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Aquaculture Collaborative Research and Development Program (ACRDP) Fact Sheet

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Saltwater Rearing of Endangered Inner Bay of Fundy Atlantic Salmon Smolt: *A Comparison with Standard Freshwater Techniques*

Summary

As part of the inner Bay of Fundy (iBoF) conservation efforts for wild Atlantic Salmon, this Aquaculture Collaborative Research and Development Program (ACRDP) project explored a novel, naturalized saltwater rearing technique to determine the effect of saltwater rearing on adult return rates and offspring viability. Wild iBoF salmon smolts were collected and reared to adults in either marine net pens (pens set up in the natural environment at a salmon farm) or a land-based freshwater hatchery. A sub-sample of adult salmon were retained for spawning experiments to determine the effect of rearing technique on offspring viability. In 2011, 43 of the adult salmon released into the Bay of Fundy were observed to return to the freshwater environment. The majority of these fish were net pen-reared individuals. In 2012, similar returning numbers were observed with the majority of the sampled returns also being from the net pen-reared group released to sea in 2011. Taking into account all known releases of salmon, the net pen-reared fish returned approximately 2:1 compared to hatchery-reared fish. The five-month survival rates of offspring were 62% from net pen-reared parents and 48% from hatchery parents, suggesting that a more naturalized rearing environment may also improve offspring survival. Results from this project have elicited widespread interest from other conservation groups and the aquaculture industry in continuing to test this theory and replicate these successes for salmon conservation elsewhere in Atlantic Canada.

Corey Clarke with tagged returning Atlantic Salmon (Photo: Parks Canada)

The Aquaculture Collaborative Research and Development Program (ACRDP) is a Fisheries and Oceans Canada (DFO) initiative to increase the level of collaborative research and development activity between the aquaculture industry and DFO. Projects under ACRDP seek to improve aquaculture environmental performance and support optimal fish health.

Introduction

As a result of severe declines in the return of spawning adults, inner Bay of Fundy (iBoF) Atlantic Salmon stocks were listed in 2003 as endangered under the federal *Species at Risk Act* (SARA). In the iBoF, 32 rivers have been designated as salmon habitat, two of which (the Upper Salmon and Point Wolfe rivers) occur on federally protected lands within Fundy National Park. As part of the Recovery Strategy for this stock, Parks Canada has partnered with Fisheries and Oceans Canada to establish a Live Gene Bank (LGB) program to preserve and protect what remains of the genetic diversity of iBoF salmon stocks.

A LGB program aims to maintain representatives of all remaining families in stocks with low population numbers while efforts are made to rebuild the stocks. Under this program, fish are captured during their seaward migration, genetically identified, reared to maturity in captivity and spawned using crosses to maximize genetic diversity. The resulting offspring are released back into the wild (the "in-river" LGB) or held and reared in captivity (the "captive" LGB).

With any captive rearing program, there are concerns with individual fitness and domestication effects. Although the iBoF LGB program has been very successful at achieving its goals of maintaining genetic diversity, adult returns from the sea remain critically low and are cited as the factor most limiting population recovery. Program managers are concerned that the freshwater environmental conditions under which the LGB fish are held and raised to maturity, being quite different from what the fish would otherwise be experiencing in the marine environment, might be contributing to a reduced natural fitness in the stock.

A growing body of literature suggests that significant reductions in captive rearing-induced domestication effects can be achieved by naturalizing the captive environment to the appropriate life stage. It was therefore hypothesized that rearing the LGB salmon in outdoor marine net pens from the smolt to maturity stages would result in increased survival and spawning success when compared to indoor freshwater rearing. This Aquaculture Collaborative Research and Development Program (ACRDP) project aimed to test this hypothesis by determining the effect of the post-smolt rearing environment on iBoF LGB salmon's ability to migrate from the marine environment into rivers and produce offspring.

Methods

Marine rearing

In 2009, a sample of smolts migrating from the Upper Salmon River in Fundy National Park was collected. Seven hundred of these smolt were transported to two net pen sites operated by Admiral Fish Farms and Cooke Aquaculture. Smolts were monitored regularly to record growth, general health and development; mortalities were removed and recorded on a weekly basis. The fish that were held in net pens were impacted by high sea lice (*Lepeophtheirus salmonis*) loads resulting in a total loss of this portion of the sample. In 2010, the study was repeated using a specialized pen design more appropriate for rearing and monitoring the relatively small numbers of wild fish required by this project. Approximately 1600 fish from the Upper Salmon River smolt collections were stocked into four of the modified net pens (Figure 1) where they were raised to maturity.

Figure 1. Four small pens and nets customized to fit within a standard commercial 70 m polar marine net pen, used to rear small groups of wild salmon to adults (Photo: Corey Clarke)

Freshwater rearing

Samples of fish from the 2009 and 2010 year classes were taken to the Fisheries and Oceans Canada (DFO) hatchery in Mactaquac, New Brunswick. A total of 300 smolt were reared to adults in fresh water tanks within the Mactaquac hatchery facility.

Ability to return from the marine environment

In early fall 2011, 344 adult fish from the net pen-reared group and approximately 150 adult fish from the hatchery-reared group were released at sea into the Bay of Fundy. All released fish were individually identifiable through passive integrated transponder (PIT) tags that were implanted during the smolt stage. Additionally, prior to release, all fish were tagged externally (Figure 2) for rapid visual identification; and select fish were tagged with acoustic transmitters for which receivers were placed near the mouth of several iBoF rivers. Acoustic transmitter receivers were monitored regularly to detect differences in homing and stray rates between net pen- and hatchery-reared fish, as well as to detect the onset of fish returning to the rivers. Once returning fish were detected, dive surveys (Figure 3) were initiated in the rivers to continue monitoring return rates via external tags. Monitoring of returns was conducted in the fall of 2011 and 2012.

Figure 2. Adult salmon equipped with external tag (Photo: Parks Canada)

Offspring survival

Sub-samples of adults reared in the net pen and hatchery environments were retained to determine the effect of the different culture techniques on offspring survival rates. In the autumn of 2011, offspring were produced in the hatchery using crosses of mature pairs from both rearing environments. The resulting offspring were monitored for five months to identify any differences in survival rates. After five months, the surviving offspring were released into the Upper Salmon River.

Results / Discussion

Ability to return from the marine environment

Following the release of the adult fish to sea in 2011, 43 tagged salmon were observed by dive surveys to return to the freshwater environment (Table 1). Of these individuals, 39 were identified from their PIT tags as net pen-reared fish; 4 were hatchery-reared fish.

Table 1. Summary of LGB project fish releases and returns during fall 2011.

Released at Sea			Returns to Freshwater		
Sea pen reared	Hatchery reared	Total Releases	Sea pen reared	Hatchery reared	Total Returns
344	150	494	39 (90.7%)	4 (9.3%)	43 (100%)

The majority of the observed returns (30 individuals; 27 net pen and 3 hatchery) were found in the Point Wolfe River, the closest river to the marine release site.

These results demonstrate that captive-reared fish do maintain some instinct to return to the freshwater environment following their release at sea. Net pen-rearing techniques might have some influence on return success, possibly reflecting an improvement in the fitness of the fish. However, the majority of captive-reared salmon (both net pen- and hatchery-reared) that were observed to return to freshwater, entered the freshwater river closest to the site of marine release rather than returning to their river of origin.

Figure 3. Two divers survey a river for returning salmon (Photo: Parks Canada)

It is important to note in the context of this study that these "returning" fish travelled from the marine release site into the rivers after spending only a limited amount of time at sea. In contrast, wild Atlantic Salmon typically spend many months in the marine environment before returning to their native rivers to spawn. Although the returns observed in this project cannot be considered analogous to those where smolts leave and return after a full ocean migration, the results suggest that increasing returns might be possible if the smolts are raised in marine net pens.

Additional observations

In 2012, 52 returning adult salmon were observed through dive surveys in the Upper Salmon and Pointe Wolfe Rivers. Of these, 30 fish were sampled for identification and it was found that 29 originated from the 2011 release as part of this project, and the majority of these were net pen-reared. Accounting for all known releases of adult

salmon to Fundy National Park rivers in 2011 (including adults released in addition to the project fish as described above), it is estimated that the net pen-reared fish returned approximately 2:1 compared to returns of hatchery-reared fish. In Fundy National Park, these return rates represent the highest of those observed in over 20 years, despite a decade of extensive recovery efforts, suggesting that rearing juvenile salmon in naturalized environments might improve their fitness and better equip them to migrate from sea to river.

Offspring survival

Forty-three families of eggs were produced using 20 mating pairs of hatchery-reared fish and 23 pairs of net pen-reared fish, all collected as smolts from the Upper Salmon River. The average survival to the eyed-egg stage of offspring produced from net pen-reared parents was 62% while survival was 48% for offspring produced from hatchery parents.

Data analysis is still ongoing, however, it is suggested that the parent's rearing environment may also influence subsequent offspring survival. Naturalized exposure, such as net pen-rearing, could increase both the ability of salmon to return, and the survival of their offspring if spawning were to occur in the wild (compounding effects).

Future research

The specialized net pen infrastructure that was designed for this study is believed to have contributed to the successful rearing of a small number of fish in the marine environment by better protecting the fish from the elements and predators and allowing closer observation of the health and performance of the fish. Further research into improving these rearing conditions and increasing survival would be beneficial. These conditions may include: net cleaning, fish handling, stocking and removal methods, and feeding including further naturalization through the incorporation of more natural feeding regimes.

Additionally, future research should continue to evaluate the marine survival and return rates of offspring from adult salmon that are net pen-reared and released at sea to return to home rivers. In further analyses of this saltwater rearing technique, it is also suggested that consideration be given to the potential risks associated with raising fish at commercial marine aquaculture sites such as an increased density of pathogens, and potential for disease transfer.

Work is currently underway by other groups to replicate these results using the methods developed in this project. Determining the repeatability of this project and the high return rates by net pen-reared fish will be crucial in evaluating the potential of applying saltwater rearing techniques to the recovery efforts for other wild salmon populations.

Conclusions

This research has fostered a successful partnership among the salmon farming industry, Fisheries and Oceans Canada, and Parks Canada to achieve significant results for the conservation of, and research on, endangered wild salmon populations. This collaboration is now poised to expand to include other conservation groups who are interested in similar activities.

A relatively small number of adult wild salmon are required to sustain endangered populations from inner Bay of Fundy rivers. Considering the immense capacity of the industry to produce adult salmon relative to the minimum conservation requirement, incredible potential exists for industry / conservation collaborative efforts. These collaborations could have significant benefits to endangered populations of wild Atlantic Salmon.

This ACRDP project (MG-09-02-002) was a collaborative effort between Fisheries and Oceans Canada (DFO), the Atlantic Canada Fish Farmers Association (ACFFA) and Parks Canada. The research was conducted by Corey Clarke (graduate student) from Memorial University of Newfoundland. The DFO contact for the project, Dr. Patrick O'Reilly, can be contacted at **Patrick.OReilly@dfo-mpo.gc.ca**.

For further information on this and other ACRDP projects, visit: **http://www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm**

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