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Acoustic telemetry development for fish passage

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Pacific Northwest
NATIONAL LABORATORY

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Acoustic telemetry development for fish passage

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INTERNATIONAL CONFERENCE ON ENGINEERING AND ECOHYDROLOGY FOR FISH
PASSAGE, CORVALLIS, OREGON

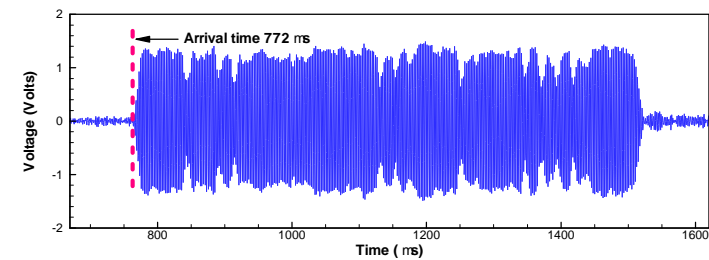
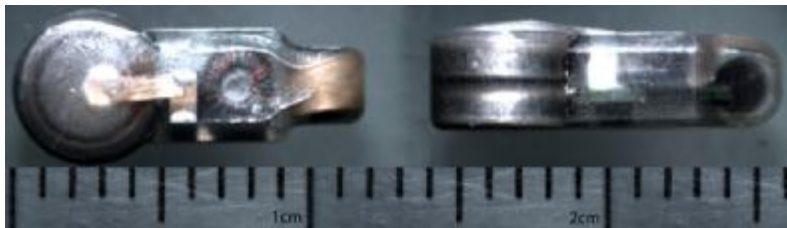
JUNE 21, 2017

- ▶ Juvenile Salmon Acoustic Telemetry System (JSATS) development
 - Started in 2001 due to limitation of available technologies
 - Initially developed to study juvenile salmon in the Columbia River Basin
 - Studied >100,000 fish from various species in different countries since 2005

- ▶ Further acoustic tag development
 - Injectable acoustic tag
 - Juvenile sturgeon acoustic tag
 - Self-powered tag
 - Eel/lamprey tag

Juvenile Salmon Acoustic Telemetry System (JSATS) Components (JSATS.pnnl.gov)

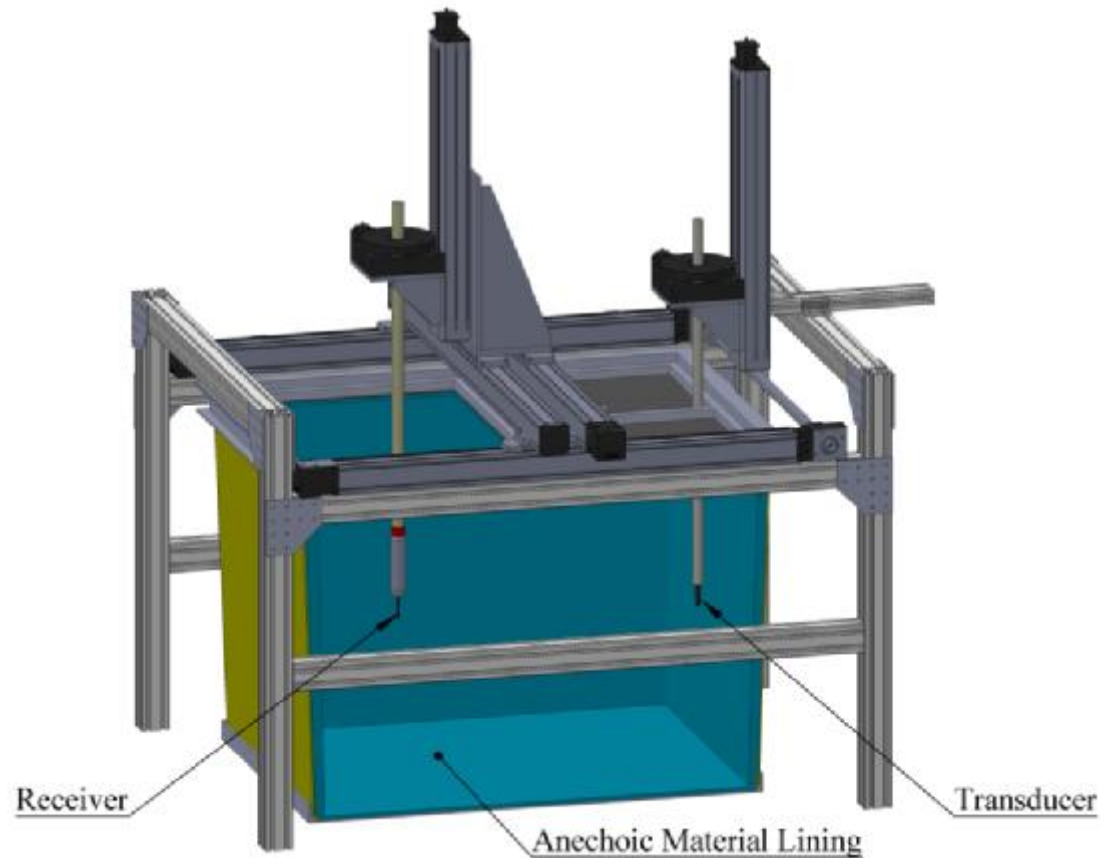
- ▶ The JSATS consists of acoustic transmitters, receivers, and data management and processing software.



(a)



PNNL Bioacoustics and Flow Lab (<http://bfl.pnnl.gov>), accredited by A2LA to ISO/IEC 17025:2005



Deng ZD, et al. 2010. "Design and Instrumentation of a Measurement and Calibration System for an Acoustic Telemetry System." *Sensors* 10(4):3090-3099.



JSATS Comparisons to Other Telemetry Options

▶ JSATS

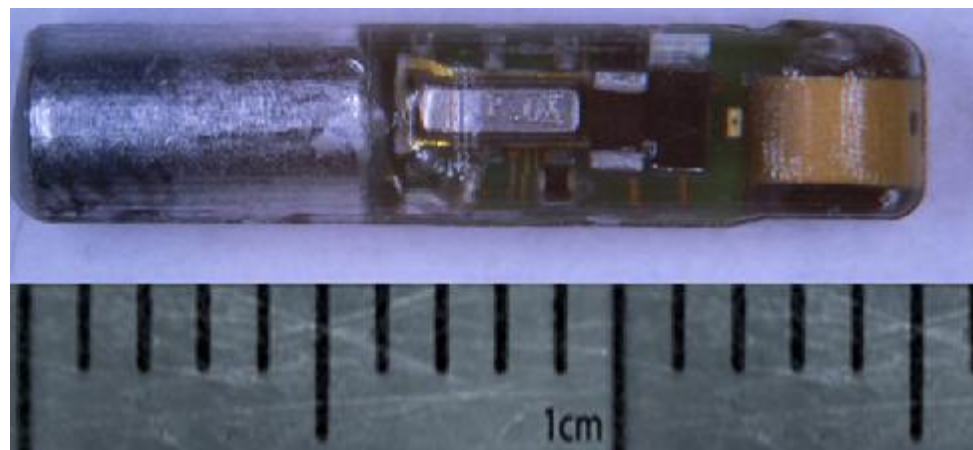
- Small tags
- Good in noisy environments (fast, shallow, turbulent, near dams/structures)
- Many tags can be in range at the same time with high detection probability
- Works in fresh and salt water
- Many free-ware tools available
- Not 'black-box'
- Competitive vendors
- Continuing development/improvements
- Receiver cost (of those we have used) is high compared to some systems but the cost has been decreasing.

▶ Other systems

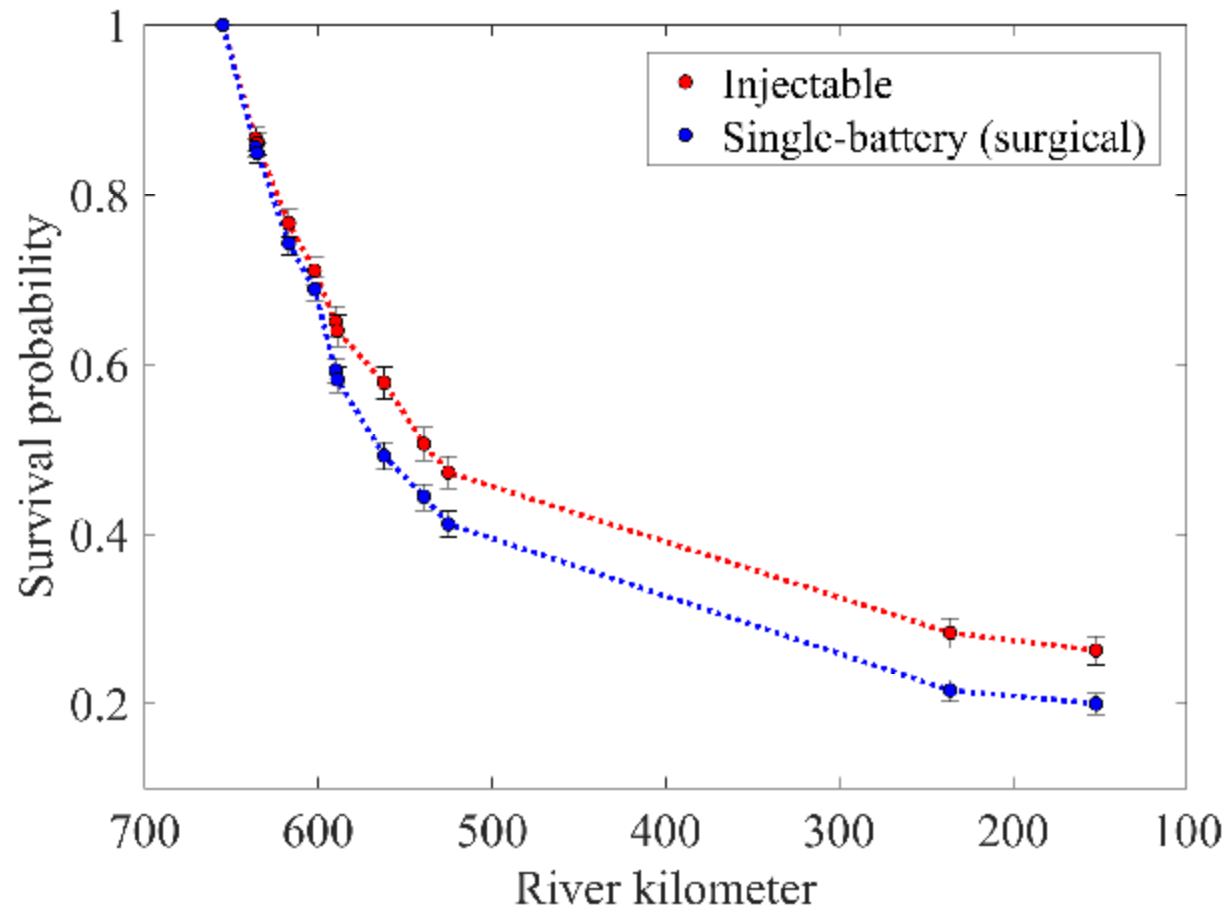
- May be better for many applications
 - E.g., few fish / large fish in receive range at the same time, salt water, very long life

Injectable Acoustic Transmitter

- ▶ Implantation by injection instead of surgery, leading to significant cost reduction in use and training
- ▶ Significantly reduced handling to fish
- ▶ Dimension: 15 mm x 3.3 mm
- ▶ Dry Weight: 217 mg
- ▶ Wet weight: 106 mg
- ▶ Volume: 0.111 mL
- ▶ Source Level:
 - 156 dB at zero deg
 - 155 dB average -90 to 90 deg
- ▶ Configurable pulse rate interval & tag code-
- ▶ Optional temperature, alternating, and hibernation mode
- ▶ Tag life: > 120 days at 3-s pulse rate interval



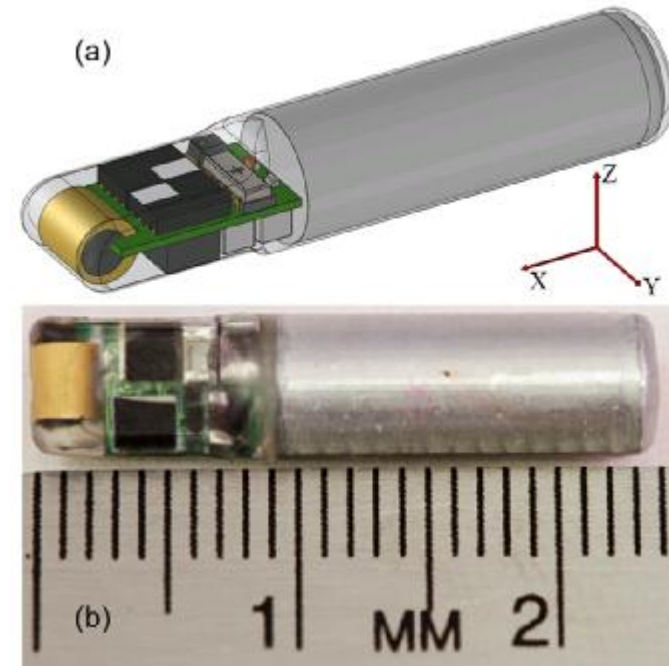
Survival rate Comparison of juvenile Chinook salmon using injectable and surgical acoustic transmitters



Deng Z, JJ Martinez, H Li, RA Harnish, CM Woodley, JS Hughes, X Li, T Fu, J Lu, GA McMichael, MA Weiland, MB Eppard, JR Skalski, and RL Townsend. 2017. "Comparing the survival rate of juvenile Chinook salmon migrating through hydropower systems using injectable and surgical acoustic transmitters." *Scientific Reports* 7:42999. doi:10.1038/srep42999

Long-term Juvenile Sturgeon Tag Specifications*

- ▶ Dimension: 24.2 mm x 5.0 mm
- ▶ Dry Weight: 718 mg
- ▶ Wet Weight: 219 mg
- ▶ Volume: 419 mL
- ▶ Source Level:
 - 161 or 163 dB at zero deg
- ▶ Configurable pulse rate interval & tag code.
- ▶ Optional temperature, alternating, and hibernation mode.
- ▶ Tag Life: 365 days at 161 dB and 15-s pulse rate interval.

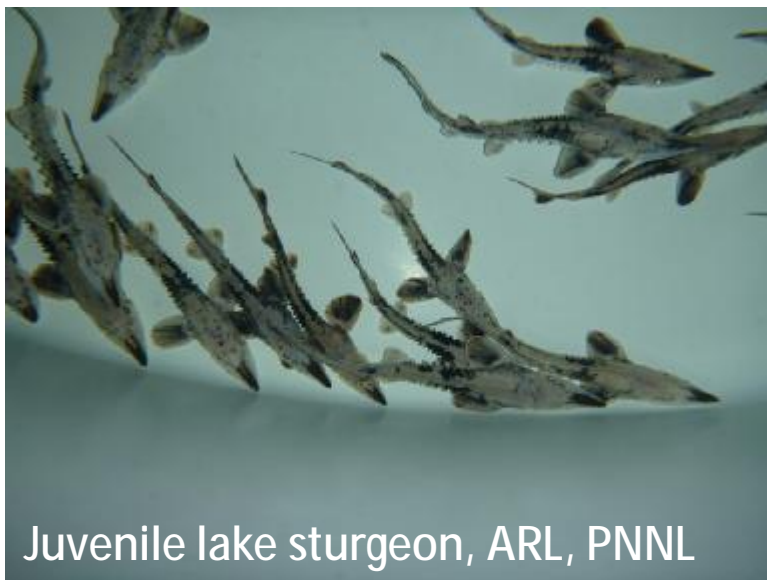


*Patent pending

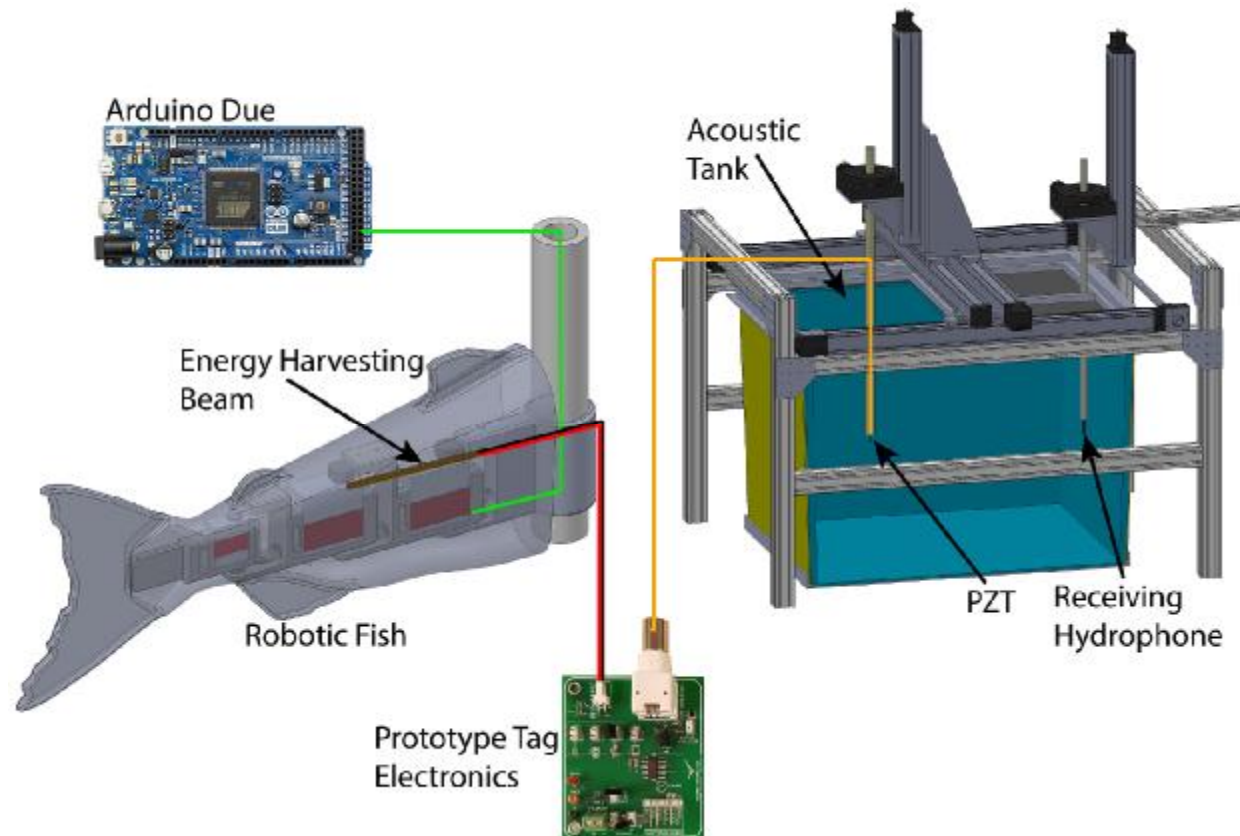
Lu, J. et al. 2016. A small long-life acoustic transmitter for studying the behavior of aquatic animals. Review of Scientific Instruments, 87(11), 114902.

Sturgeon Tag Applications

- ▶ Small juvenile (< 1 year old) sturgeon.
- ▶ Long term monitoring for adult fish such as adult lamprey.
- ▶ Noisy environment such as immediate tailrace due to higher source level.
- ▶ Mobile tracking due to longer detection range.



Self-powered Acoustic Transmitter*: Benchtop testing

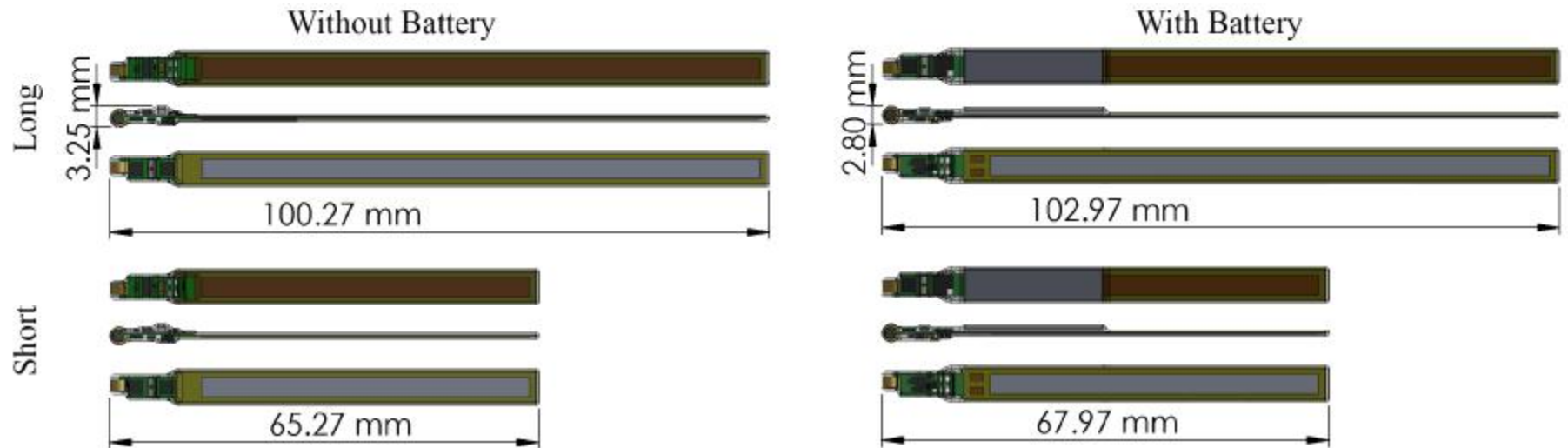


*Patent pending

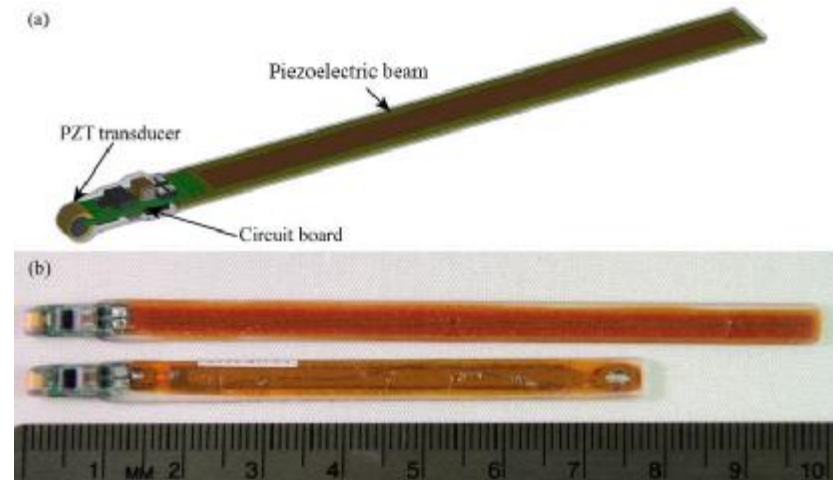
Li H, C Tian, and Z Deng. 2014. "Energy Harvesting From Low Frequency Applications Using Piezoelectric Materials." *Applied Physics Reviews* 1(4):041301.

Li H, C Tian, J Lu, MJ Myjak, JJ Martinez, RS Brown, and Z Deng. 2016. "An Energy Harvesting Underwater Acoustic Transmitter for Aquatic Animals." *Scientific Reports* 6:33804. doi:10.1038/srep33804

Self-powered Acoustic Transmitter



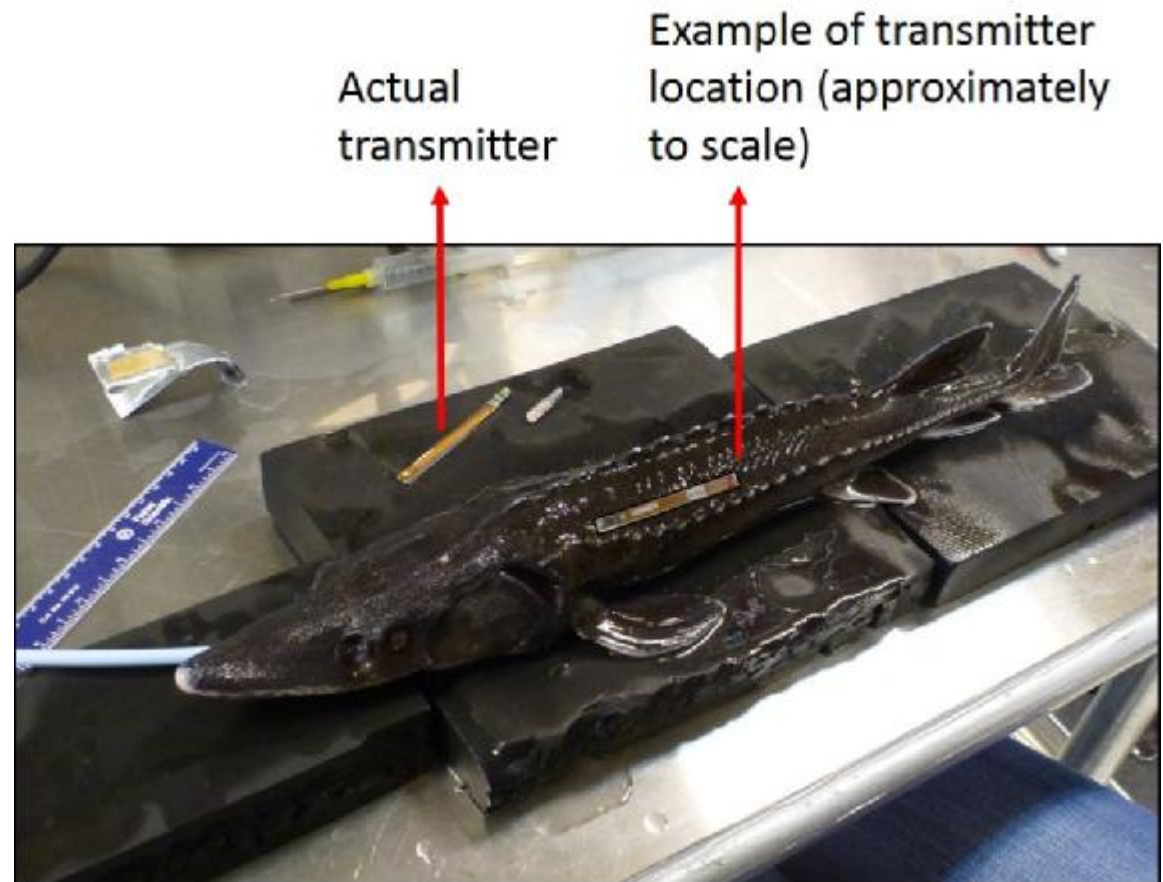
- Option 1 (i.e. "without battery"): The weights are 1.05 and 0.80 grams, respectively.
- Option 2 (i.e. "with battery"): The weights are 1.10 and 0.85 grams, respectively.
- Tag lengths can vary based on power requirements and fish characteristics of specific applications.



* The short tag in the photo used an off-the-shelf piezoelectric beam instead of a custom one and thus was slightly longer than the one shown in the CAD.

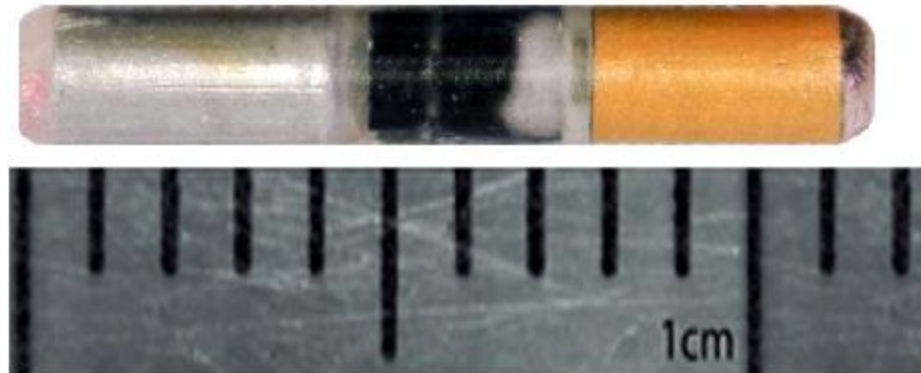
Self-powered Acoustic Transmitter: Live fish experiments

- ▶ 65-mm tag implanted in 30 juvenile white sturgeon (37.8 ± 2.9 cm) for laboratory holding study in April 2017.
- ▶ Implanted on the flank (side); incision was just posterior of the gills and just above the flank scutes.
- ▶ 8–10-mm incision was first made with a No. 11 blade that only cut barely beneath the skin.
- ▶ Conduct a field trial on white sturgeon in 2017 in collaboration with Idaho Power Company, Grant County PUD, and ATS.



First Generation Juvenile Eel/lamprey Acoustic Transmitter*

- ▶ Dimension: 12.0 mm x 2.0 mm
- ▶ Dry Weight: 80 mg
- ▶ Source Level: 147 dB
- ▶ Configurable pulse rate interval & tag code
- ▶ Optional temperature, alternating, and hibernation mode
- ▶ Tag life: > 20 days at 5-s pulse rate interval



* Available for licensing, patent pending

Eel tagging: Tag Inserted Anteriorly, no Suture



Juvenile Eel/lamprey Acoustic Transmitter Pilot Field Trial

- ▶ Primary objective: Validate the functionality and evaluate the performance of the new transmitter in field environments
- ▶ Juvenile lamprey
 - Tagged and released 100 fish in April and May 2017
 - Three autonomous receiver arrays were deployed between McNary Dam and John Day Dam in the Columbia River
 - Preliminary data showed high detection probability (100%).
- ▶ Juvenile Eel
 - At Roanoke Rapids Dam in North Carolina in collaboration with Dominion Power
 - Plan to tag about 100 fish in June 2017

Development Summary

Tag Type	Dimension	Dry Weight (g)	Source Level	Tag Life	Primary Application	Status
Injectable Tag	15 mm X 3 mm	0.216	155-156 dB	> 100 days at 3-s PRI	Juvenile salmon and other small fish	Completed
Sturgeon Tag	24 mm x 5 mm	0.718	161 or 163 dB	365 days at 15-s	Juvenile sturgeon; adult lamprey; Noisy environment	Completed
Self-powered tag	70 or 100-mm in length	0.8 to 1.11	150 dB	Long	Long-term monitoring	Planned for 2017 field trial
Eel/lamprey	12 mm X 2 mm	0.08	148 dB	20 to 30 days at 5-s	juvenile eel; juvenile lamprey	Planned for 2017 field trial

2018 and Beyond

- ▶ Looking for partners to conduct full scale field study for juvenile eel in 2018 or beyond.
- ▶ Looking for partners to extend applications to other species such as American shad, delta smelts, river hearing.
- ▶ Looking for partners to extend self-powered tag to other applications.
 - Plan to conduct a pilot trial for juvenile sturgeon in the Columbia and Snake River Basin in 2017

Acknowledgements

- ▶ US Army Corps of Engineers: Brad Eppard, Scott Fielding, Ricardo Walker.
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Questions?

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- ▶ <http://bfl.pnnl.gov/>