Pacific Northwest
NATIONAL LABORATORY

Animal–Tracking Technologies

LICENSING AND COLLABORATION OPPORTUNITIES

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

Pacific Northwest National Laboratory (PNNL) 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 and wildlife behavior and the hazards they face when encountering dams and other structures.

What we offer. For research with live fish and wildlife, 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:

- Gaining a better understanding of 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; however, 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.

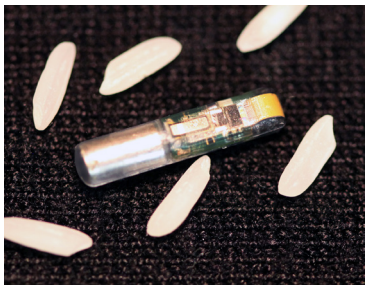
APPLICATIONS

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
- Expansion to applications that include tagging 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 high-energy-density 3-volt battery. It 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. It is now commercially available through Advanced Telemetry Systems.

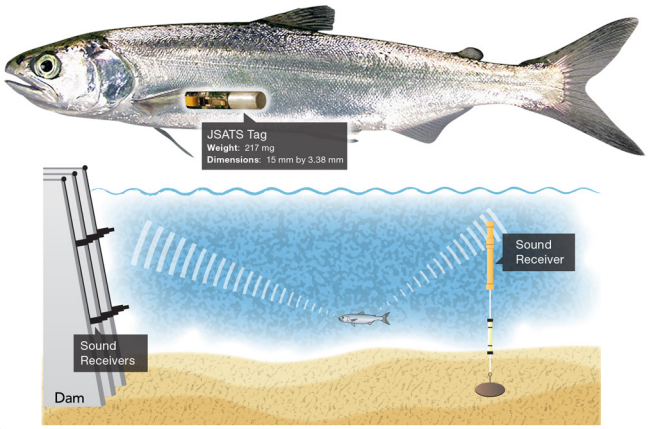


Specification Highlights

- Dry weight: 0.22 g
- Length: 15 mm
- Diameter: 3.38 mm
- Transmitter life: 120 days at 3-second ping rate (PNNL version).

Patents: 10,033,469 and 10,033,470

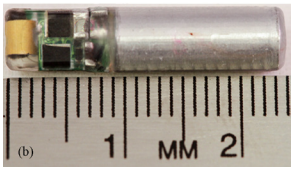
We also demonstrated the feasibility of a low-frequency design at ~200 kHz, which is more suitable for marine applications. It has a source level of 150 dB and a tag life of 140 days at 5-second ping rate. Compared to the smallest low-frequency acoustic tag commercially available, our design is 16 dB higher in source level, significantly lighter in weight, and lasts three times longer.



PNNL's acoustic telemetry tags release beeps, unique to each tagged fish. Receivers placed in rivers, lakes, or other waterbodies receive the signals as the tagged fish swim by, and collect data that help researchers map the precise 3D location of each fish and determine if those fish were injured during their travels.

LONG-LIFE HIGH-POWER 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. It is also applicable for noisy environments and salt water. This 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 , 3D tracking of adult salmon in the immediate tailrace of a large dam, and juvenile sablefish in marine environments.



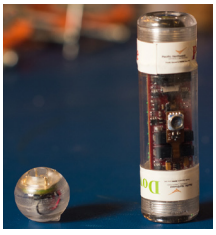
Specification Highlights

- Length: 24.2 mm
- Width: 5.0 mm
- Dry weight: 0.7 g
- Wet weight: 0.2 g
- Source Level: 161 or 163 dB at zero degrees
- Configurable ping rate interval and tag code
- Optional temperature, alternating codes, and hibernation mode
- Transmitter life: 365 days at 161 dB and 15-second ping rate

Patent: 10,101,429

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 reuseable device measures 11 parameters with multiple sensors that include a 3D rotational velocity sensor, a 3D linear acceleration sensor, a pressure sensor, a temperature sensor, and a 3D orientation sensor. It is also equipped with a radio frequency transmitter, a recovery module, and a communication module.

The Sensor Fish has been tested in Asia, Australia, Europe, and multiple locations in the United States. It is commercially available through Advanced Telemetry Systems.

A miniaturized version of the Sensor Fish (Sensor Fish Mini) has also been developed. The Sensor Fish Mini can be used for physical measurements and evaluation of fish passage conditions in in small hydro systems and structures with small clearance. It can also be deployed for physical measurements during scaled turbine testing and to evaluate the machine dynamics of turbines. It has a spherical shape with a diameter of 23 mm and has a mass of ~6.4 g.

Sensor Fish Highlights

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

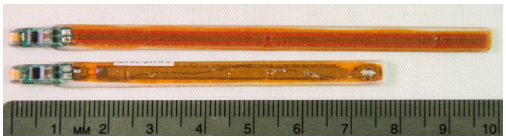
Patent: 10,067,112

Sensor Fish Mini Highlights

- Diameter: 23 mm
- Weight: ~6.4 g

Patent: 16/351,373

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.

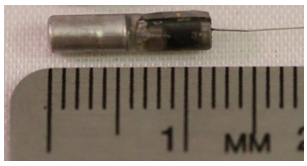
There are two designs for the transmitter. In one, the energy is generated and used in real time, so the fish has to be moving for the tag to have enough power to send a signal. In the second design, a battery is recharged with energy from the fish's movement and stored until needed. The self-powered 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 tag 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 tag 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.

We are optimizing the design of the RF tags with multiple versions tailored to hoary, eastern red, and silver-haired bats, as well as the Myotis species. These state-of-the-art tags will be paired with a 3D tracking algorithm to provide high-resolution behavioral information about flight patterns, which will help answer questions about how bats respond to turbines on a landscape scale.

Specification Highlights

Coded version

- Length: 11.85 mm
- Weight: 0.16 g - about 0.1 g lighter than commercially available tags, but with a signal strength about 10 dB stronger
- Projected transmitter life:
  - 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

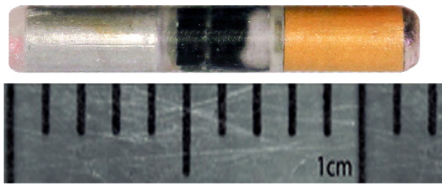
Uncoded version

- Length: 11.22 mm
- Weight: 0.15 g
- Projected transmitter life:
  - Low-signal-strength uncoded transmitter: 15 days at a 2-second ping rate, 37 days at a 5-second ping rate, and 69 days at a 10-second ping rate.

Patent: 10,236,920

EEL AND LAMPREY TAG

PNNL's smallest acoustic tag to date, this tiny patented transmitter was designed specifically for studying juvenile eel and lamprey. It has been tested in the lab and field with both eel and lamprey. The field trials demonstrated the feasibility of using this new tag to study juvenile lamprey and eel passage behavior and survival in various environments including a fast moving large river,immediate forebay and tailrace of a dam, and shallow water. PNNL is interested in partnerships with operators or agencies interested in further developing and demonstrating this technology.

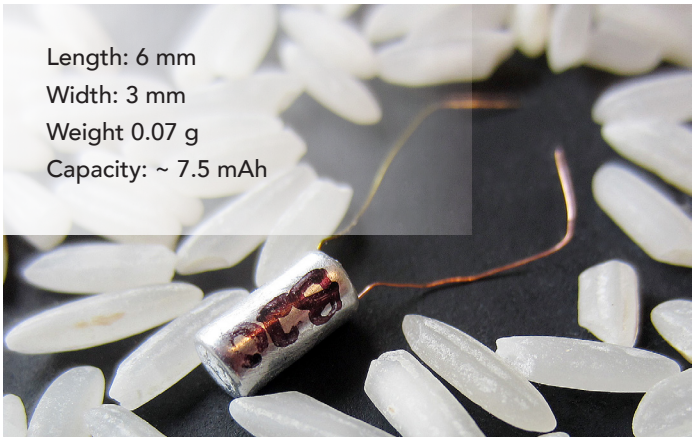


Specification Highlights

- Dry Weight: 0.08 g
- Length: 12.0 mm
- Diameter: 2.0 mm
- Transmitter life: 40 days at 5-second ping rate

Patent: 15/393,617

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.

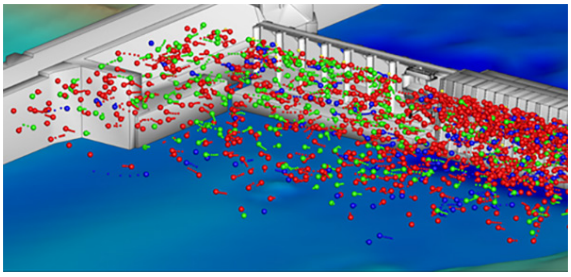
SOFTWARE

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

Pacific Northwest National Laboratory draws on signature capabilities in chemistry, Earth sciences, and data analytics to advance scientific discovery and create solutions to the nation's toughest challenges in energy resiliency and national security. Founded in 1965, PNNL is operated by Battelle for the U.S. Department of Energy's Office of Science. DOE's Office of Science is the single largest supporter of basic research in the physical sciences in the United States and is working to address some of the most pressing challenges of our time. For more information, visit PNNL's News Center. Follow us on Facebook, LinkedIn, and Twitter.

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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