Cultured Atlantic Salmon in Maine

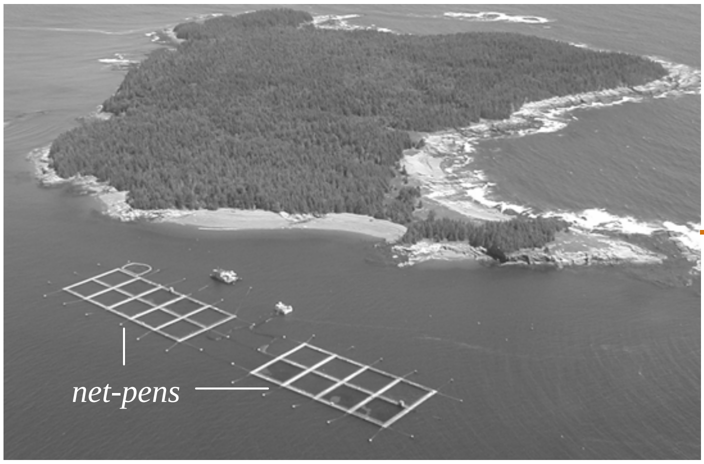
The term aquaculture refers broadly to the human-driven production of aquatic organisms: fish, mollusks (shellfish), crustaceans (such as shrimp) and plants. Aquaculture usually entails some sort of intervention in the organism's rearing to enhance production, such as regular feeding and protection from predators. In Maine, the culture of Atlantic salmon serves two distinctly different purposes: enhancement of wild populations and commercial food production.

Conservation Hatchery Program. In response to depleted runs of wild adults returning to spawn, the State of Maine and the U.S. Fish and Wildlife Service (USFWS) initiated a *river-specific* stocking program (releasing the offspring of individuals collected from a specific river back into that river). Creating *broodstock* (the adults from which gametes are obtained for production) for the Gulf of Maine distinct population segment (GOM DPS) initially focused on returning adults. However, due to low return rates, parr were collected instead and raised as broodstock.

The focus of the conservation hatchery program has been to produce fry, parr and smolts for river-specific stocking with two goals in mind: increasing the size of wild and captive river-specific populations and buffering against extirpation of this unique segment of the species *Salmo salar*.

As part of Maine's Atlantic salmon conservation hatchery program, fry (to right) and smolts are reared at Green Lake National Fish Hatchery in circular tanks.

Commercial Aquaculture Industry. While the conservation hatchery program focuses on juvenile production, the commercial aquaculture industry rears fish through adulthood.



Instead of directly stocking juveniles into the wild, commercially reared juveniles are moved from inland commercial hatcheries into marine net-pens along Maine's coast at the time of *smoltification* (the process whereby smolts become physiologically tolerant of saltwater). There they spend roughly 18 months before they are harvested as adults, processed and shipped to market. This is a form of farming that produces food for human consumption.

Maine's salmon farming industry has been operating since the 1980s and has grown rapidly over the last two decades, producing an estimated 20 metric tons in 1984 to a high of more than 16,400 metric tons (>36 million pounds) of harvested salmon in 2000.

Although commercial aquaculture provides an important source of locally grown protein and economic benefits, it also poses risks to Maine's endangered populations of wild Atlantic salmon. The potential for both ecological and genetic interactions between wild Atlantic salmon and aquaculture escapees is a risk that NEST managers try to manage in order to allow for the co-existence and sustainability of the commercial aquaculture industry and wild populations.

In Maine, cases of chronic and large escapements of Atlantic salmon from commercial aquaculture sites have been documented. Fish can escape during the freshwater rearing phase from inland commercial hatcheries and also during the marine "grow-out" phase from net pens along Maine's coast. Currently, there is one industry hatchery and a large number of marine sites located in close proximity to rivers with remnant populations of wild salmon. Although some rivers have trapping facilities in which farmed Atlantic salmon can be excluded from passing, the potential for interactions between farmed escapees and remnant Atlantic salmon populations has been identified as posing a significant threat to the species.

Aquaculture Escapees

Genetic Interactions. Genetic studies demonstrate that there are significant differences between North American and European-origin Atlantic salmon. Unlike that of the conservation hatchery program, the genetic makeup of commercial aquaculture broodstock historically included fish of both North American *and* European origin.

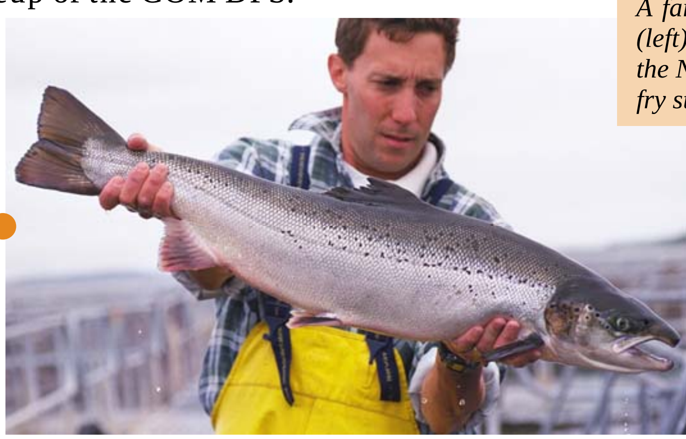
Commercial aquaculture escapees returning to Maine rivers can include reproductively mature fish. Thus, there exists a possibility that escapees will interbreed with endangered individuals. Interbreeding can lead to disruption of local adaptations and dilution of unique genes.

Although natural selection may be able to purge wild populations of maladaptive genetic traits, regularly occurring interaction between farmed and wild salmon makes this less likely. This loss of fitness is termed *outbreeding depression* and is more likely to occur when breeding is between genetically different populations.

Relatively small populations, like the GOM DPS, are particularly vulnerable to the negative consequences that may result from such genetic interactions. Even at low numbers, escapees could represent a substantial portion of the total salmon population residing in or returning to some rivers. In the extreme, genetic interactions have the potential to irreversibly alter the genetic makeup of the GOM DPS.

Ecological Interactions. Ecological interactions between aquaculture escapees and wild salmon can take many forms:

- **Habitat Disturbance.** Escapees typically reproduce later in the year and can limit the success of wild spawners through *redd superimposition* (the "digging" up existing redds to create new ones).
- **Competition.** Because of domestication, farmed salmon are inherently less adapted to a natural environment than their wild counterparts. However, they may have competitive advantages at certain life stages. Studies suggest that escapees and their progeny can out-compete wild salmon under certain conditions.
- **Disease.** Although many disease-causing pathogens can infect Atlantic salmon in the wild, intensive (especially high density) fish culture increases the risk of infections from parasites (e.g. sea lice) and lethal diseases such as Infectious Salmon Anemia (ISA). Wild Atlantic salmon smolts and adults may be exposed to pathogens when passing in close proximity to infected marine aquaculture sites. Recent outbreaks of ISA in the aquaculture industry pose a problem for farmers and fish managers alike.
- **Predation.** Marine net-pens may aggregate predators and increase the risk of predation for outmigrating postsmolts and returning adults passing in proximity of these sites.



A farmed aquaculture adult at a marine net-pen site off Maine's coast (left) and a post-spawn Atlantic salmon caught in a rotary screw trap on the Narraguagus River (right). Aquaculture fish tend to be stockier than fry stocked or naturally reared individuals.

Minimizing Potential Threats

1 An important aspect of minimizing the negative impacts of aquaculture escapees inhabiting or migrating into rivers where remnant populations of wild salmon exist is being able to identify which individuals are of aquaculture origin.

Two general identifying characteristics are fin deformities (typical of hatchery rearing) and body shape/size. Comparing growth patterns of annuli present on a fish's scales (much like the rings of a tree) from hatchery and naturally reared specimens to those of potential aquaculture escapees using computer software also provides insight into origin determination.

Novel techniques used to identify the origin of farmed fish are being developed through collaborative efforts between federal agencies , research scientists, geneticists and the Maine aquaculture industry. One technique, *genetic marking*, centers on identifying unique genetic markers which can be used to accurately assign individual fish to their parents utilizing genetic analysis software. Another technique identifies the unique isotopic signature found in the bone-like structures within a fish's inner ear.

When combined, these new techniques strengthen our ability to verify the origin of individuals of potential aquaculture origin.

2 Recent permitting requirements, court rulings, and consent decrees prevent the commercial rearing of non-North American genetic strains of Atlantic salmon in Maine. In consultation with the federal resource agencies, state and federal permits require that only Atlantic salmon of known North American origin are reared inland and at sea to reduce adverse cross-breeding effects in case of escapes. NEST is working in cooperation with state and federal personnel to conduct audits of commercial hatcheries and marine sites to assess compliance with these new restrictions.

3 Escaped fish from aquaculture facilities located on or near rivers that support remnant wild Atlantic salmon populations pose a significant threat to those populations. The development of Containment Management System plans seeks to eliminate these escapes. In cooperation with environmental groups, federal and state regulators and resource agencies, Maine fish farmers developed plans to reduce escapes from commercial hatcheries and marine net pens. NEST is working cooperatively to conduct external audits to verify compliance with containment at both hatchery and marine net-pen aquaculture sites.

Finding Identity in One's Inner Ear?

Like humans, bony fishes have earbones (referred to as "otoliths" or "earstones") that they use to help maintain their sense of balance. These small, bone-like structures are located beneath a fish's brain inside the inner ear canals. Similar to the rings of a tree, otoliths have rings by which fish biologists can determine a fish's age and/or growth rate. NEST is currently exploring the potential utility of otoliths in identifying the origin (hatchery or naturally reared) of Atlantic salmon found in Maine rivers.

Otoliths are particularly unique in that they reflect the unique water conditions under which a fish developed. An otolith's stable oxygen isotopic ratios can provide rich information about habitat alteration, water temperature, migration, and environmental conditions that individual fish encounter. Stable carbon isotopic ratios reflect changes in sexual maturation and dietary shifts.

NEST's aquaculture liaison, David Bean, surgically removes an otolith from an Atlantic salmon smolt.

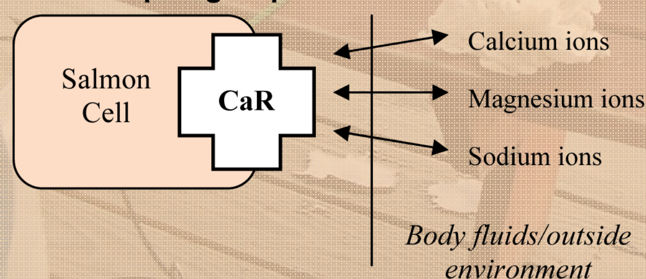
Although commercial aquaculture issues remain, the Maine salmon farming industry has adopted and implemented many of the protective measures recommended by federal resource agencies to minimize potential threats to the GOM DPS. NEST's involvement has thus shifted to oversight and monitoring and more resources are now available for experimental projects associated with the conservation hatchery program. Current projects involve evaluating alternative rearing and stocking strategies and experimental techniques to enhance the efforts of the conservation hatchery's role in supporting endangered populations of Atlantic salmon.

Rearing

NEST funded a collaborative study with a local private research company (MariCal) at USFWS's Green Lake National Fish Hatchery (GLNFH) to assess the potential utility of preconditioning smolts for entry into saltwater before stocking in the wild. This research draws on technology developed to increase survival of smolts placed directly into marine net-pens.

Used by the commercial aquaculture industry and now conservation hatchery programs for both Atlantic and Pacific salmon species, Mari-Cal's SeaReady™ process preconditions smolts for seawater entry and aims to decrease the physiological stress associated with this transition.

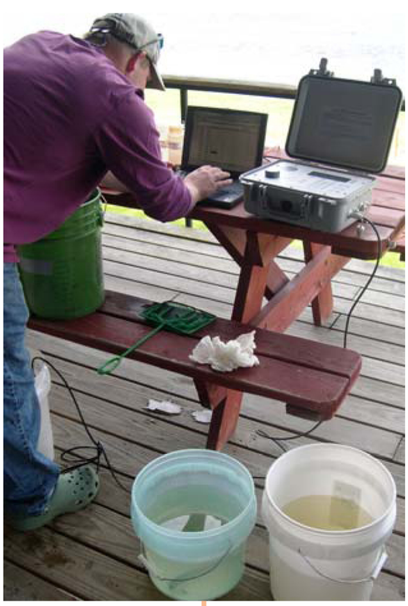
The SeaReady™ process centers on osmoregulation (the control of the water and electrolyte balance in the body) and specialized calcium ion receptor proteins (CaRs) that coordinate the body's various responses to ions and nutrients both inside and outside the body. Added to hatchery feed and water for several weeks during the early stage of pre-adult salmon growth, a combination of minerals present in seawater and common amino acids stimulate CaRs to activate the natural process of smoltification before stocking. It is believed that smolts that undergo this preconditioning will perform better than their counterparts in the wild, as the stress of smoltification can make smolts more vulnerable to predation and other environmental factors. Studies will conclude in 2007 with the final two sea winter returns of pair groups.



Preliminary results from show that SeaReady™ treated fish exhibit enhanced hypo-osmoregulatory ability compared to smolts not undergoing treatment. Based on the number of adults returning to spawn after one winter at sea, these data support the hypothesis that the SeaReady™ process has the potential to enhance returns of Atlantic salmon stocked in Maine rivers under the conservation hatchery program.

Stocking

As an assessment tool, telemetry enables NEST researchers to quantify the affects of different mitigation techniques employed towards Atlantic salmon restoration, including novel rearing techniques (e.g. SeaReady™) and stocking strategies (e.g. stocking timing and location). Through its ongoing telemetry projects, NEST can not only identify smolt emigration run timing and duration, but also quantify migration success and identify where mortalities occur.



Hatchery reared smolts from GLNFH recover from tagging in buckets as NEST contractor Ed Hastings tests ultrasonic "pingers". Telemetry enables NEST to track the migration of tagged individuals and assess different stocking strategies.

The Northeast Salmon Team (NEST) operates within the Northeast Region of NOAA Fisheries Service to promote the recovery and future sustainability of Atlantic salmon.

We are composed of fisheries managers and scientists jointly based out of the Orono, Maine Field Station; scientists based out of the Woods Hole, Massachusetts Northeast Fisheries Science Center (NEFSC) and Narragansett, Rhode Island Laboratory; and managers based out of the Gloucester, Massachussets Northeast Regional Office (NERO).

Please visit our website at **http://www.nefsc.noaa.gov/salmon/**