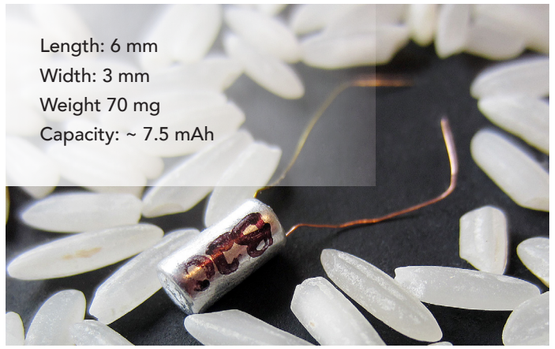
MAKING MICROBATTERIES BETTER



PNNL is seeking companies interested in manufacturing microbatteries. Our scientists designed a new tiny battery to power fish-monitoring tags because those on the market were either too big to allow for an injectable tag or didn't last as long as needed. Slightly larger than a long grain of rice, the PNNL lithium carbon monfluoride battery cuts the weight of current microbatteries by nearly half while packing twice the energy. The PNNL microbattery works better in cold water, sending clearer signals than current batteries at low temperatures.

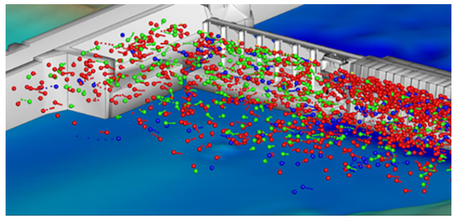
SOFTWARE

This software, available for licensing, helps collect and analyze the data necessary to learn more about fish behavior and ecosystems.

Hydropower Biological Evaluation Tools (HBET)

This suite of analytical tools evaluates the physical and biological performance of existing, refurbished, or newly installed hydro-turbines wherever fish passage is a regulatory concern. The tools include study design, data processing, and biological response tools with applications to various turbine designs and other passage alternatives. A centralized database can be accessed remotely. HBET is currently based on Sensor Fish data, but is compatible with other measurement technologies, such as acoustic telemetry.

3D Tracking V2.0



This software tool accurately and efficiently estimates the time sequence of 3D locations of fish tagged with transmitters. It collects enough detail to assess the function of dam-passage design alternatives, for example. It estimates a fish's location by calculating the time difference of arrival from all hydrophones that detect the transmission from the tag on that fish. During field tests at several dams, 3D Tracking V2.0 performed significantly better than other available solvers.

ACCREDITED TEST FACILITY

PNNL is home to the Bio-Acoustics & Flow Laboratory, the only lab in the nation accredited by the American Association for Laboratory Accreditation to ISO/IEC 17025:2005 for hydrophone sensitivity measurements and power level measurements of sound sources for frequencies from 50 kHz to 500 kHz for both military equipment and commercial components. This certification permits us to perform primary certified testing on instruments made by others or ourselves, reducing costs and providing significant flexibility in testing.

ABOUT PNNL AND OUR SPONSORS

Interdisciplinary teams at PNNL address pressing issues in energy, the environment, and national security through advances in basic and applied science. Founded in 1965, PNNL employs about 4,400 staff and has an annual budget of nearly $1 billion. It is managed by Battelle for DOE's Office of Science and provides solutions to DOE and other federal agencies, as well as industry.

Funding for the technologies described in this brochure has been provided by the Wind and Water Power programs within the DOE's Office of Energy Efficiency and Renewable Energy, the U.S. Army Corps of Engineers, and the Electric Power Research Institute.

HOW CAN WE HELP YOU?

You can tap into PNNL's expertise through sponsored or collaborative research, and by licensing technologies and software. Qualifying businesses may be eligible for no-cost technology assistance. Companies also can try out a technology through a six-month non-exclusive research and option license.

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Web Resources
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Fish-Tracking Technologies

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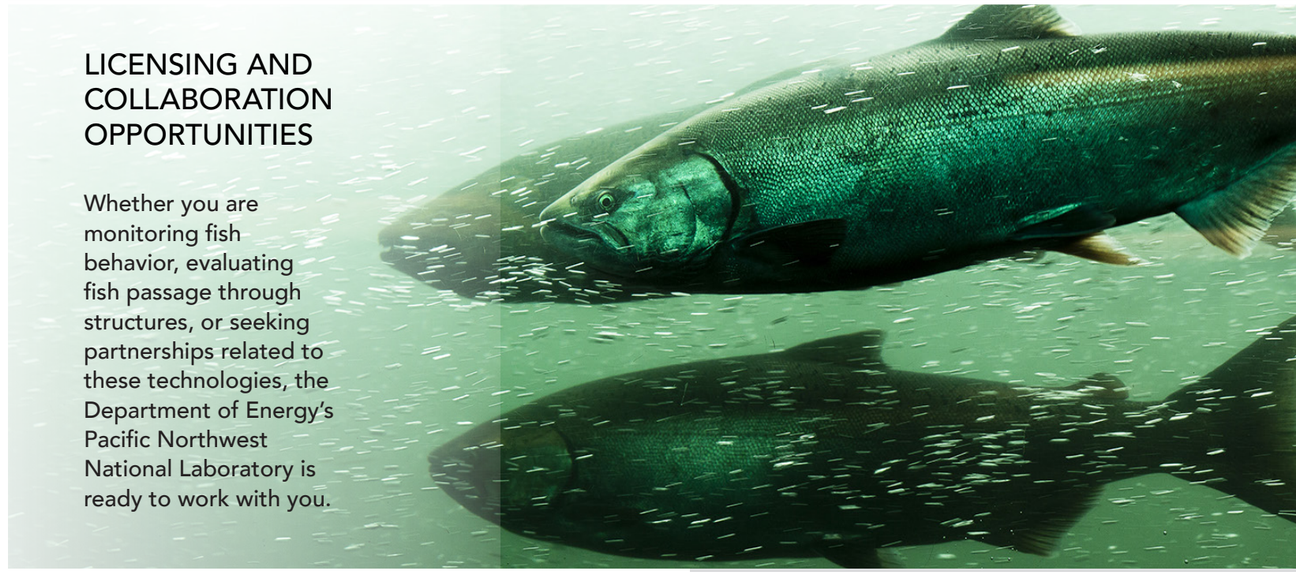


LICENSING AND COLLABORATION OPPORTUNITIES

Whether you are monitoring fish behavior, evaluating fish passage through structures, or seeking partnerships related to these technologies, the Department of Energy's Pacific Northwest National Laboratory is ready to work with you.

Pacific Northwest National Laboratory works with businesses and other organizations to move its research innovations into the marketplace. Among these available innovations is a suite of technologies and software used to better understand fish behavior and the hazards they face when encountering dams and other structures.

What we offer. For research with live fish, you can access some of the smallest and most lightweight tags available. You may also wish to use the instrumented Sensor Fish, which takes more than 2,000 measurements per second as it moves through water and around structures. You can also access analytical software that supports 3D-location tracking and fish passage evaluation.

Validated field experience. Since 2005, more than 100,000 fish in the U.S., Australia, Brazil, and East Asian countries have been tracked and studied using tags from this suite of technologies. With the results, government, academic, and commercial organizations are:

- Better understanding the impacts of dams and climate change on fish
- Making more informed decisions about designs of turbines and other in-water structures
- Submitting more accurate, site-specific data to satisfy permitting and environmental reporting requirements.

Working with us. We have developed and validated these technologies with fish and they are also available for testing with small mammals and amphibians. We would love to talk with you about licensing these technologies or customizing them through collaborative research. Please see our contact information on the back page.

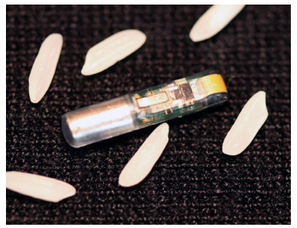
Applications

PNNL's tracking and sensing technologies are applicable to a wide range of species, research goals, commercial applications, and locations:

- Evaluation of fish guidance, behavior, and passage around structures, such as hydroelectric dams, using high-accuracy, high-efficiency 3D tracking
- Determination of ferry terminal impacts on juvenile salmonid movements in salt water
- Assessment of freshwater and marine habitats
- Observation of predator-prey interactions
- Determination of water temperature stratification and dissolved gas effects on fish survival and migration behavior
- Potential to tag bats, birds, small mammals, and amphibians.

INJECTABLE ACOUSTIC TAG

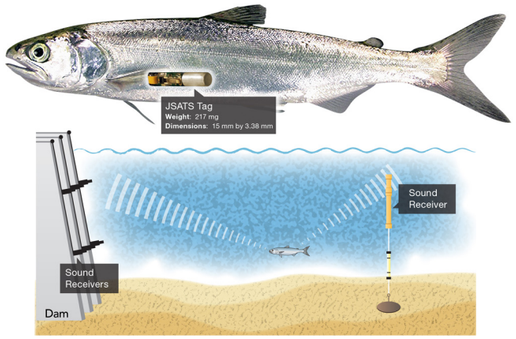
Rather than requiring surgical placement, this tag can be inserted into fish with a simple needle injection, allowing the fish to heal quickly and providing dependable information about their behavior. This injectable tag is powered by a tiny 3-volt battery and lasts more than five times longer than commercially available tags, collecting data for 120 days at a 3-second ping rate compared to 23 days for other technologies at the same ping rate. It also features a delayed start option, a temperature sensor, and the ability to transmit two alternating codes. It has been field-tested with Chinook salmon and juvenile Muskellunge and tested in the lab with Chinook salmon, delta smelt, and catfish.



Specification Highlights

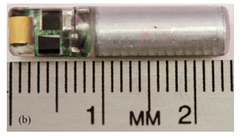
- Dry weight: 217 milligrams
- Length: 15 mm
- Diameter: 3.38 millimeters
- Transmitter life: 120 days at 3-second ping rate.

Patent: 14/014,035



PNNL's acoustic telemetry tags release quiet beeps, unique to each tagged fish. Receivers placed in rivers, lakes, or other bodies of water pick up the signal as the tagged fish swim by, collecting data that help researchers map the precise three-dimensional location of each fish and determine if they were injured during their travels.

LONG-LIFE STURGEON ACOUSTIC TAG



This tag is designed for detecting, identifying, and monitoring species such as juvenile sturgeon and adult eel and lamprey with longer migration patterns and lifespans. This small tag can last for up to one year with a 15-second ping rate and can be detected from as far as 500 meters away—perfect for fish like sturgeon and adult eels that live deep underwater. This tag also features a configurable ping rate interval and tag code, the option to measure temperature, alternating codes, and a hibernation mode. It has been deployed for long-term tracking of juvenile sturgeon.

Specification Highlights

- Length: 24.2 mm
- Width: 5.0 mm
- Dry Weight: 718 mg
- Wet Weight: 219 mg
- Source Level: 161 or 163 dB at zero degrees
- Configurable ping rate interval and tag code
- Optional temperature, alternating, and hibernation mode
- Transmitter life: 365 days at 161 dB and 15-second ping rate interval

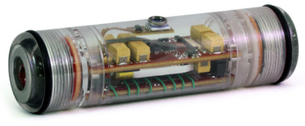
Patent: 14/631,587

SENSOR FISH

PNNL's Sensor Fish—a synthetic smolt-sized stand-in—is another valuable tool in understanding the conditions fish face as they encounter hydroelectric dams or other structures. The Sensor Fish is armed with multiple sensors, each taking more than 2,000 measurements per second. It can be deployed in turbines, spillways, and sluiceways. For example, by characterizing fish passage conditions including shear forces, collisions with structures, acceleration, and pressure, the Sensor Fish can help improve decisions that increase fish survival and lessen injury.

The tube-shaped device measures 11 parameters with multiple sensors that include a three-dimensional rotation velocity sensor, a three-dimensional linear acceleration sensor, a pressure sensor, a temperature sensor, and a three-dimensional orientation sensor. The Sensor Fish also is equipped with a radio frequency (RF) transmitter, a recovery module, and a communication module. Once the Sensor Fish is collected by boat, it is placed in a docking station where its battery is recharged and the data it collected are transferred. The Sensor Fish Communicator software links directly to the Sensor Fish, making it easy for researchers to communicate with the hardware, convert data, and plot the data—all with a single application. It even converts native raw data files into comma-separated variable files that can be used to plot the results.

The Sensor Fish has been tested in Asia, Australia, Europe, and multiple locations in the United States.

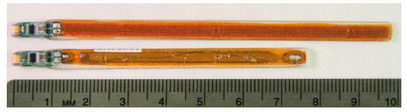


Specification Highlights

- Length: ~89 mm, similar to the size of a salmon, with other models in development to mimic other fish species
- Diameter: ~ 25 mm
- Weight: ~ 43 g

Patent: 14/871,761

SELF-POWERED ACOUSTIC TAG



This tag uses the movement of the fish to power and recharge batteries rather than relying solely on a battery—allowing data to be collected for well over a year instead of only a month or two. A longer monitoring period allows for a more complete view of fish behavior and of the impact of river obstructions for fish with longer migration patterns, such as sturgeon, lamprey, and eels.

There are two designs for the transmitter. In one, the energy is generated and used in real time, so the fish has to be moving for the tag to have enough power to send a signal. In the second design, a battery is recharged with energy from the fish's movement and stored until needed. The self-powered tags were lab-tested with juvenile white sturgeon and rainbow trout. In both species, the tags were implanted in a tiny incision in a quick 75-second process.

Specification Highlights

- Length: Can vary based on power requirements and fish characteristics of specific applications. A 100-mm tag was used for 53-cm rainbow trout and a 77-mm tag was used for 38-cm juvenile white sturgeon.
- Weight, option 1, without a battery: 1.05 and 0.80 g, respectively
- Weight, option 2, with a battery: 1.10 and 0.85 g, respectively

Patent: 15/088,032

INJECTABLE RADIO-FREQUENCY (RF) TAG

This small and powerful RF transmitter with a diameter of just 2.95 mm can be injected into fish using a 9-gauge needle. Two designs: One transmits coded signals and the other transmits uncoded signals. To accommodate different transmitter life requirements, each design can be configured to provide a high- or low-signal strength. They can also be used to study bats, birds, small mammals, and amphibians.

Both designs are about 40 percent smaller than the smallest RF transmitter on the market. The service life of the coded low-signal-strength tag is up to 58 percent longer, while the service life of the coded high-signal-strength tag is comparable to commercially available tags. The uncoded version provides an even longer service life than the coded one, with the low-signal-strength uncoded tag lasting as long as 69 days at a 10-second ping rate interval.

Specification Highlights

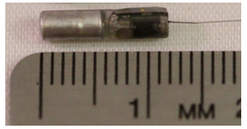
Coded version

- Length: 11.85 mm
- Weight: 160 mg– about 100 mg lighter than commercially available tags, but with a signal strength about 10 dB stronger
- Projected transmitter lifetime:
  - Low-signal-strength transmitter: 11 days at a 2-second ping rate, 27 days at a 5-second ping rate, and 52 days at a 20-second ping rate
  - High-signal-strength transmitter: comparable to commercially available tags

Uncoded version

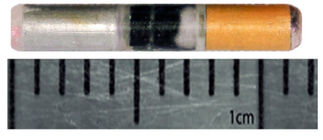
- Length: 11.22 mm
- Weight: 152 mg
- Projected transmitter lifetime:
  - Low-signal-strength uncoded transmitter: 15 days at a ping rate interval (PRI) of 2 seconds, 37 days at a PRI of 5 seconds, and 69 days at a PRI of 10 seconds

Patent: 15/087,936



EEL AND LAMPREY TAG

PNNL's smallest acoustic tag to date, this tiny acoustic transmitter was designed specifically for studying juvenile eel and lamprey. This patent-pending tag has been tested in the lab with both eel and lamprey and will be tested in the field in 2017. PNNL is interested in partnerships with operators or agencies interested in further developing and demonstrating this technology.



Specification Highlights

- Weight: approximately 0.08 grams in air
- Length: 12.0 mm
- Diameter: 2.0 mm
- Transmitter life: Prototype lasts 20 to 30 days at a 5-second ping rate interval