IGH Residualism Studies

Background

Wild anadromous and non anadromous forms of *Oncorhynchus mykiss* coexist naturally and are considered to be two different life history forms of the same species (Behnke 1992). Recent efforts to identify consistent genetic differences between the two forms that occur naturally in five river systems in British Columbia were unsuccessful (Docker and Heath 2001). Non anadromous or mature parr are typically male and can play a significant role in spawning with anadromous females (Seamons 2003). The contribution of mature parr may significantly increase the effective population size in small populations of salmonids (Martinez, 1999).

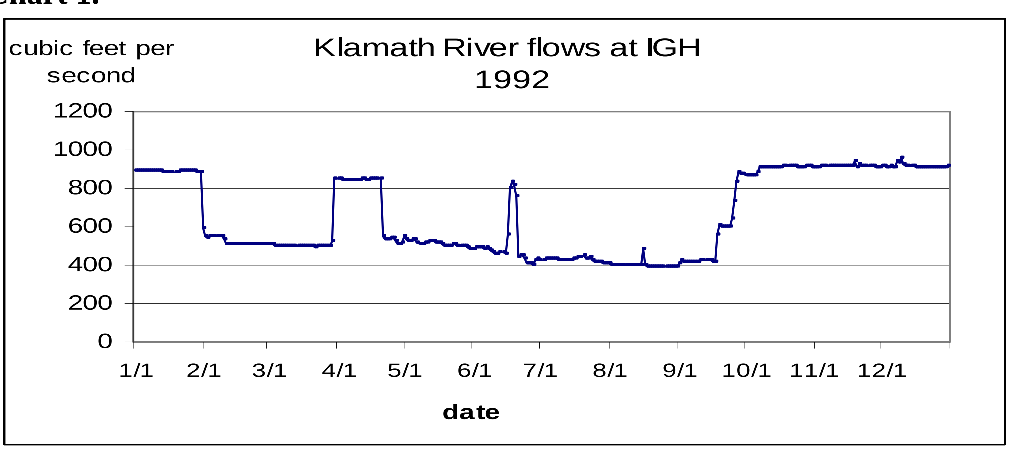
Residualism in hatchery populations

While it is the goal of steelhead hatcheries to produce smolts, as with the wild populations, a percentage of the hatchery produced *O. mykiss* will complete their life cycle in fresh water or residualize. A number of environmental factors are known to affect the development of smolts including: photo period, water temperature, flow, and lunar period (Meehan and Bjornn 1991). Physiological factors such as size at time of release is also an important factor in determining whether juvenile steelhead develop into smolts. Chrisp and Bjornn 1978, determined that the hatchery reared steelhead classified as smolts were significantly larger than steelhead classified as intermediates and parr. Due to the nature of conventional hatchery releases, i.e. large numbers of fish released over a short period of time, if residualism occurs it can result in competition between hatchery stocks and wild fish for food and habitat (Vincent 1987).

Steelhead production at IGH

Iron Gate Hatchery production goal and constraints calls for the release of 200,000, yearling steelhead at a minimum size of six inches (IGH goals and constraints, 1996). Wild steelhead in Klamath River tributaries typically rear in fresh water for two years prior to emigration (Hopelain 1998). In an effort to mimic the life history of wild steelhead, and to increase the size of the fish at the time of release, IGH reared and released 139,999 two year old steelhead into the Klamath River on 3/27/92. This release coincided with extremely low flows in the Klamath River of 496 cubic feet per second, (cfs) Chart 1.

Chart 1.



Steelhead production at IGH continued

Flows were increased to 850 cfs for three weeks following the release in an unsuccessful effort to trigger emigration. Local fisherman discovered that these fish could be easily hooked resulting in media coverage and the origin of the idea that IGH steelhead do not go to the ocean. A large number of the release group remained in the Klamath River directly below IGH until mid June.

The 1990s were a period of low abundance for anadromous fish in the Klamath River and its tributaries. Although the number of adults returning to the hatchery increased in 2001, the lack of IGH marked steelhead caught in the lower river fishery had some people convinced that IGH steelhead were still residualizing.

The Steelhead Research and Monitoring Program

The Steelhead Research and Monitoring Program, (S-RAMP) was established in 2000 to determine the status and trend of steelhead populations in Northern California.
A study was initiated to determine if IGH steelhead were residualizing in the Klamath River. The objectives of the study was to design and implement an effective in-river sampling program to study the behavior of IGH steelhead after release and to determine what percentage of the release group left volitionally from the hatchery.
During the spring of 2001, a total of 811 steelhead were collected in the Klamath River downstream of the hatchery by electrofishing. Of these, 81%, (664) were wild and 18%, (147) were hatchery steelhead. Twelve percent (98) of the total steelhead were from the 2001 release and only 5% (41) were 2 year old steelhead having adipose and right maxillary clips from the 2000 release. The volitional release occurred from March 19th to April 30th, during this period 22,171 or 69.3% of the of the release group left the hatchery volitionally (Lamson 2001)

2002 Projects

In 2002 we analyzed the otoliths of mature steelhead returning to IGH to determine if they had been to the ocean. Otolith microchemistry has been effectively used to identify anadromous and resident *Onchorhyncus mykiss* (Zimmerman, Reeves 2000). Otoliths are primarily composed of precipitated calcium carbonate and continue to grow throughout the life of a fish. Due to the similarities in ionic radius and valence of the calcium and strontium ions, strontium ions can be incorporated into the calcium carbonate structure of the otolith (Pollard, 1999). Strontium is substituted for calcium in proportion to its concentration in the water and it is present in much higher concentrations in seawater than in freshwater. An electron microprobe is used to measure the strontium and calcium levels in the otolith. The electron beam from the microprobe causes X-rays of characteristic wavelength for strontium and calcium to be emitted from the points sampled: the greater the rate of X-ray emission, the greater the concentration of the element in the sample. If the strontium/calcium (Sr/Ca) ratios are measured along a transect from the first part of the otolith formed (primordia) to the last area formed at the outer edge of the otolith, it is possible to determine if an individual fish is anadromous and if it is the progeny of an anadromous mother. Rapid increases in Sr/Ca ratios along the transect indicate entry into saltwater. Progeny of an anadromous mother will show a higher Sr/Ca ratio in the primordia than in the freshwater rearing portion of the transect.

Methods

<u>Sampling Returning Adults at Iron Gate Hatchery</u>

In the fall of 2001 and the spring of 2002 we sampled the adult steelhead returning to IGH. As in previous years, returning steelhead were sorted by hatchery personnel according to their readiness to be spawned. Fish that were not ready were held in circular tanks at the spawning building and rechecked periodically. After spawning, S-RAMP personnel bio-sampled each fish. Data collected included fork length, sex, scales, clips observed, clips applied and tissue samples for genetic analysis. Otoliths were collected from mortalities. We collected otoliths in 2000, 2001 and 2002 from steelhead mortalities at Iron Gate Hatchery. Beginning with the steelhead reared in 1997 (brood year 1997) all of the steelhead released by IGH were clipped. Each brood year was assigned a unique clip; adipose, adipose left and adipose right respectively. Nineteen otoliths from known-age IGH steelhead and one wild steelhead from the Shasta River were selected for study.

<u>Otolith Microchemistry Analysis</u>

A total of nineteen otoliths from known-age IGH origin steelhead were prepared and analyzed. Eight of the nineteen otoliths showed rapid increases in the Sr/Ca ratio outside of the point estimated to be the first annulus at 700 microns (example Chart 2). This increase in Sr/Ca ratio occurred for over at least a 100 micron length of the transect and had maximum values greater than 2.0. Eight of the otoliths showed little change in the Sr/Ca ratio and were judged to be non-anadromous, as in Chart 4. The remaining three samples had similarities to both the anadromous and the non-anadromous categories and were classified as intermediate (Chesney 2003).

Scale analysis of Iron Gate Hatchery (IGH) steelhead in 1983 determined that 78.4% of the 119 fish sampled entered the ocean at age 2 (Hopelain, 1998). Since IGH releases steelhead as yearlings, it is expected that many of these fish will remain in fresh water for a year after release. For the purpose of this study we considered a fish to be residualized if it was sexually mature with no evidence of ocean entry.

Summary:

I believe that a considerable percentage of the two year old steelhead released from IGH in March of 1992 residualized in the Klamath River. I think this occurred primarily because of the large size and maturity that these fish achieved in two years in the hatchery environment. I also believe that the very low flows which occurred in the Klamath River during 1992 contributed to the residualism of these fish. This was the only year that steelhead were released at age two and the only year that this higher than expected residualism was observed.

Based on the low percentage of hatchery to wild fish observed in the Klamath River in 2001, and the high percentage of 1+ steelhead that volitionally left the hatchery, I believe that IGH steelhead are currently exhibiting the range of life history forms observed in other wild and hatchery populations of *0. mykiss.* This fact was confirmed by microchemical analysis of 19 IGH origin steelhead otoliths in 2002. From a 19 fish sample, eight fish were anadromous and eight were non anadromy. A comparison of the mean Sr/Ca values in the primordia and mean values outside of the estimated first annulus show that anadromous progeny where produced by both anadromous and non anadromous mothers (example Chart 2 and Chart 3) , and non anadromous progeny where produced by anadromous and non anadromous mothers, (Charts 4 and 5). This is significant because it shows that IGH origin fish that residualize are able to produce anadromous progeny in the next generation.

Recent studies have demonstrated that anadromy is a life history form that is retained even if steelhead are landlocked for 70 years or 12-14 generations (Thrower 2004). Fish passage above Iron Gate dam will enable wild and hatchery origin steelhead to spawn with individuals that have been isolated by the dams, thereby increasing the effective population size. Rather then posing a risk to *O.mykiss* populations above PacificCorps dams, I believe that restoration of fish passage will benefit the overall population of *O.mykiss* in the Klamath River. *O. mykiss* stocks upstream of IGH were historically part of the same population as IGH steelhead. Providing passage will reconnect these populations and enable IGH to achieve its stated goal of "operating in such a way that populations and genetic integrity of salmon and steelhead stocks are maintained" and assist fishery managers in the recovery of Klamath basin natural stocks.(CDFG, NMFS Joint Hatchery Review Committee 2001).

Chart 2; anadromous mother, anadromous offspring
mean Sr/Ca in the primodia, 1.558 mean Sr/Ca outside of 700 microns, 1.647

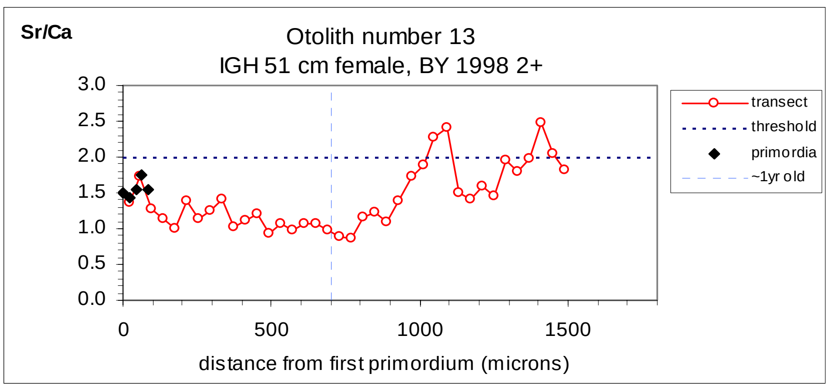


Chart 3; non –anadromous mother, anadromous fish
mean Sr/Ca in the primodia, 0.978 mean Sr/Ca outside of 700 microns, 1.460

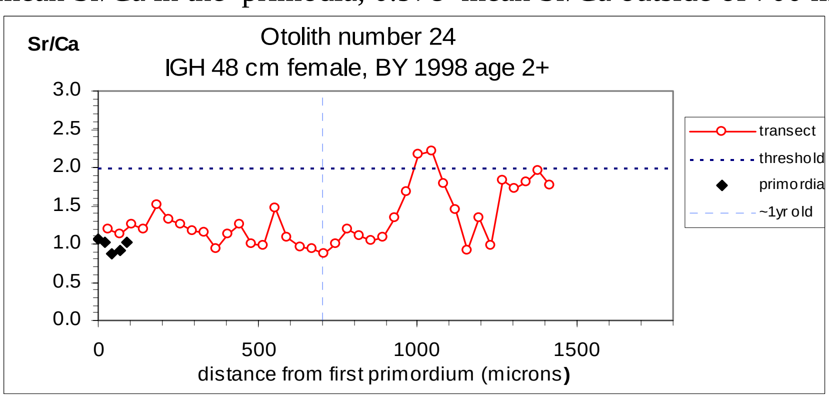


Chart 4; non-anadromous mother, non-anadromous fish

mean Sr/Ca in the primodia, 1.042 mean Sr/Ca outside of 700 microns, 1.151

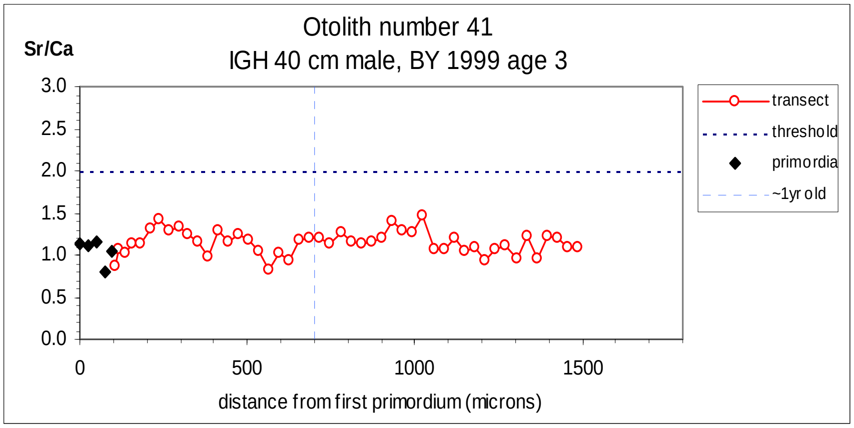
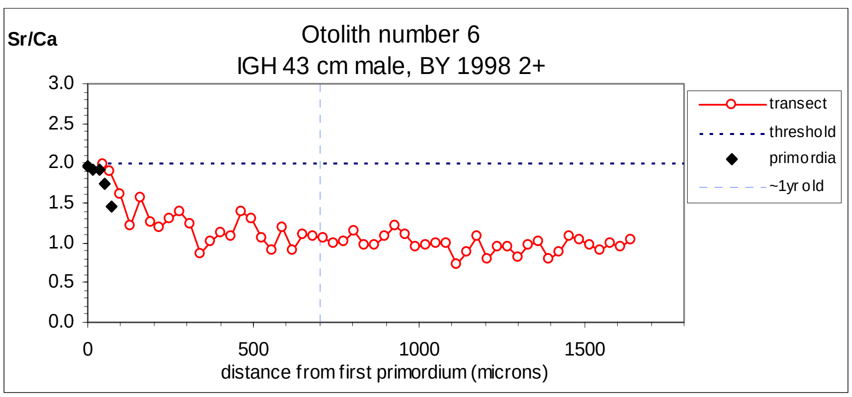


Chart 5; anadromous mother, non-anadromous offspring

mean Sr/Ca in the primodia, 1.801 mean Sr/Ca outside of 700 microns, 0.974



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