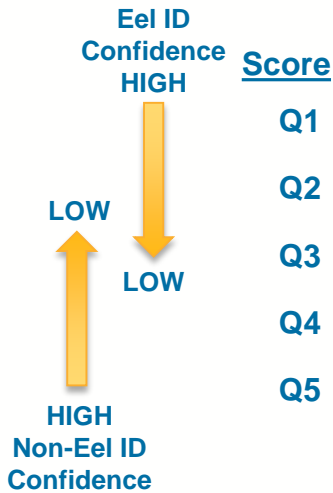
EEL ID SCORE = Q5

1-m PVC Pipe



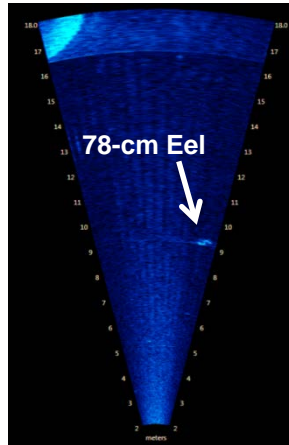
CLASSIFICATION TEST: EEL (Q1-Q3) ERROR RATE

Confusion Tables for Eel IDs Among Randomized Target Releases



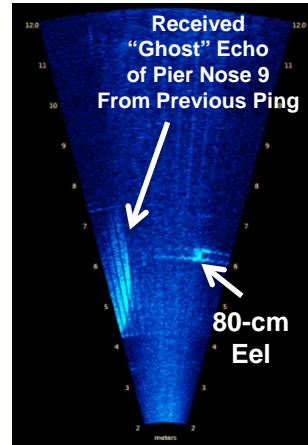
Score

- Q1
- Q2
- Q3
- Q4
- Q5



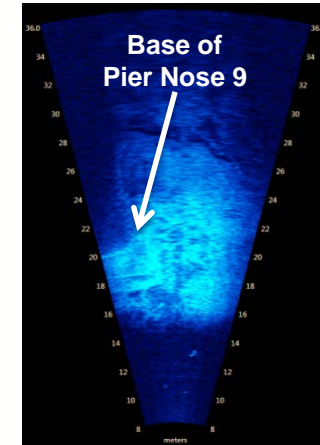
Setting 1

48 beams/ 2-18 m range
-13° Down



Setting 2

96 beams/2-12 m range
-13° Down



Setting 3

48 beams
-32° Down

	TRUE EEL	TRUE NON-EEL
Q1-Q3 EEL ID	TRUE (+)	FALSE (+)
	5 100%	1 12%
Q4-Q5 NON-EEL ID	FALSE (-)	TRUE (-)
	0 0%	7 88%

	TRUE EEL	TRUE NON-EEL
Q1-Q3 EEL ID	TRUE (+)	FALSE (+)
	5 83%	1 11%
Q4-Q5 NON-EEL ID	FALSE (-)	TRUE (-)
	1 17%	8 89%

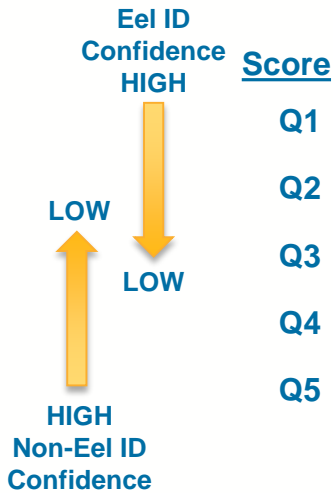
	TRUE EEL	TRUE NON-EEL
Q1-Q3 EEL ID	TRUE (+)	FALSE (+)
	1 20%	0 0%
Q4-Q5 NON-EEL ID	FALSE (-)	TRUE (-)
	4 80%	4 100%

INITIAL CLASSIFICATION SCHEME:

Q1+Q2+Q3= EEL, Q4-Q5, Missed = NOT EEL

CLASSIFICATION TEST: EEL (Q1-Q2) ERROR RATE

Confusion Tables for Eel IDs Among Randomized Target Releases



Score

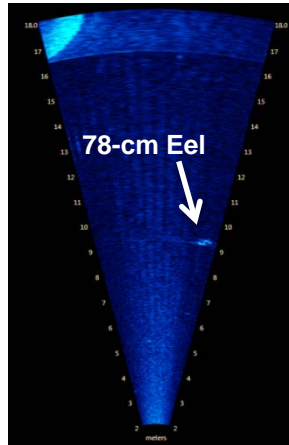
Q1

Q2

Q3

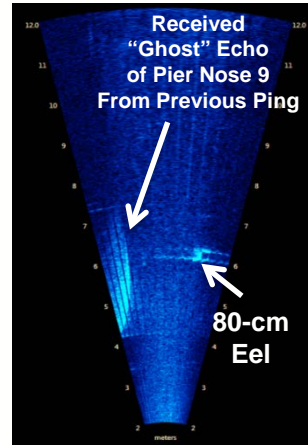
Q4

Q5



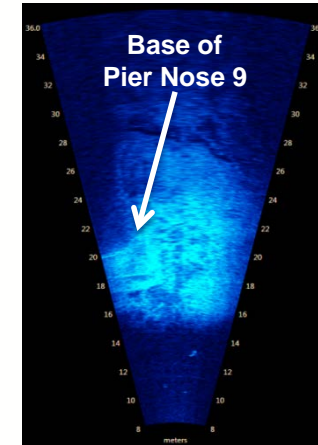
Setting 1

48 beams/ 2-18 m range
-13° Down



Setting 2

96 beams/2-12 m range
-13° Down



Setting 3

48 beams
-32° Down

Q1-Q2 EEL ID
Q3-Q5 NON-EEL ID

TRUE EEL	TRUE NON-EEL
TRUE (+)	FALSE (+)
4 80%	0 0%
FALSE (-)	TRUE (-)
1 20%	8 100%

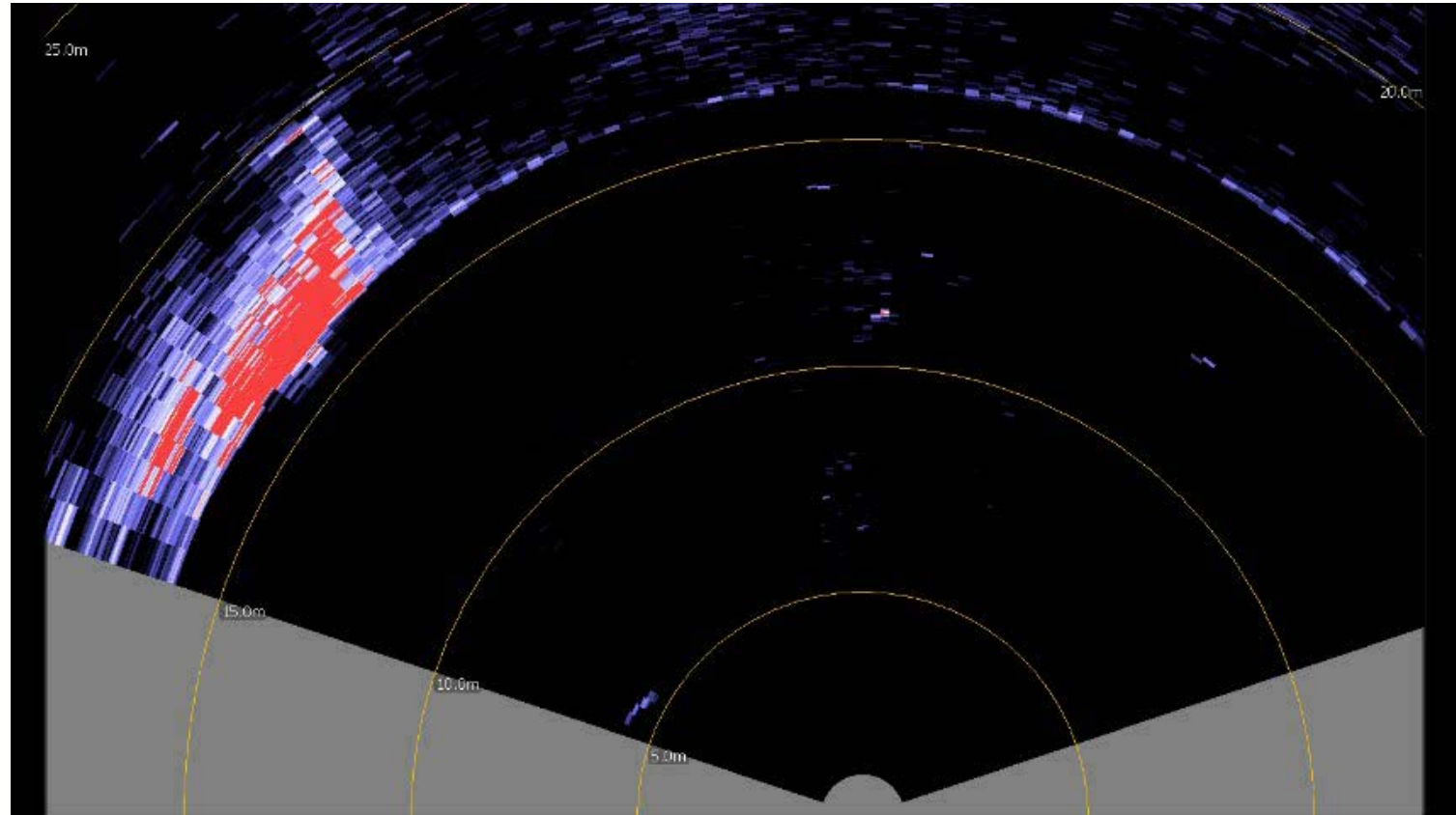
TRUE EEL	TRUE NON-EEL
TRUE (+)	FALSE (+)
2 33%	0 0%
FALSE (-)	TRUE (-)
4 67%	9 100%

TRUE EEL	TRUE NON-EEL
TRUE (+)	FALSE (+)
0 0%	0 0%
FALSE (-)	TRUE (-)
5 100%	4 100%

**PREFERRED CLASSIFICATION SCHEME:
Q1+Q2 = EEL, Q3-Q5, Missed = NOT EEL**

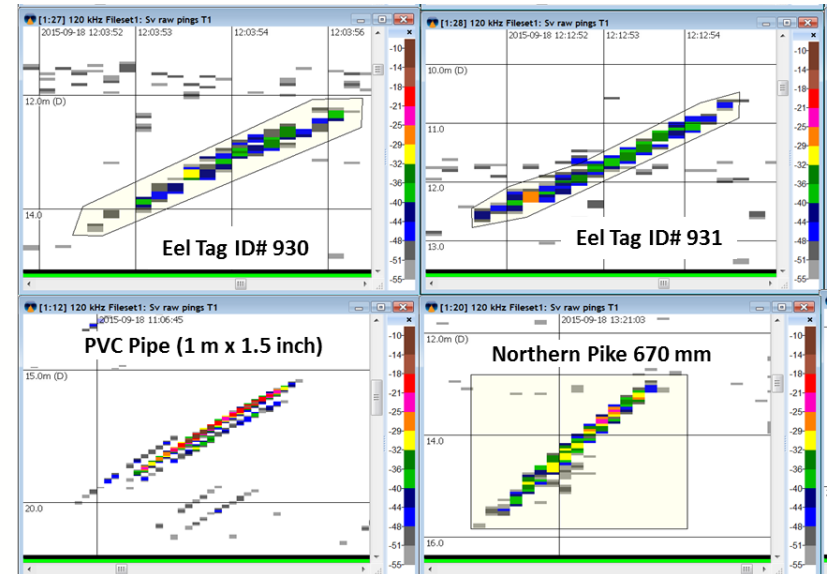
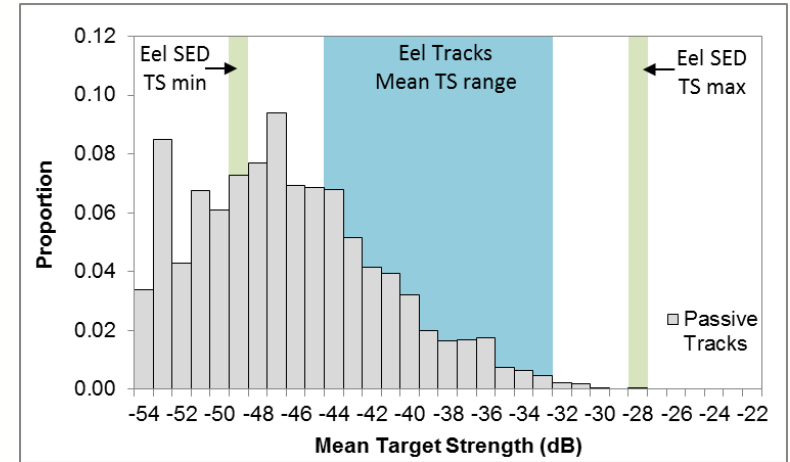
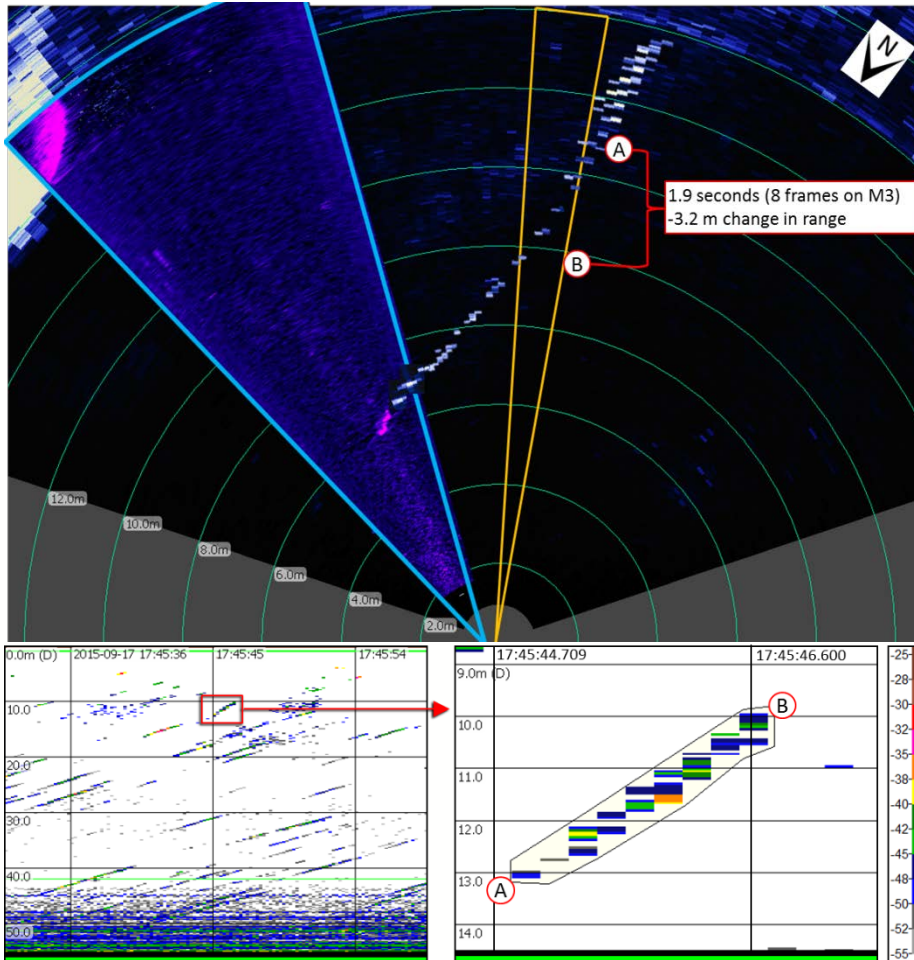
M3 EXAMPLE OF AN EEL

83-cm Eel (ID 931) at 9 m on 18 Sep 2015 (~12:13)



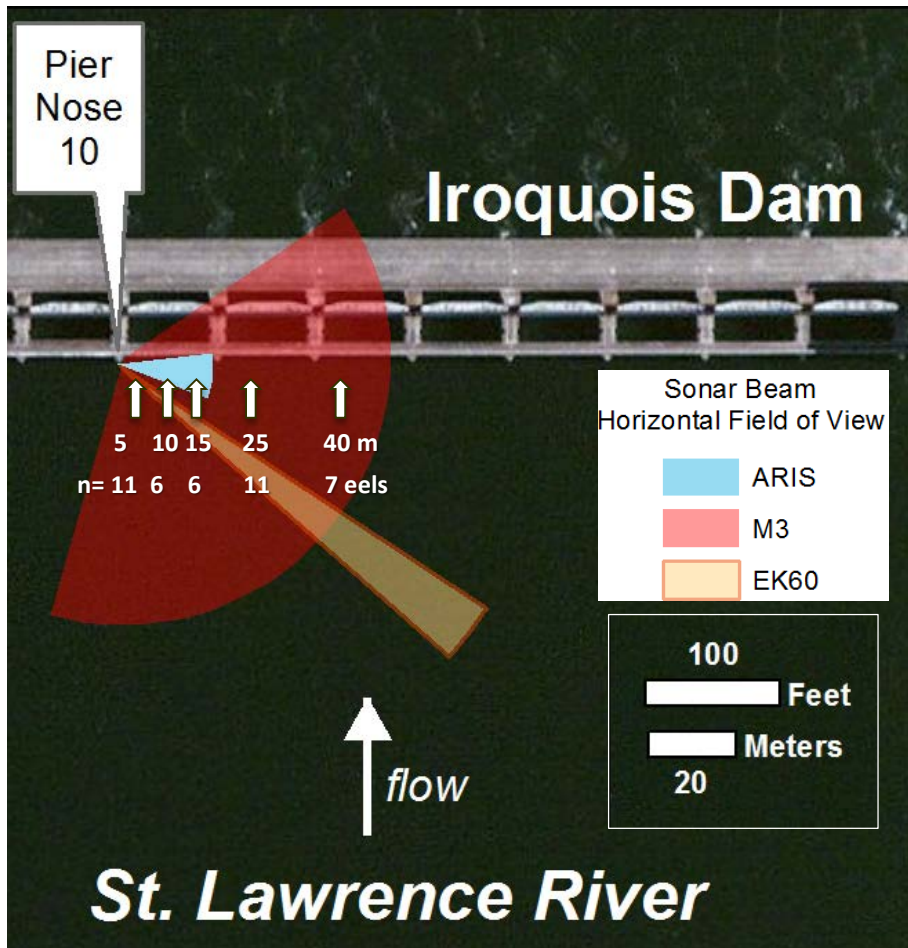
EXAMPLE OF EK60 ECHOGRAMS

Matched to known range and time

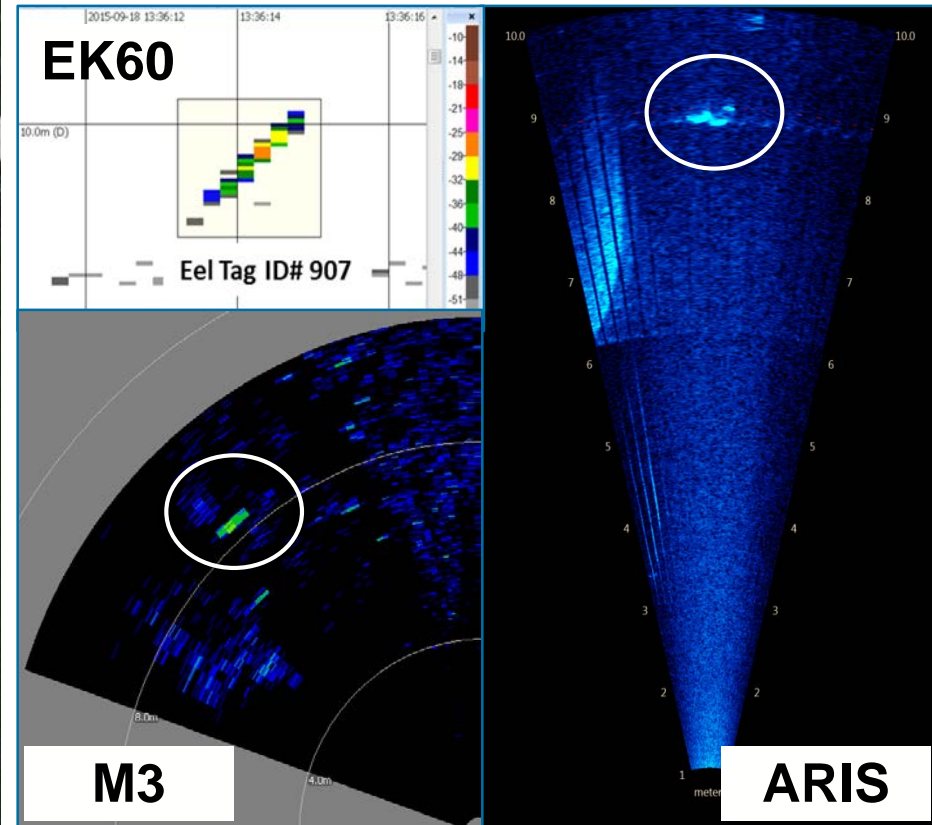


PHASE 2: RANGE TEST

Released live tethered eels into beams at 5 range intervals



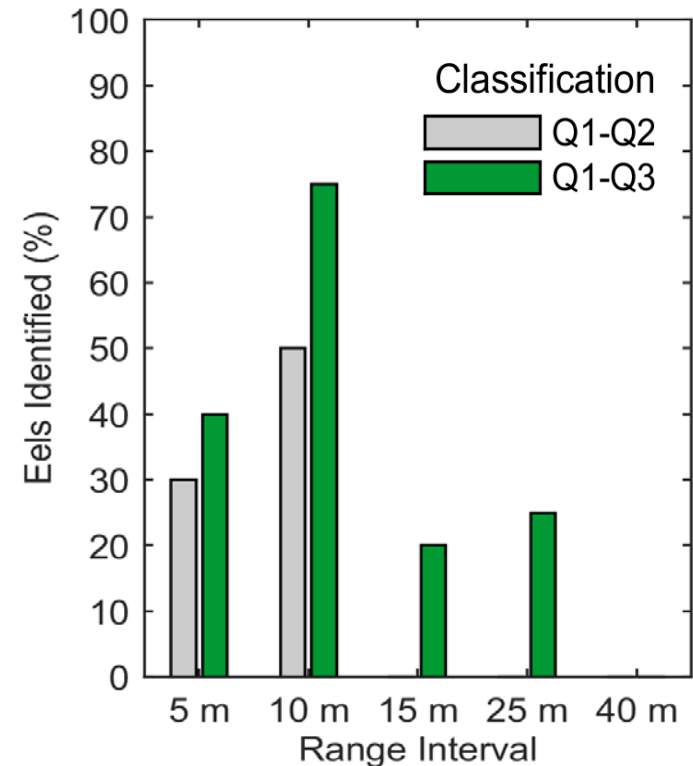
- 80-cm eel released at 5 m
- Detected at 9 m in 3 sonars



NOTE: Eel TL = 70-89 cm, tether lengths = 3-7 m

PHASE 2: RANGE TEST SUMMARY

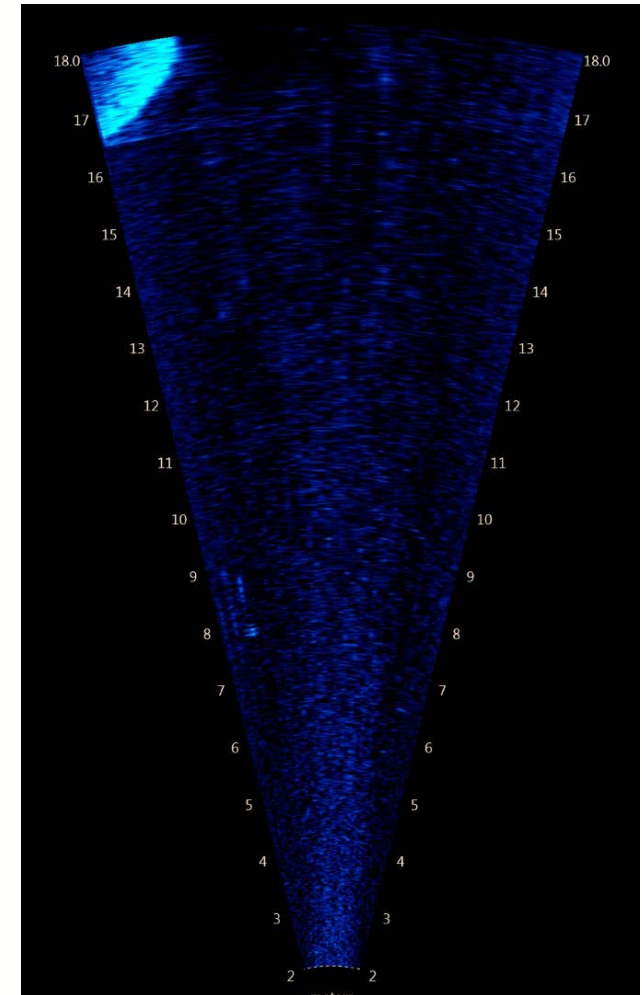
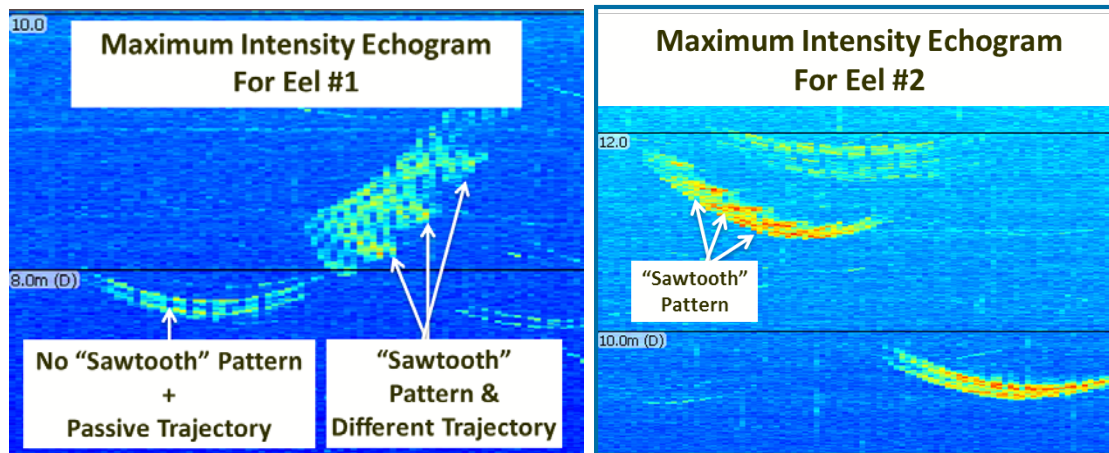
- Targets were detected by all sonars at multiple ranges
- ARIS sonar identified eels:
 - 30% at 5 m
 - 50% at 10 m
- Accepting more uncertainty eels, 25% at 25 m were identified as eels
- M3 and EK60 sonars detected targets, ID was only possible with the knowledge of the range and time of tethered eel release



PHASE 3: RESULTS OF SONAR MONITORING

Continuous Monitoring of Out-migrating Eels at Iroquois Dam

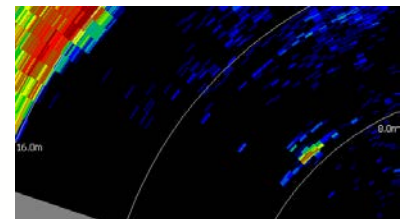
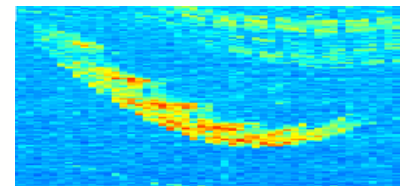
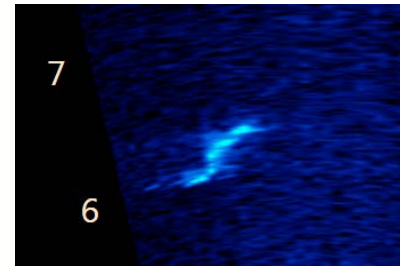
- No eels in 15-22 July 2015
- 2 eels in 17-19 September
 1. ID Quality Score 1: 18Sep 2015 01:06 (after midnight)
 2. ID Quality Score 2: 18Sep 2015 04:16 (pre-dawn)
- Estimated lengths of 95 cm & 64 cm



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



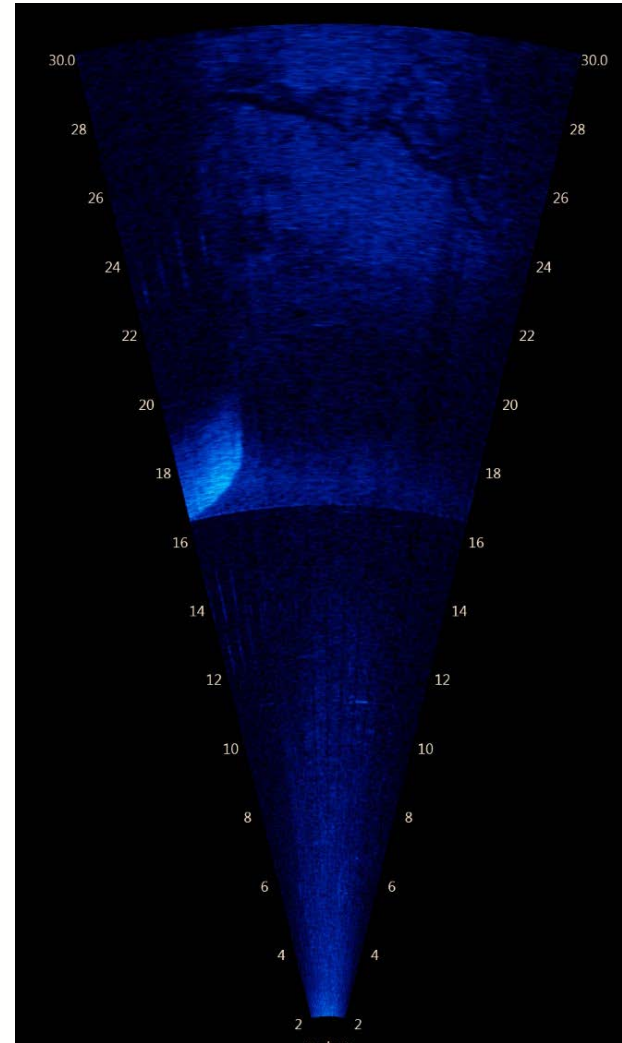
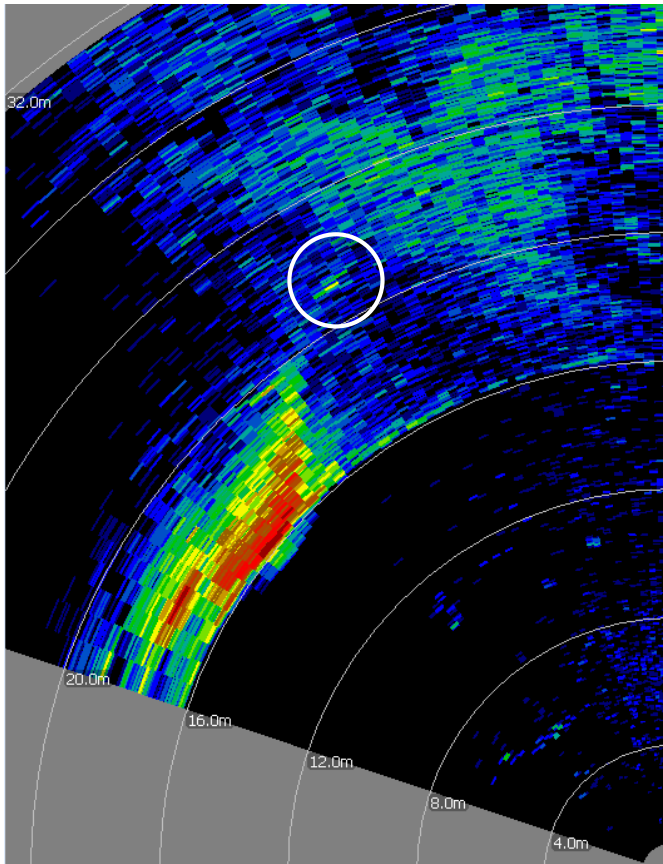
ACKNOWLEDGEMENTS

- 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

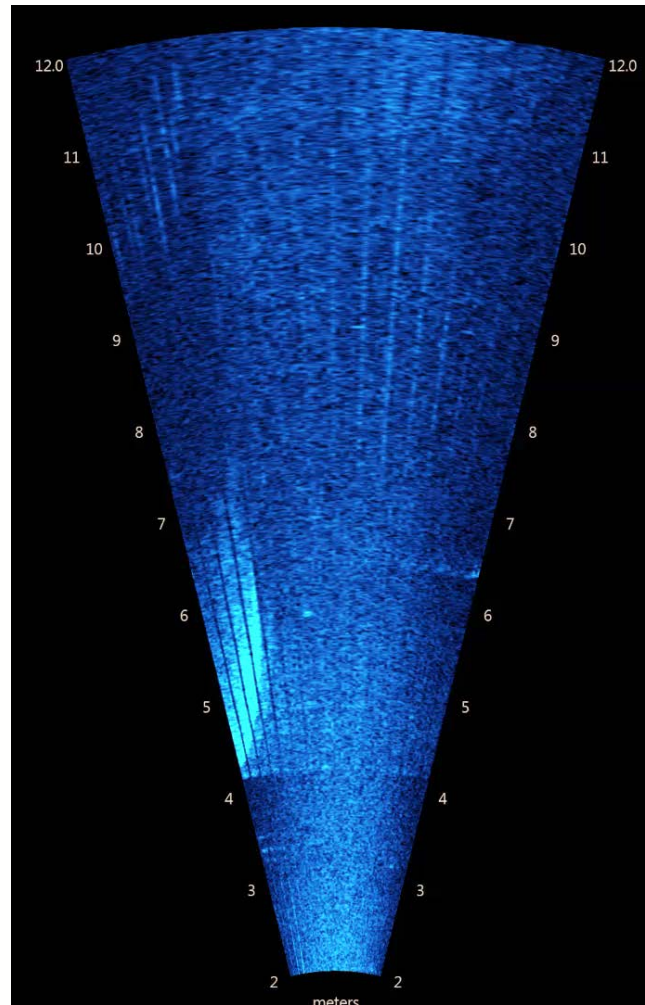
Released 79-cm eel with 4-m tether at nominal 25-m interval

(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

