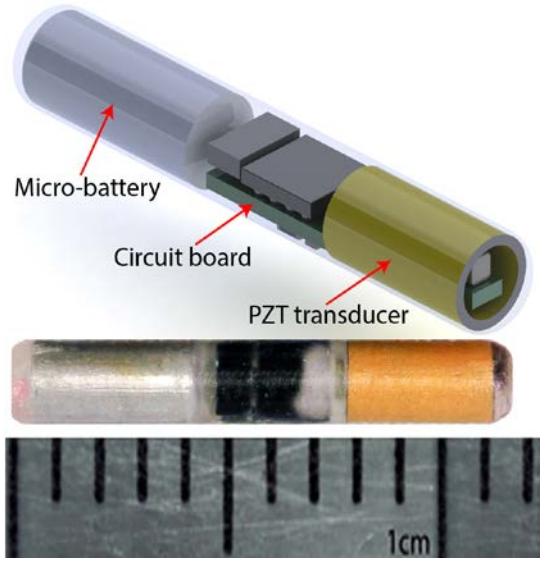


Monitoring Technology Development for Sensitive Species (Eel/Lamprey Tag Development)

WBS: 1.3.1.601

Hydropower Program

October 9, 2019

Daniel Deng, Ph.D.

PNNL

Project Overview

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Project Summary

Under this project we designed, prototyped, and performed laboratory and field tests of an acoustic micro-transmitter that can be used to study the behavior and survival of juvenile American eel and Pacific lamprey. The ability to implant acoustic transmitters and track the movement of juvenile eel and lamprey provides information on migration routes, habitat use, and hydropower dam survival rates to make more informed management decisions regarding new and existing hydroelectric facilities.

Project Objective & Impact

The objectives were to 1) design, prototype, and perform laboratory and field tests of an acoustic micro-transmitter that can be used to study the behavior and survival of juvenile eel and lamprey 2) provide information to develop mitigation measures for safer passage of eel and lamprey and reduce impact on these species and US hydropower production. Final products include a revolutionary acoustic telemetry system consisting of a patented eel/lamprey tag, field deployment protocols, tagging protocols for juvenile eel and lamprey, and other commercially available components. The ability to implant acoustic transmitters and track the movements of species and life stages of fish that have never been studied at this level of detail before advances our understanding to inform designs of new hydropower systems that minimize or avoid environmental impacts.

Project Information

Project Principal Investigator(s)

Daniel Deng

WPTO Lead

Tim Welch

Project Partners

US Army Corps of Engineers, Cube Hydro, Dominion Energy, Maryland Department of Natural Resources, Pacific States Marine Fisheries Commission, Umatilla Tribe, US Fish and Wildlife Service, West Virginia Department of Natural Resources, Yakama Tribe

Project Duration

- Project Start Date: October 1, 2014
- Project End Date: September 09, 2018

Alignment with the Program

Hydropower Program Strategic Priorities

Environmental R&D and Hydrologic Systems Science

Big-Data Access and Analysis

- Technology R&D for Low-Impact Hydropower Growth
- R&D to Support Modernization, Upgrades and Security for Existing Hydropower Fleet
- Understand, Enable, and Improve Hydropower's Contributions to Grid Reliability, Resilience, and Integration

Alignment with the Hydro Program

Environmental R&D and Hydrologic Systems Science

- Develop better monitoring technologies to evaluate environmental impacts
- Develop technologies and strategies that avoid, minimize, or mitigate ecological impacts
- Support development of metrics for better evaluating environmental sustainability for new hydropower developments
- Assess potential impacts of long-term hydrologic variations to hydropower generation and flexibility
- Improve abilities to assess potential methane emissions from reservoirs
- Better identify opportunities and weigh potential trade-offs across multiple objectives at basin-scales

This project provides the first active acoustic tag technology that is small enough for use to evaluate fish passage of juvenile eels and lamprey through hydroelectric facilities. This project supports goals to better evaluate environmental impacts. Information and data that this tool provides can inform adaptive management processes and other assessments.

Alignment with the Hydro Program

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Technology R&D for Low-Impact Hydropower Growth

- Enable the design and development of new Standard Modular Hydropower (SMH) technologies for both existing water infrastructure and new stream-reach development. This new approach to systems design for hydropower projects incorporates ecological and social objectives for river systems earlier in design processes
- Leverage new advancements in manufacturing and materials to dramatically lower costs of SMH components and systems designs
- Support development of necessary testing infrastructure for new technologies

This project is providing the eel/lamprey tag tool and related protocols to the hydropower community that will enable new sensitive species monitoring capabilities to inform the development of SMH technologies (e.g., component designs and facilities) for existing and new applications for low-impact growth. It can also provide information about species interactions with SMH facilities that can inform sustainable operations.

Project Budget

FY17	FY18	FY19 (Q1 & Q2 Only)	Total Project Budget FY17–FY19 Q1 & Q2 (October 2016 – March 2019)	
Costed	Costed	Costed	Total Costed	Total Authorized
$568K	$500K	$0K	$1068K	$1068K

USAC provided 50% cost share from FY15 to FY17.
These partners provided in kind support: Cube Hydro, Dominion Energy, Maryland Department of Natural Resources, Pacific States Marine Fisheries Commission, Umatilla Tribe, US Fish and Wildlife Service, West Virginia Department of Natural Resources, Yakama Tribe

Management and Technical Approach

Challenges facing American eels in East Coast rivers and Pacific lampreys in West Coast rivers:

- American eel and Pacific lamprey interact with hydropower dams during their migrations and are considered species of concern throughout their range due to population declines
  - Young eel drift to rivers and streams as juveniles, migrate upstream to grow, and migrate back to the sea as adults to spawn
  - Lamprey migrate out to the sea 5-7 years after they hatch in rivers, live in the sea, and return to rivers to spawn
- Knowledge of eel and lamprey behavior, movements, and habitat use can provide information to hydro owner/operators for:
  - Developing mitigation strategies
  - Informing hydro design
  - Minimizing impacts to fish

Management and Technical Approach

Multi-disciplinary and multi-phase approach:

- Develop the planned range of applications with stakeholders
- Derive design specifications
- Design and implementation
  - Develop a primary micro-battery by reducing length and diameter and using soft packaging materials
  - Integrate the functionality of the tag onto an integrated circuit
  - Optimize the transducer design by exploring other resonance modes
  - Design form factors that allow implantation of juvenile eel and lamprey
  - Develop an implantation procedure that minimizes the time required and reduces biological effects in juvenile eel and lamprey
  - Assess manufacturability and cost of the parts and whole unit
- Laboratory evaluation using benchtop tools and laboratory water tank
- Pilot field trial with industry partners
- Full Field trial with industry partners
- Technology transfer and commercialization

End-User Engagement and Dissemination Strategy

Mechanisms for end-user engagement and dissemination strategy included the following:

- Work closely with partners on design specifications and field applications
- Three multi-agency/stakeholder meetings
- Three one-on-one webinars
- 21 presentations at conferences, workshops or institutions
- One approved patent
- Two PNNL news releases
- Multiple media coverage
- 14 journal articles from 2015 to 2019
  - *These articles have been cited 400+ times*

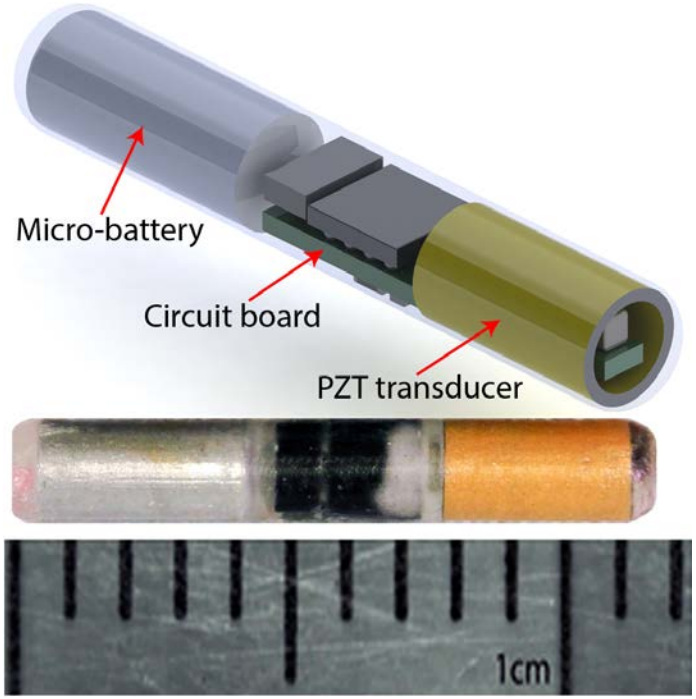
Technical Accomplishments

Development History:

- Started in October 2014
- Finalized design in September 2016
- Developed implantation procedure in June 2016
- Conducted pilot field trials in 2017 and 2018

First Generation Juvenile Lamprey/Eel Acoustic Transmitter Specifications:

- Dimension: 12.0 mm x 2.0 mm
- Dry Weight: 0.08 gram
- Tag life: 30 days at 5-s ping rate
- Additional features include temperature sensor, delayed start



Technical Accomplishments (Cont.)

Juvenile Eel Tagging Study in the Lab

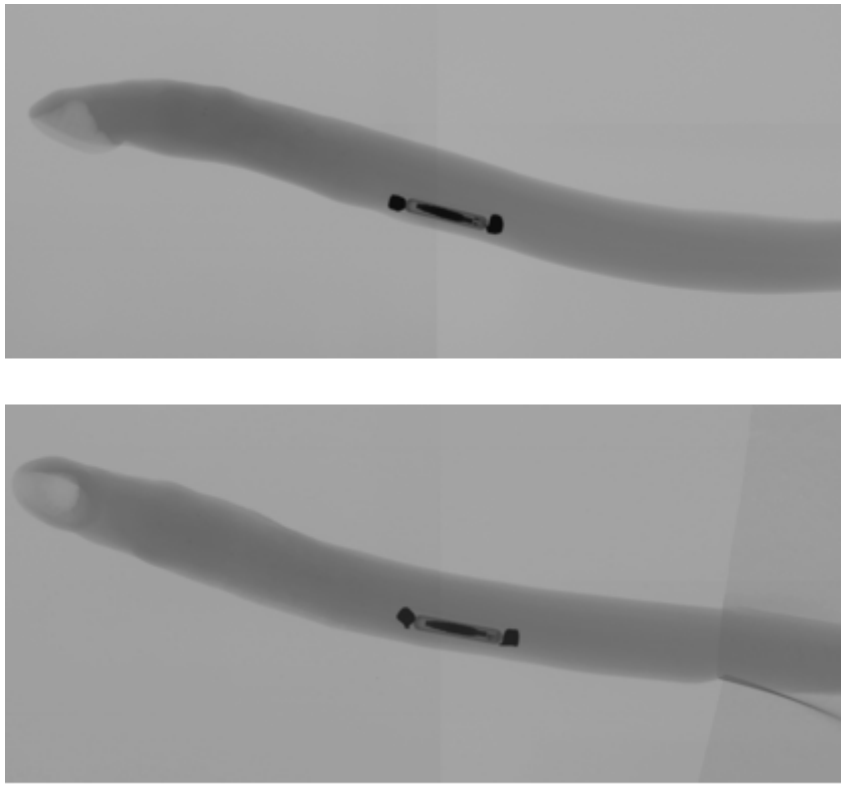
- Juvenile (yellow stage) American eels (113-208 mm)
- No fish died during a 38-day holding study.
- Only one of 26 eels lost its tag.
- Tags were surgically placed in the body cavity without causing significant injury or infections at the tagging site.
- There were no significant differences in swimming ability between implanted and control groups.

Mueller et al. 2017. "Retention and Effects of Miniature Transmitters in Juvenile American Eels." Fisheries Research 195:52-58.

Technical Accomplishments (Cont.)

Juvenile Lamprey Tagging Study in the Lab

- The tag is likely to have little impact on survival over a 28-day holding period for fish greater than 130 mm.
- Tags can be placed surgically in the body cavity without causing significant hemorrhaging or fungal infections at tagging site.
- The sustained swimming tests showed no significant differences in swimming ability between implanted and control groups (120 to 160 mm).



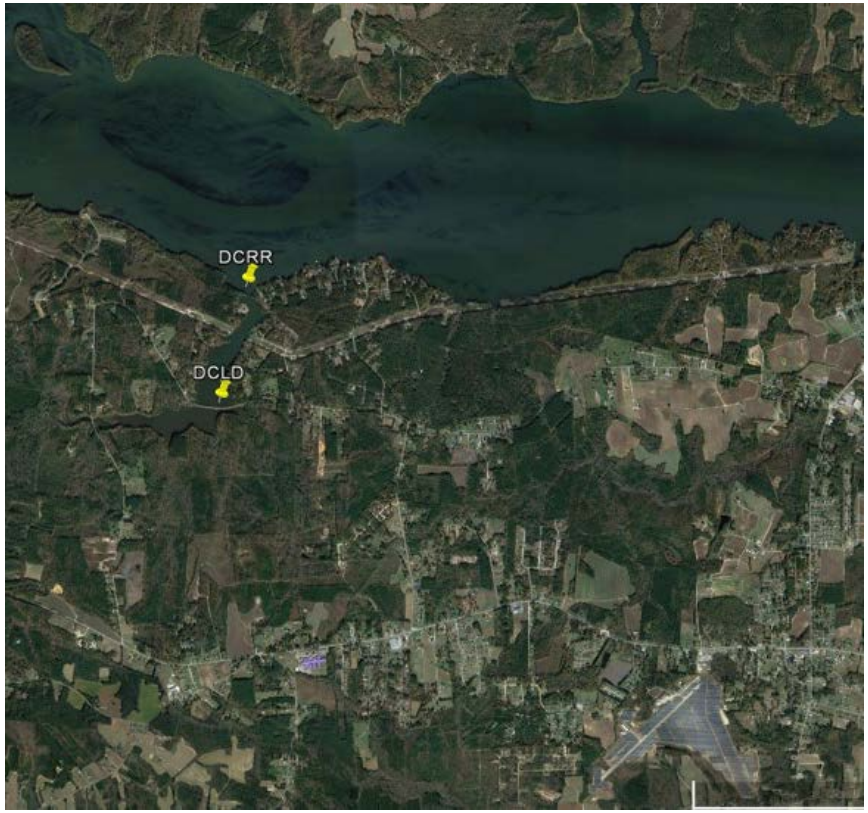
X-ray images of dummy tags inside body cavity of juvenile lamprey.

Mueller et al, 2019. "Methods for Implantation of a New Micro Acoustic Tag in Juvenile Pacific Lamprey and American Eel." Journal of Visualized Experiments. 145: e59274

Juvenile American Eel Field Tagging Trial in North Carolina

Purpose: To determine the best location for releasing upstream migrating eel collected at the dam. Demonstrate feasibility of technology in the dam forebay and shallow river water.

- Conducted at Roanoke Rapids Dam in North Carolina in collaboration with Dominion Energy
- 110 of 115 tagged juvenile eels were detected
- 36 out of 38 were detected in shallow water



Technical Accomplishments (Cont.)

Juvenile American Eel Pilot Trial on Potomac River

Purpose: Determine the best location for an eel ladder and demonstrate the feasibility of the technology in noisy tailrace environment.

- Conducted at Dam 4 and 5
- Tagged 103 yellow-phase American eels: 53 at Dam 4 and 50 at Dam 5
- For fish at Dam 4, 87% were detected at Dam 4. 17% moved upstream and detected at Dam 5.
- For fish at Dam 5, none moved upstream to Dam 5 and 26% moved downstream and detected at Dam 4.

Technical Accomplishments (Cont.)

Juvenile Pacific Lamprey Field Trial

- Conducted trial between McNary Dam and John Day Dam
- Tagged 100 fish and 98 percent were detected
- Gather information on fish collection, tagging, and release
- Determine the detection probability and distribution of tagged fish
- Determine what side of the river lamprey used and for how long

Progress Since Project Summary Submittal

- The patent on the transmitter design has been approved
- Filed a patent on the micro-battery design
- USGS and Yakama Nation has secured funding to study juvenile Pacific lamprey in Yakima River using the eel/lamprey transmitter
- Michigan State University has secured funding to study juvenile sea lamprey in the Great Lakes region
- Columbia River Inter-Tribal Fish Commission has applied for funding to study juvenile Pacific lamprey in the Columbia River estuary

Future Work

- Ongoing development to increase the tag life to 50 days at 5-second transmission interval
- Identify more partners to test the transmitter
- Commercialize the transmitter
- Ongoing laboratory study to evaluate use of the eel and lamprey transmitter in small salmon (30–100 mm long)
- Apply the effectiveness of the transmitter to study other species including American shad, delta smelt, river herring, sea lamprey, and Asian carp
- Further reduce the transmitter size if needed for other applications