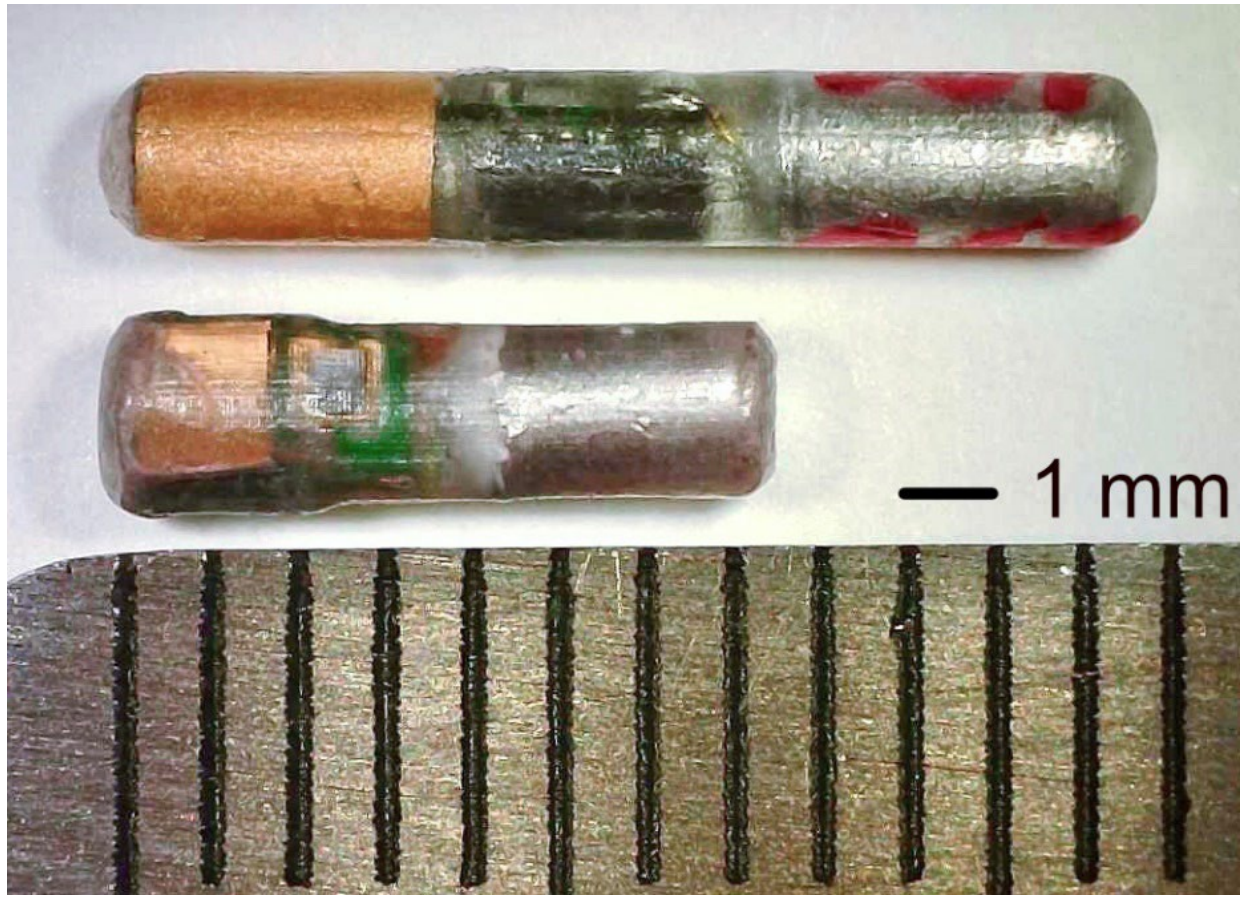
1.3.1.604 Monitoring Technology Development for Sensitive Species: America Shad Transmitter Development



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Project Overview

Project Summary

American shad is a migratory fish native to a large range across the East Coast of the US. American shad are an economically valuable fishery, but their populations have been declining throughout their historic range. More than 100 US hydropower facilities with a total capacity of >4 GW will have expiring Federal Energy Regulatory Commission (FERC) licenses over the next 10 years and are within the native range of American shad. PNNL is developing a revolutionary acoustic transmitter that can be used to study the behavior and survival of species such as American shad to inform hydropower mitigation and species management.

Intended Outcomes

The ability to safely implant acoustic transmitters and track the movements of species and life stages of fish like American shad, that have never been studied before at this level of detail, would greatly advance our understanding of fish migration timing and behaviors, habitat use, fishway use and performance, and fish survival rates at hydropower facilities. All resulting in more informed management decisions regarding new and existing hydroelectric facilities and better designs of new hydropower systems that minimize or avoid environmental impacts.

Project Information

Principal Investigator(s)

- Daniel Deng

Project Partners/Subs

- Eagle Creek Renewable Energy
- Kleinschmidt Group

Project Status

New projects

Project Duration

- Project Start Date: April 2020
- Project End Date: March 2023

Total Costed (FY19–FY21)

$900k

Project Objectives: Relevance

Relevance to Program Goals:

- Challenge: Addressing Environmental Impacts and Hydrologic Uncertainties
- Environmental and Hydrologic Systems Science
  - Develop better monitoring technologies to study river systems and evaluate environmental impacts
- This project provides the first active acoustic tag technology that is small enough for use to evaluate fish passage of juvenile American shad 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

Project Objectives: Approach

Approach: Multi-disciplinary and multi-phase

- Develop the planned range of applications with stakeholders
- Derive design specifications and technology performance goals
- 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 American shad
  - Develop an implantation procedure that minimizes the time required and reduces biological effects in juvenile American shad
  - 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

Project Objectives: Expected Outputs and Intended Outcomes

Outputs:

- A revolutionary acoustic transmitter that can be used to study the behavior and survival of sensitive species such as juvenile American shad.
- A tagging protocol that minimizes the time required for implantation and reduces biological effects in juvenile American shad.
- Pilot field demonstration of the technology at a hydroelectric facility.
- Intellectual properties in the form of patent applications.
- Three peer-reviewed articles documenting the transducer design, battery, and implantation.

Outcomes:

- New operational practices or mitigation / passage technologies developed for American shad and other key species or life stages that have not been studied before.
- Reduced cost-time for American shad studies through new information on migration routes, habitat use, and hydropower dam survival rates.
- Reduced impact on American shad and increased survival rates through hydro systems.
- Efficient environmental sensing due to the microbattery.
- Commercial benefits from licensing and manufacturing of technology.

Project Timeline

FY 2020

April 2020: Project started in Q2

June 2020: Completed a comprehensive literature review of 43 gray and peer-reviewed sources on tagging juvenile Clupeidae (herring and shad family)

September 2020: Defined range of applications in collaboration with key stakeholders

FY 2021

December 2020: Derive design specifications based on the range of applications

March 2021: Evaluated four design options and select two designs for prototyping

June 2021: Developed an implantation procedure including optimal transport methods, holding/rearing conditions, and a handling method

September 2021: Developed a manufacturing protocol for the first-iteration tag prototype (V0.5)

Project Budget

Total Project Budget – Award Information		
DOE	Cost-share	Total
$900K	$K	$900K

FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	Costed	Costed	Total Costed
$0K	$300K	$600K	$900K

End-User Engagement and Dissemination

Target Users / Audience:

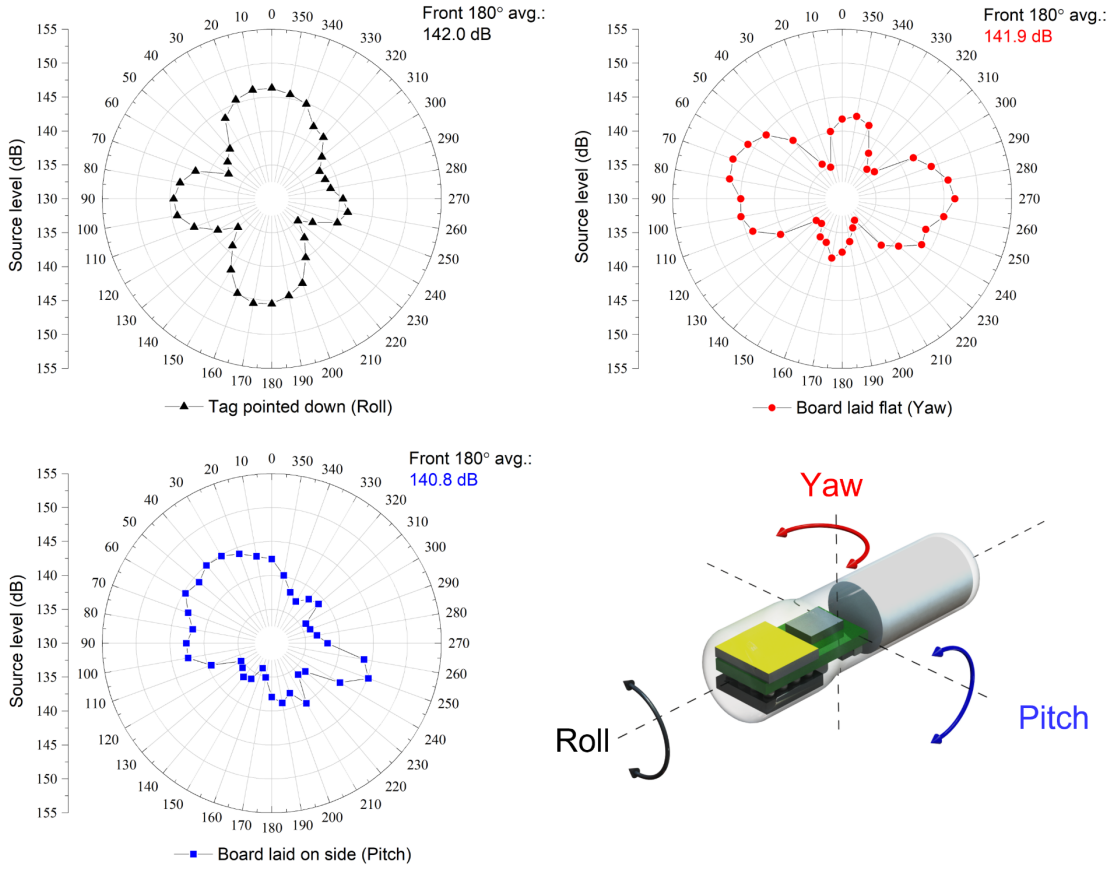
- **Shad Tag:** Members of the hydropower community, including fisheries and natural resource managers, regulatory agencies, hydropower project owners/operators, researchers, and consultants.
  - This tag may also meet requirements for other sensitive fish species, including delta smelt
- **Microbattery:** has the potential for broad market of microsensor community.

Actions and plan:

- Discussed with key stakeholders and partners to facilitate the development of the application space for all parties interested in the development of the new transmitter to meet specific study objectives for American shad.
  - Including Government agencies (11), Developers/Utilities (5), Consulting Companies (7), Academia (6).
- Worked directly with a hydropower owner/operator and a consulting company to design and conduct a pilot field demonstration to test the performance of the prototype shad tag.
- Reached out to communities that may have a direct interest in development of applications for other fish species.
- Will work with UC Davis and ICF International on applications to delta smelt under a project funded by California Department of Fish and Wildlife
- Will share results with the target audience through a combination of stakeholder meetings, webinars, peer-reviewed publications, regular email correspondences, and workshop/conference presentations.
  - The peer-review publications target researchers, engineers, regulators, and consultants.
  - The workshop/conference presentations target a general industry audience.
- Will post relevant information on the technology at an accessible PNNL website (http://JSATS.pnnl.gov).
  - This approach will allow us to stay engaged with the potential users of the technology as well as the general public to obtain their feedback, so the product of this project can best address real-word applications and needs.

Performance: Accomplishments and Progress

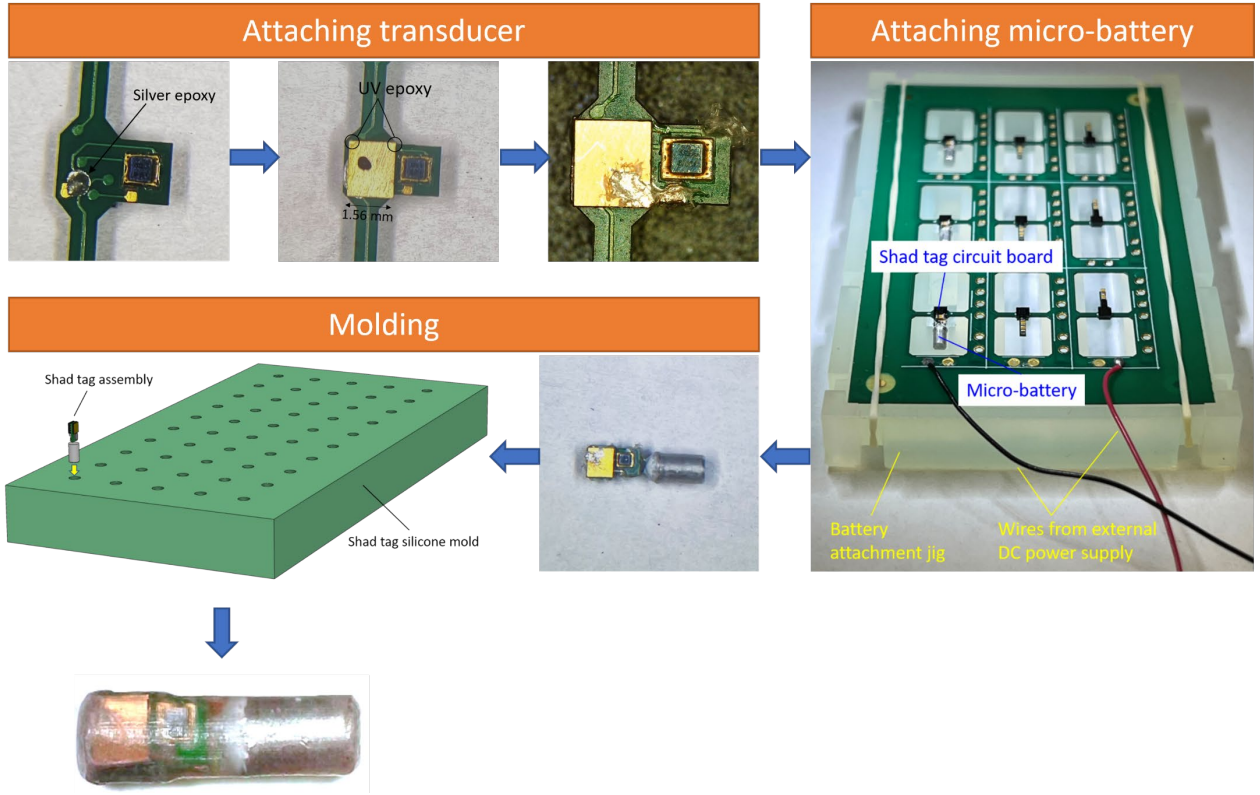
- Developed the Shad Transmitter and manufactured prototypes
  - Dimension: 7.6 mm x 2.0 mm
  - Mass: 0.05 g
  - Source Level: 142 dB
  - Configurable pulse rate interval & tag code
  - Optional temperature, alternating code, and hibernation mode
  - Tag life: ~28 days at 5-s pulse rate interval
- Evaluated the performance of the prototypes in the lab
- Conducted preliminary evaluation of detection and tracking performance of the prototypes at Lower Granite Dam



Beam patterns of the Shad Transmitter

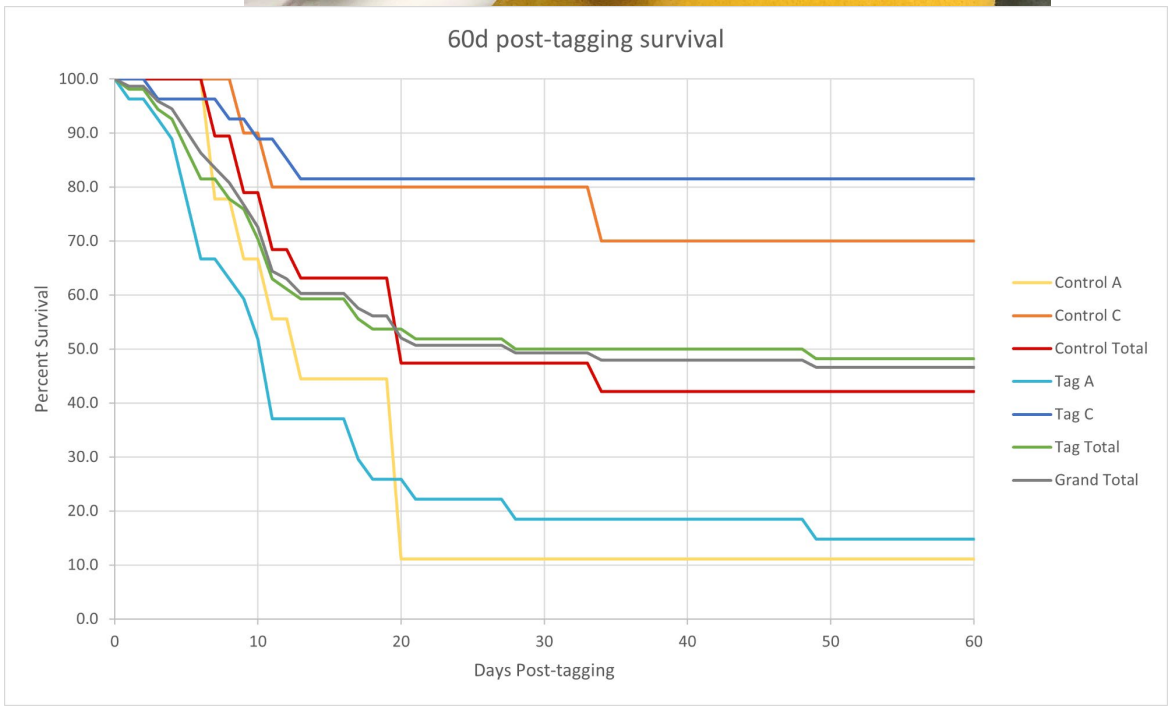
Performance: Accomplishments and Progress (cont.)

- Developed a manufacturing protocol for the first-iteration tag prototype (V0.5)
- Filed a patent on Intelligent ON/OFF Mechanisms and Quasi-location awareness transmitter in May 2021 and another patent on the Shad Transmitter design in June 2022
- Published a paper in *The 15th International Conference on Underwater Networks and Systems* journal
- Presented the preliminary results in conferences (e.g. Fish Passage Conference) and seminars (e.g. Univ. of Washington and Virginia Tech)



Performance: Accomplishments and Progress (cont.)

- Developed an implantation procedure that minimizes the time required and reduces biological effects in juvenile American shad
- Identified optimal transport methods, holding/rearing conditions, and a handling method appropriate for handling and surgery that maximized American shad survival
- Conducted long-term (60-day) holding experiment:
  - 54 tagged – 69-105mm (avg 89mm)
  - 19 control – 82-100mm (avg 91mm)
  - 2 tanks; controls help identify tank effects
  - Tank effect – 25% mortality by day 6 for Tank A
  - Tank C 60-day survival
    - 81.5% for tagged (avg. growth 10mm)
    - 70% for control



Performance: Accomplishments and Progress (cont.)

Conducted experiment to evaluate susceptibility to predation

- Methods
  - 10 Bass per tank
  - ~10 control shad and ~10 tagged shad
  - Goal - end at ~50% consumption
  - Survival = Not eaten + not wounded
  - Nine trials with duration 3min – 2hr 6min (median 7min 39s)
  - Tagged shad 55-100mm (avg 80mm)
  - Control shad 56-97mm (avg 79mm)
  - 171 shad tested

- Results:
  - 114 eaten, 11 wounded, 3 killed, 23 controls and 20 tagged survived
  - No difference in survival by treatment
  - Larger fish were more susceptible to predation

Future Work

- Budget: $900k
- Optimize the first iteration prototype (V0.5) and finalize the V1.0 design of the transmitter
- Conduct comprehensive biological evaluation of the transmitters including long-term holding and susceptibility to predation
- Manufacture and evaluate the prototype transmitters in the lab and controlled field conditions
- Develop a study design for the pilot field demonstration at York Haven Dam
- Conduct the pilot field demonstration at York Haven Dam

Q&A