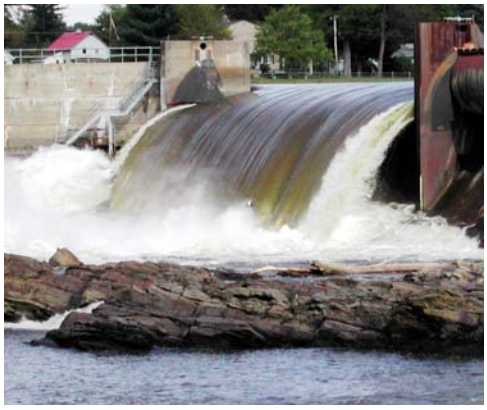
USGS Leetown Science Center

Fish Passage Research: S.O. Conte Anadromous Fish Research Laboratory

The Leetown Science Center's S.O. Conte Anadromous Fish Research Laboratory conducts basic and applied scientific studies of fish passage and migration to define underlying principles and relationships of fish behavior and hydraulics, and to develop integrated, predictive research that can be applied to a wide range of fish passage problems



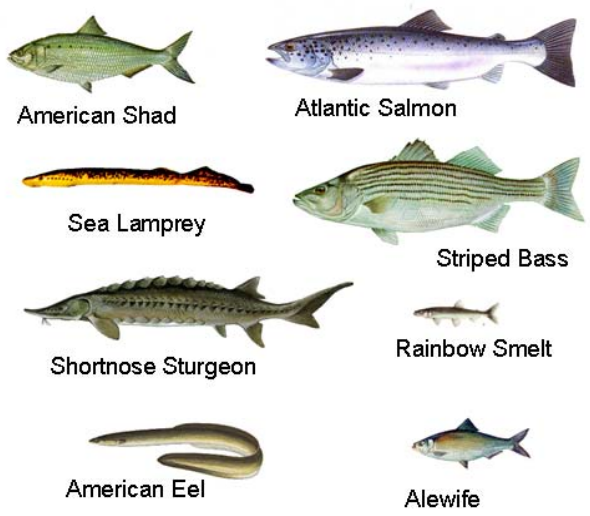
Right: Dams can create serious barriers to fish migrations, and can incur delays, injury, and mortality

Over 75,000 dams are listed in the National Inventory of Dams for the United States. These and other man-made barriers fragment riverine and stream habitats that can impact and limit the persistence of fish populations and lead to local extinctions. Research on fish passage with its associated biological and engineering disciplines is an essential component to the successful restoration of migratory fish populations and their ecosystems. These populations include anadromous (spawning in freshwater), catadromous (spawning at sea) and riverine fish species.

Below: Ice Harbor technical fishway on the Connecticut River, evaluated by CAFRL for passage of Atlantic salmon and American shad

The Leetown Science Center's Silvio O. Conte Anadromous Fish Research Laboratory (CAFRL) was established in 1991 to conduct applied and basic scientific studies on migratory fish populations. The fish passage component of research at the Lab was initially focused on evaluation of fishways ("fish ladders") in a controlled laboratory setting, with an emphasis on engineered structures. CAFRL has expanded this research to include:

- Large-scale, long-term, basic science projects with a strong applied component
- Multidisciplinary and watershed-scale studies
- Technical support to both government agencies and private organizations



Above: some anadromous and catadromous fishes of eastern North America that require fish passage

Research Focus Areas

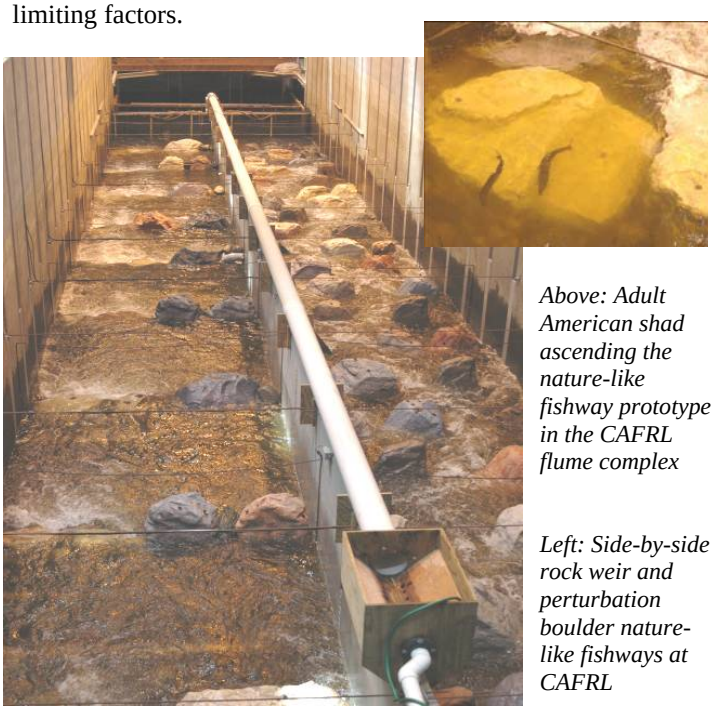
Basic Science Projects With Applied Components

Hydraulic and biological evaluation of conventional and new technical fishways Anadromous fish are important interjurisdictional species targeted for conservation efforts by state and federal agencies along the US Atlantic coast. Previous evaluations have shown that many fishway designs suitable for anadromous salmonids like Atlantic salmon are less suitable for upstream passage of other weaker swimming species such as sea lamprey or sturgeon. CAFRL researchers examine the development and performance of existing fishway designs, and test and evaluate new and innovative upstream passage structures, including low head dam notches and high-slope technical fishways.

For example, many sturgeons are threatened worldwide by dams, but the development of fish passage for these species has been slow. Research on juvenile behavior of North American sturgeons at CAFRL led to the development of a prototype spiral side-baffle fish ladder that passes adult sturgeon as well as a diverse array of other fish species with modest swimming abilities. This design could contribute greatly to worldwide conservation and passage of sturgeons and other migratory fish. Moreover, the small footprint and modular construction of the spiral side-baffle design are great potential cost advantages over other designs.

Left: Adult sturgeon ascending spiral side-baffle fishway at CAFRL

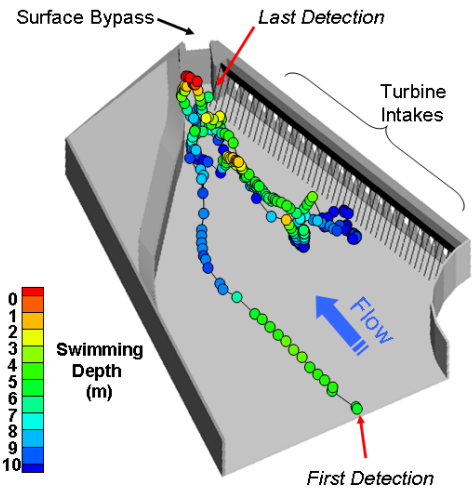
Laboratory and field evaluation of nature-like fishways Current designs of nature-like fishway structures use natural substrates (rocks, boulders), engineered to effectively dissipate flow energy. These designs have wide application and are particularly well suited for low-head dams (<5 m in height) that otherwise are not suitable for removal. Nature-like fishways can be constructed at low head dams or as part of a dam removal to completely eliminate physical or hydraulic passage barriers and restore river continuity. However, only limited assessment of these fishways has been performed to determine both species use and performance (passage efficiency), particularly under controlled conditions. Few data are available on the effects of slope and flow on the hydraulic characteristics of natural fishways or the relative suitability of these designs for migrant fishes, particularly riverine resident species found throughout much of the US. Data generated from this project allows agencies to provide defensible nature-like fishway designs and gives construction and operation guidance to dam owners. Research may also lead to potential increases in usable design slopes resulting in significant reductions in overall length of natural fishways where space and/or construction costs are limiting factors.



Above: Adult American shad ascending the nature-like fishway prototype in the CAFRL flume complex

Left: Side-by-side rock weir and perturbation boulder nature-like fishways at CAFRL

Investigation of migratory behaviors and passage technologies for freshwater eels Due to coastwide declines of eel recruitment in recent years, concern has been raised about the impacts of hydroelectric projects and other barriers on migrating juvenile and adult eels in both the US and Canada. Conte scientists evaluate existing upstream eel pass structures and develop new low-cost prototype structures for juvenile eels at large and small dams. The project also involves evaluation and development of downstream passage technologies for adult silver-phase eels, to assess how eels utilize existing and new guidance and bypass structures in hydroelectric forebay environments. These studies employ advanced radio and acoustic telemetry to quantify and evaluate complex migratory and passage behaviors of migrating adult eels.



Right: Track of an adult downstream migrant eel in a hydroelectric forebay as determined by 3-D acoustic telemetry in a CAFRL study

Evaluation of hydraulics on behavior and swimming performance of upstream migrant fishes Resource agencies and the hydroelectric power generation community are actively looking for predictive methods to reduce the adverse effects that dams, hydroelectric generation projects, and associated fish passage structures have on migratory fishes. Hydraulic factors such as flow, water velocity, and turbulence influence the behavior and swimming performance of upstream migrant fishes. Other factors such as shear stress, turbulence, cavitation, and pressure fluctuation can also damage fish that pass through turbines, over spillways, bypass structures, and under spill gates and other structures. Understanding the effect these factors have on fish swimming performance, injury, and survival is essential, and important in establishing engineering and biological design criteria that will assist in predicting and minimizing their effects and impacts on migratory fishes.

Bypass systems to protect downstream migrant sturgeons at dams Protection of bottom-migrating fishes like sturgeons from turbine entrainment is of growing concern to fisheries agencies worldwide. Conte scientists are conducting research to develop a bypass system for these fishes using North American sturgeons as the model. Tests with different bar-rack structures and water flow configurations are conducted in the CAFRL flume to understand fish behavior in relation to the near-field environment. Fish behavior, guidance, and passage success are monitored to identify the best configuration of bar-rack design, orientation, and flow relationships.

Left: Installation of experimental angled bar rack and deep bypass entrance in CAFRL flume facility. Underwater video cameras and telemetry antennas record behaviors of fish near the rack

Technical Transfer and Support at CAFRL

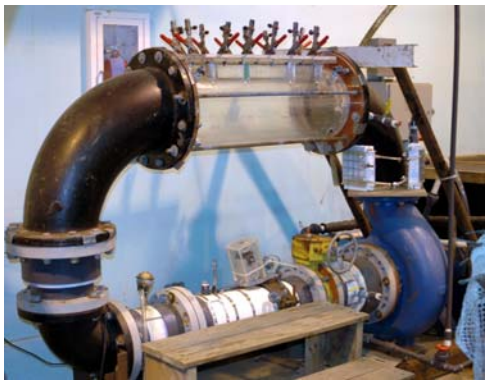
Conte staff have provide considerable technical transfer assistance to managers and other researchers, particularly in the following areas:

- Telemetry technology, including use and data analysis of passive integrated transponder (PIT) tag antenna technology for assessing passage at stream and river barriers
- Quantitative evaluation of performance of fishways and other passage structures, in lab and field
- Advanced statistical analysis of passage and migration data
- Applied hydraulics and bioengineered structures
- Hydraulic instrumentation and measurement

Watershed-Scale Studies

Behavior and migration by early life stages of North American sturgeons Information on innate downstream migrations (timing, duration, distance, etc.) of sturgeon early life stages is critical for agencies to protect and manage populations that spawn upstream of dams. Conte scientists and colleagues in China and Romania are conducting studies in artificial streams that focus on understanding migrations by young sturgeons worldwide.

Effects of dams and fish ladders on survival, stress and development of anadromous fish To complete their life cycle, anadromous fish like Atlantic salmon must make the arduous journey upriver for spawning. This upstream migration against river flow is inherently difficult and energetically costly, and can be made more challenging when fish are faced with fish ladders, fish lifts and other alterations in the normal flow regime. Using a combination of behavioral and physiological monitoring, Conte scientists have developed methods to assess the effect of fish ladders on energetics, stress, and reproductive preparedness of migrating adults. This approach can be used to determine the ultimate reproductive and population impacts of dams, fish ladders and climate change on anadromous fishes.



Right: 50 hp flow respirometer used in fish passage swimming energetics studies

Downstream migration of juvenile Atlantic salmon Atlantic salmon were extirpated from southern New England in the 1800's, and remaining populations in Maine were listed as endangered in 2000. Restoration efforts include stocking of Atlantic salmon as fry (when they would normally emerge from gravel) and as downstream migrating smolts. Knowledge of the timing of downstream migration of fry-stocked and smolt-stocked fish, and an understanding of the factors that limit their survival during downstream migration is critical to current restoration efforts. Conte scientists have used telemetry (passive integrated transponders and acoustic tags) to monitor behavior, and physiological assessments to monitor the fishes capacity to enter seawater. Important interactions among the effects of dams, flow and temperature on downstream migration and survival of emigrating juvenile salmon have been identified from this research.

Evaluation of fragmentation effects on stream networks Road crossings over upland streams have created thousands of culverts, bridges and small dams in many watersheds, and have the potential to result in significant habitat fragmentation. This project uses a combination of long-term focused study sites, culvert evaluations, and genetic information to quantify the effects of habitat fragmentation on stream networks. Results indicate that stream fragmentation can have significant effects on population persistence of stream fish and that even very small first- and second-order streams make important contributions to population persistence. Applications of genetic tools will also be used to monitor the outcome of restoring fish passage and reconnected fragmented populations

Above: culverts block fish migration and fragment thousands of kilometers of stream habitat

Watershed-scale assessment of Atlantic salmon smolt production Millions of Atlantic salmon fry are stocked into tributaries of the northeastern US each year in an effort to restore salmon populations, but it is not known to what extent different tributaries contribute to smolt and adult return production. In collaboration with hatchery managers, this project is using genetic information from the hatchery broodstock to determine stocking location (tributary) of outmigrating smolts and returning adults in the Connecticut River. Results will indicate the relative fish production of tributaries and will help identify how various controlling factors (e.g. stream flow, temperature regimes, and dams) influence production.

Effects of Contaminants Relative to Dam Removal and Dredging CAFRL's Maine Field Office (MFO) conducts evaluations of the release of organic and metal contaminants during sediment resuspension events as might accompany fish passage-related dam removals, and river-bed/harbor dredging. The effects of these contaminants on fish embryo and larval survival, immune function and behavior can be significant, and MFO is developing non-lethal biomarkers for the detection of contaminant exposure in both migratory (e.g. Atlantic salmon) and resident fish species. MFO currently conducts identification and monitoring of contaminants in resident fish species in the Penobscot River (Maine) to evaluate contaminant redistribution in the river, both upstream and downstream, before and following the removal of two head-of-tide dams.

Right: Trap sampling of pre-dam removal fishes from the Penobscot

CAFRL Fish Passage Research Capabilities:

Hydraulics/Engineering

- 38 m long open channel flume facility with 5 m working depth; two 3 m width, one 6 m width; maximum 10 m^3/sec (350 cfs) flow
- 120 m^2 (1300 ft^2) hydraulic lab with 0.3 m^3/sec (10 cfs) maximum flow
- 1-, 2-, and 3-D velocity measurement instrumentation, including acoustic Doppler and laser particle image velocimetry
- Flow, pressure and level instrumentation
- Analog and digital real-time data acquisition
- Extensive model fabrication and instrumentation
- Hydraulic and civil engineering expertise

Fish Passage Evaluation

- Advanced telemetry instrumentation (radio, acoustic, PIT; 3-D acoustic telemetry)
- High speed (1000 frames/sec), low-light, and infrared video

Behavior

- Data logging and mobile (boat) tracking telemetry
- Advanced hydroacoustic survey equipment
- Controlled laboratory tanks for behavioral studies

Physiology

- Large swimming respirometer capable of determining maximum fish swim speed and migration energetics
- Enzyme- and radioimmunoassay for the determination of growth, reproduction, osmoregulation, and stress-response hormones
- Protein biochemistry and fluorescent immunocytochemistry for establishing capability of fish to move between fresh water and seawater

Ecology

- Field studies focused on individually-identifiable fish
- Analysis and interpretation of ecological data
- Mathematical modeling of population dynamics
- Capture-mark-recapture modeling

Genetics

- DNA extraction, purification, fragment analysis and sequencing
- Polymerase chain reaction (PCR) analysis
- Data analysis, interpretation, and software development

Contaminants

- Measurement of regulation and induction of contaminant-sensitive biomarker genes (e.g. cytochrome P4501A) using enzymatic and molecular techniques.
- Organic contaminant analysis (pesticides, polychlorinated biphenyls, polynuclear aromatic hydrocarbons) in water, sediment and tissue samples.
- Assessment of immune function in fish using pathogen challenge experiments

For more information, visit the CAFRL website:

http://www.lsc.usgs.gov/CAFLindex.asp

Or contact:

Steve Garabedian, Branch Chief
S. O. Conte Anadromous Fish Research Laboratory
U. S. Geological Survey, Biological Resources Discipline
1 Migratory Way, P.O. Box 796
Turners Falls, MA 01376
voice: (413) 863-8300
fax: (413) 863-9810
email: sgarabedian@usgs.gov

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