Identifying the problem

Facts, Observations and Evidence

The Atlantic salmon is an anadromous fish species, spending most of its adult life in the ocean coming back to spawn in freshwater rivers. The adult creates a redd, where it lays the eggs, in the fall. After hatching the salmon undergo several stages of their lifecycle in the freshwater. The fry leave the spawning grounds in search of food and develop into parr. After two years, the fry undergo the process of smoltification, where their physiology changes so that they can live in salt water. At this stage the smolt leaves the river and heads to the ocean, where most ultimately head to feeding grounds off of Greenland. The salmon usually live in the ocean for 2-3 years before they return to the river they were hatched in.

In the United States, the historical grounds of the Salmon ranged on the northeast coast south to the rivers of Long Island Sound. Currently, remnants survive only in 8 rivers in Maine, the largest of which is the Penobscot River. Historically in Maine, salmon landings were as high as 90 million tons in the late 1800s. (Baum 1997) By the 1940s the commercial fisheries in Maine were closed, and by the 1990s, less than 2000 adult salmon were returning annually to all of the rivers in Maine, despite over 13 million juvenile salmon stocked annually.

To identify the cause of the minimal returns, the mortality in the river and the sea run mortality were determined. To minimize the potential mortality as parr and fry, a number of smolts are stocked shortly before they are set to leave for the sea. Some of the smolts were pit-tagged with radio labels to identify near shore mortality. Data collected demonstrated a significant mortality from the time when the fish reached the estuary and made it to the open ocean. This mortality would correspond to heavy predation in the bay, or failure of the smolt to survive the transition from fresh to salt water.

During the smoltification process, the salmon has significant biological changes in the gill structure for osmoregulatory processes. In fresh water the salmon needs to maintain a higher salt content in its blood as compared to the water it is in. When in seawater, the salmon needs to maintain a lower salt content in the blood compared to the water it is in. During this change in the gill structure, the salmon is most sensitive to stressors or damage to the gill. Studies have shown that gill deformities can be caused by low pH and by high aluminum. In both of these cases the deformities occur as the cation binding to the gill structure.

The National Resource Council in 2004 specifically stated that the affects of acid rain on smolts is one of the most significant factors impeding the recovery of the Atlantic salmon; "*The problem of early mortality as smolts transition from freshwater to the ocean and take up residence as post-smolts needs to be solved. If, as seems likely, that the difficulty of the transition is due in part to water chemistry, particularly acidification, the only methods of solving the problem are changing the water chemistry and finding a way for the smolts to bypass the dangerous water.*"

The related Brook Trout has had similar extirpation from streams and ponds in many northeast locations due to low pH.

The question to be answered is**:** What is causing the increased mortality of Atlantic salmon?

Some hypotheses as to possible (and perhaps intertwined) causes include:

Low pH. Salmonids (Atlantic Salmon, Brook Trout, and related species) are known to be sensitive to pH, with stress occurring below pH 5, and mortality below pH 4.5. The pH of the aquatic ecosystem can be lowered due to natural acid inputs, such as dissolved organic carbon (DOC), or through anthropogenic inputs, predominantly acid rain. The acid rain is created from nitrogen oxides and sulfur oxides emissions. These may be episodic or chronic conditions.

High Aluminum. Aluminum will bind to the gills of the salmonids and irreversibly damage the gills, preventing the fish from uptaking oxygen. Aluminum will get into the water systems predominately from leaching from the ground when acid rain impacts a system.

Elevated Temperature Salmonids are temperature sensitive. When stream temperatures reach over 22ºC, salmon are severely compromised. When temperatures reach over 26ºC, mortality often ensues. The temperature of the stream can change due to increases in air temperature, reduction in boreal cover, or reduction in underground cold-water stream inputs.

Increased predation. There are two major predators. As the fish swim to the ocean as smolts, they are met by a host of predators such as cormorants and seals. The populations of both of these predators have increased in recent years. Another predator is humans, and overfishing is of concern. Starting in the 1950s, salmon have been caught in their ocean feeding grounds off of Greenland and Newfoundland. The catch has steadily declined with the decreasing populations.

Identifying Possible Analysis Methods

There are three hypotheses that have been put forward that could be responsible for the decline of the Atlantic Salmon. The purpose of this exercise is to identify analysis methods that could be used to test the chemical species that contribute to each of these hypotheses. Among the various analytical methods you find that may be applicable to this measurement, identify their strengths and weaknesses (e.g., sensitivity, expense, ease of use, reproducibility).

Hypothesis 1. *Episodic acid rain events overcome the buffering capacity of the water system and decrease the pH leading to stress and mortality in Atlantic salmon parr and smolts.*

Q1. Using available literature and other sources of information, identify possible analytical methods that could be used to monitor acidity.

Hypothesis 2. *Acid rain has increased the leaching of calcium from freshwater, reducing the nutrients available for salmonids. This loss of calcium prevents salmon from properly undergoing the smoltification process resulting in mortality when the fish head to the ocean.*

Q2. Using available literature and other sources of information, identify possible analytical methods that could be used to detect calcium and measure their levels in components of the water (e.g., free, organic bound).

Hypothesis 3. *Acid rain has increased the leaching of aluminum, resulting in a high concentration of free aluminum ion resulting in gill damage, leading to the main cause of mortality of Atlantic Salmon during the smoltification process.*

Q3. Using available literature and other sources of information, identify possible analytical methods that could be used to detect aluminum and measure their levels in components of the water (e.g., free, organic bound).

The rest of the module primarily focuses on the first two hypotheses.

References:

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