- radio and acoustic tag development and testing
- egg and fry development in response to temperature and dissolved nitrogen gas
- flow quantification and modeling
- new generation hydroturbine design
- hyperbaric chamber testing to simulate turbine passage
- endangered species protection and recovery
- testing and calibration of underwater active and passive acoustic equipment.

Rearing and Experimental Facilities

Shear Tank

ABOUT THE ECOLOGY GROUP

The Ecology Group at PNNL consists of more than 50 aquatic and terrestrial biologists who work on a broad range of projects for federal and industrial clients worldwide. The group develops and deploys science and technology that helps clients accomplish their primary mission while protecting and enhancing ecological resources.

For more information, contact

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ABOUT PNNL

Pacific Northwest National Laboratory is a Department of Energy Office of Science national laboratory where interdisciplinary teams advance science and technology and deliver solutions to America's most intractable problems in energy, the environment and national security. PNNL employs 4,900 staff, has an annual budget of nearly $1.1 billion, and has been managed by Ohio-based Battelle since the lab's inception in 1965.

Pacific Northwest
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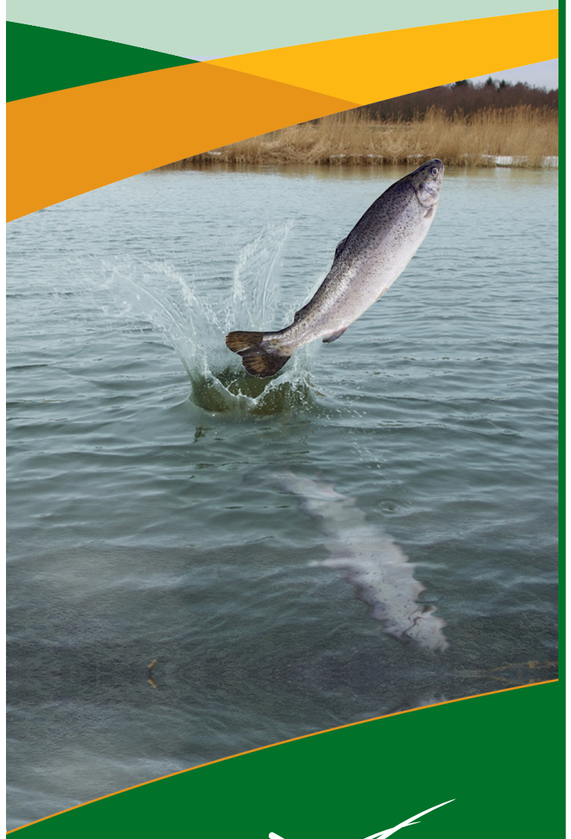
September 2011

PNNL-SA-82549

Science and Technology for Environmentally Sustainable Waterpower and Water Use



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Waterpower is becoming an increasingly important element of our nation's energy supply. In the western United States, hydropower provides 44 percent of the electrical generating capacity. Yet, there are environmental issues that can adversely impact energy availability and cost as well as the sustainability of water use for energy production. Researchers at Pacific Northwest National Laboratory (PNNL) are advancing environmental frontiers in the prediction and management of waterpower system performance, including hydropower. PNNL fisheries scientists are developing and applying the science and technologies that enable optimization of waterpower and environmental benefits in three key areas.

FISH PASSAGE AND SURVIVAL

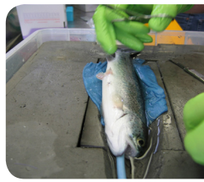
Juvenile Salmon Acoustic Telemetry System (JSATS)

The JSATS employs acoustic transmitters and receiving systems to remotely track tagged fish in one, two, or three dimensions. Acoustic transmitters are small enough for implantation in the smaller migratory individuals of the juvenile Chinook salmon and steelhead populations of the Columbia River basin. Its utility is applicable to a wide range of aquatic species.

JSATS Transmitter

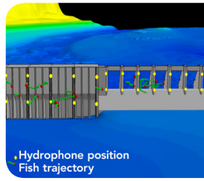
Research benefitting from the JSATS technology includes

- monitoring of behavior, movement, and habitat use, and estimation of survival and travel time of juvenile salmonids migrating through freshwater river, reservoir, estuary, and marine habitat and past hydroelectric dams
- determination of impacts of ferry terminals on juvenile salmonid movements in saltwater
- estimation of route-specific dam passage survival of juvenile salmonids
- observation of predator–prey interactions
- evaluation of fish guidance and passage structures at hydroelectric dams using detailed 3D tracking
- monitoring of delayed mortality of juvenile salmonids transported past hydroelectric dams in barges.



Surgical Implantation of JSATS Transmitter

JSATS Autonomous Receivers



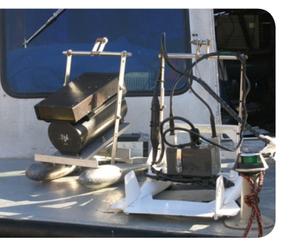
Fixed Array Deployment

Hydroacoustics

PNNL uses fixed-aspect hydroacoustics technologies to evaluate the route-specific passage distribution of fish at hydroelectric facilities. Mobile hydroacoustics systems estimate horizontal and vertical distribution and relative abundance of fish in the reservoirs of the Columbia, Snake, and Willamette river systems.

Studies involving hydroacoustics encompass

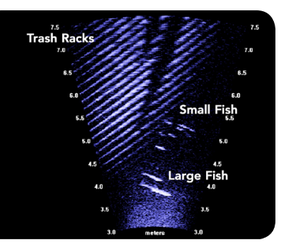
- estimation of route-specific dam passage
- evaluation of fish passage structures at hydroelectric dams
- evaluation of behavioral guidance structures.



Deep Sensor Platforms

Acoustic/Video Imaging

Acoustic imaging is used to record near video-quality images of the underwater environment and fish images in dark and turbid waters. The recorded images are employed to monitor behavior and movement in response to structural changes at dams for fish passage. PNNL scientists and engineers also use video technology to survey and characterize deepwater fall Chinook salmon spawning regions.



Acoustic Camera

Typical studies include

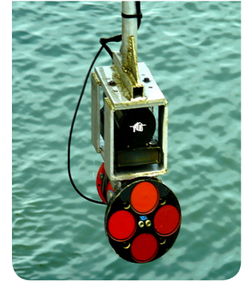
- evaluation of behavior near structures
- characterization of bottom substrate surface features and texture
- determination of bottom composition, habitat associations, coverage areas, and signs of disturbance.

Flow Measurement

ADV Measuring Flow at Fish Screen

PNNL uses acoustic Doppler velocimeters (ADVs) and acoustic Doppler current profilers (ADCPs) to measure water flow at and near structures to evaluate flows and turbulence.

The data collected are analyzed to determine river current velocities in conjunction with fish habitat characterization during acoustic imaging fish passage studies.

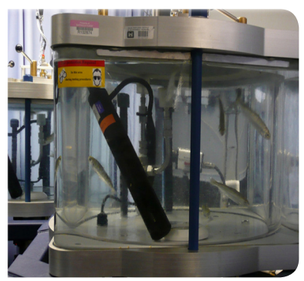


ADCP and DIDSON Acoustic Camera

Fish Bypass System and Turbine Design

Investigations into the injury and mortality of fish exposed to pressure changes associated with dam passage have become more common over the last 15 years. Fish can be damaged when exposed to rapid decreases in pressure while passing through hydroturbines, spillways, or pump storage facilities. Rapid decompression leads to expansion of gas within the fish either as bubbles or in the swim bladder. Decompression can also lead to gas coming out of suspension in the blood or tissues.

To determine how pressure changes influence fish, fisheries researchers at PNNL use hyper/hypobaric chambers. The Mobile Aquatic Barotrauma Laboratory (MABL) simulates how pressure changes impact fish when passing through hydroturbines and bypass systems. The MABL can both increase (hyper) or decrease (hypo) the pressure in the fish and the water surrounding them. Information gathered from this research can lead to safer passage routes for fish, reducing the environmental impact of hydroelectric facilities. Additional applications include evaluating injuries from spillway passage, landing of fish during commercial fishing, and other scenarios involving rapid pressure changes.



PNNL-Developed MABL

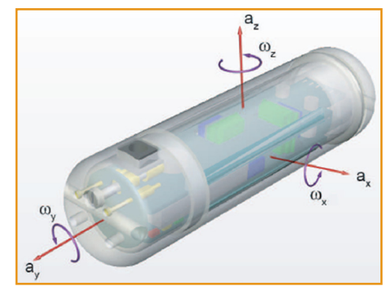
Barotrauma-Induced Eye Injury

Sensor Fish

Juvenile salmon passing through hydroelectric dams are subjected to environmental conditions that can potentially kill or injure them. An autonomous smolt-size sensor package—the Sensor Fish—developed by PNNL fisheries scientists and engineers has been sent through turbines, spillways, and bypass routes at Columbia and Snake river dams and at high-head dams in Oregon and Idaho to collect first-ever data on the conditions that juvenile salmon experience in dam passage.

The data captured enable

- determination of measurable passage conditions – hydraulic, mechanical, or structural stresses
- correlation of passage conditions with specific observed injuries
- identification of the most stressful locations for fish during passage and design of safer turbines and passage routes through hydroelectric dams.



Sensor Fish

RIVERINE PROCESSES

PNNL employs state-of-the-art methods, electronics, sensors, and computer hardware and software in support of operational management, environmental planning, mitigation, and restoration of river systems. Our work spans the life history and behavioral, physiological, and physical habitat requirements for many species, including Pacific lamprey, white sturgeon, steelhead trout, and several species of Pacific salmon.

Typical approaches include development of bathymetry datasets, mapping and analysis of channel morphology, development of hydraulic models and hydrology statistics, and development of spawning habitat models and habitat suitability indices.

Riverine Study Site (Hell's Canyon of the Snake River)

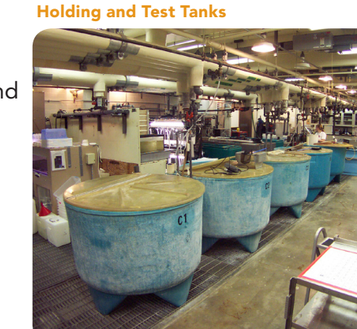
These approaches have been applied in the following research areas:

- modeling of climate change impacts on river systems
- evaluation of habitat suitability and predictive modeling
- evaluation of ground water and surface water interactions (hyporheic zone)
- investigations of integrated fluvial geomorphology and habitat
- characterization of critical aquatic habitat.

AQUATIC RESEARCH LABORATORY (ARL)

The ARL is a one-of-a-kind capability that employs state-of-the-art equipment to expand sustainable hydropower, advance the understanding of how climate change may impact the hydropower system, and integrate environmental protection into hydropower operation. Since the 1970s, ARL projects have developed and used science and technology to monitor and predict the impacts of hydropower development and operation on fish passage issues and, more broadly, to sustainable hydropower.

Research studies conducted with ARL capabilities involve

- fish physiology and energetics in relation to water flow fields and shear/turbulence
- fish behavior in response to physical structure and flow

Holding and Test Tanks