# Use of Scale Analyses to Determine the Early Life History Strategies of Snake and Columbia River Fall Chinook Salmon


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## EXECUTIVE SUMMARY

We collected and analyzed scales from adult Snake River fall Chinook salmon *Oncorhynchus tshawytscha* to evaluate their juvenile life history strategies. Scales were collected at Lower Granite Dam on the Snake River from returning fall Chinook salmon that had been PIT-tagged and released as juveniles in 2005, 2006, and 2007 and returned as adults in 2006, 2007, and 2008. Scale analyses were conducted as part of a multi-agency tagging study to evaluate dam passage strategies.

Study fish for scale analyses included 1) naturally produced subyearling fall Chinook salmon collected, PIT tagged, and released in the Snake and Clearwater Rivers; 2) surrogate subyearlings PIT-tagged at hatcheries (reared as surrogates for natural subyearlings); 3) PIT-tagged hatchery production yearling and subyearlings also PIT-tagged and released in the Snake and Clearwater Rivers; and 4) subyearling fall Chinook salmon PIT tagged and released during fall at Lower Granite Dam to evaluate late-season transport.

Scales were analyzed by the Washington Department of Fish and Wildlife to determine whether fish entered the ocean as subyearlings or yearlings (age-at-ocean entry), as well as their age and size at maturity. Scale data will be combined with juvenile PIT-tag detection data to provide more complete and accurate passage histories. Results presented here are for scales collected from adults returning from 2006 through 2008. For adults returning in 2009 through 2011, scale analyses are not yet available. Therefore, because each fall Chinook year class has up to 5 age classes of returning adults, we do not yet have a completed scale analysis for any prior release year.

Proportions of adults with subyearling vs. yearling juvenile migration histories will likely vary among age classes within a given year class (and may vary among year classes as well). Therefore, scale analyses from all returning fish from a given release year must be complete before interpretations of age at ocean entry can be made. This information will be reported when scale analyses for all age classes from a given release year are completed. In this report, we summarize the number of PIT-tagged juveniles potentially returning as adults for scale sampling and the number of scales collected each year to date. We also discuss the background and motivation for the scale analyses.

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## BACKGROUND

Snake River juvenile fall Chinook Salmon *Oncorhynchus tshawytscha* utilize the mainstem Snake and Columbia Rivers for both migration and rearing. As such, hydrosystem operations and transportation strategies can influence the behavior and survival of this ESA-listed species. However, the effects of hydrosystem operation and transport strategies on behavior of subyearling Chinook salmon are not well understood and have not yet been studied in a systematic manner. Such studies are critical in informing management agencies for example, as to the efficacy of transportation during periods of spill vs. non-spill.

### Consensus Proposal

Attempts to develop a study to evaluate the effects of the hydrosystem on Snake River fall Chinook salmon have yielded disagreements between entities as to the optimal study design. All of these entities are working toward the common goal of establishing hydrosystem-operation and fish-passage strategies that will support recovery while maintaining tribal harvest of Snake River fall Chinook salmon. As part of a long-term goal to develop a regional approach to determine these operations and strategies, a consensus research proposal was developed.

Lead agencies for the proposal were the Nez Perce Tribe, National Marine Fisheries Service (NOAA Fisheries), and U.S. Fish and Wildlife Service, although the proposal was developed in cooperation with interested parties throughout the Pacific Northwest. The proposal was titled, *Evaluating the Responses of Snake and Columbia River Basin fall Chinook Salmon to Dam Passage Strategies and Experiences* and is publicly available via the internet (Marsh et al. 2007). This proposal provided a path forward despite several unresolved points of contention among the agencies involved.

One contested point was whether or not, and in what manner, to use surrogate subyearlings in studies to evaluate management strategies for Snake River fall Chinook salmon. Surrogate subyearlings were reared specifically for research on Snake River fall Chinook because numbers of naturally produced subyearlings have been insufficient for PIT-tagging studies (Connor et al. 2007). Surrogates are reared for release at a smaller size in order to match the size of naturally produced subyearlings, but are still large enough to be implanted with a passive integrated transponder (PIT) tag (i.e., 70-75 mm fork length).

The surrogate rearing strategy is accomplished at Umatilla Hatchery by controlling the incubation rate of eggs and at the Dworshak NFH by limiting feed to slow rates of growth. Surrogates are tagged and then trucked to release sites in late May to early July to coincide with periods of peak historical abundance of natural parr in the Snake and Clearwater Rivers (Connor et al. 2007). Study designs included in the consensus proposal (discussed below) rely on the use of these smaller surrogate fish to represent the juvenile life history strategies of wild subyearling fall Chinook.

An additional subject under discussion is whether or not jacks (2-year-old age-0 ocean entrants) and mini-jacks (2-year-old age-1 ocean entrants) should be included in the calculation of SARs. Under the consensus proposal, it was agreed that jacks and mini jacks would be included in evaluations and reporting, while the decision could be deferred as to whether or not to include information on jacks in consideration of management options.

## Proposed Study Designs

The consensus proposal outlined two different analytical approaches proposed for monitoring and evaluating the response of Snake River fall Chinook salmon to dams in the Federal Columbia River Power System. Both approaches involve implanting fall Chinook salmon with passive integrated transponder (PIT) tags (Prentice et al. 1990a), and both compare smolt-to-adult return rates (SARs) among fish with different migration histories at the Snake River collector dams (i.e., Lower Granite, Little Goose, Lower Monumental, and McNary Dams). However, the first design compares metrics between groups assigned as juveniles to a pre-designated passage route, while the second compares metrics between groups of adults based on passage experience. Each approach has its merits and limitations, which are visited briefly below.

### Passage Strategy Design

The passage strategy design was originally developed to compare two different management strategies specifically for Snake River Basin fall Chinook salmon (Marsh and Connor 2004). The two strategies were 1) to transport migrating fish that are diverted at collector dams or 2) to bypass migrating fish that are diverted at collector dams back to the river. To represent these strategies, two groups of PIT-tagged fish would be released at locations upstream from Lower Granite Reservoir, but would be treated differently at Snake River collector dams. Using the separation-by-code facilities at collector dams (Marsh et al. 1999; Downing et al. 2001), fish collected from the release groups designated TWI, or transportation with inriver migration, would be diverted for transportation. A second treatment group, designated BWI, or bypass with inriver migration, would be diverted to the facility bypass system for return to the river.

For both the TWI and BWI treatments, a substantial portion of tagged fish in each group will not be detected (Prentice et al. 1990b) at any of the four collector projects. Failure to detect a tagged fish can occur when fish pass the dam via spillways or turbines, which are not equipped with PIT-tag detection systems. Summer spill operations have high effectiveness (pass high numbers of fish through the spillways), so spill passage may account for a considerable proportion of non-detected fish in a given group. Failure to detect fish can also occur when a fish chooses a reservoir-type life history strategy (Connor et al. 2005). These fish overwinter in reservoirs and pass the dams in late fall or early the following spring, when fish bypass and PIT-tag detection systems are not operating.

A key advantage of the passage strategy design is that it requires few assumptions about the proportions of fall Chinook salmon that enter the ocean as yearlings after overwintering in reservoirs or in the estuary (Connor et al. 2005), since these proportions can reasonably be assumed to be similar for both treatment groups. On the other hand, both treatment groups will have returning adults that were never detected as juvenile migrants, and the return rates for these fish can also be assumed to be similar. Therefore, return rates between treatment groups will be more similar, and detecting a significant difference between treatments will be more difficult.

**Passage Experience Design**

A second analytical approach compares groups of PIT-tagged juvenile migrants based on their passage experience at the dams (Schaller et al. 2007) and is presently used for evaluations of spring/summer Chinook salmon and steelhead *O. mykiss*. Under this study design, the passage experiences of Snake River fall Chinook would be determined from juvenile PIT-tag detection data. Fish would be released at locations upstream from Lower Granite reservoir, and returning adults would be classed into one of three groups for comparison. The first group would be designated $T_0$ to indicate a juvenile history of transportation from a collector dam. The second group would be designated $C_0$, for fish that passed as juveniles without being detected at any of the four collector dams (meaning they passed via spillways and/or turbines at each dam). The third group would be designated $C_1$, and would represent fish that were collected and bypassed back to the river at one or more collector dams.

The passage experience design can provide unbiased estimates of the number of smolts in the $C_0$, $C_1$, and $T_0$ study groups, but it relies on the assumption that all fish are active seaward migrants. This assumption is currently the subject of debate, since the latter approach will miss essential data if applied to groups of PIT-tagged fish that include considerable numbers of individuals that pass dams during winter.

Under both analytical approaches, a key demographic metric derived will be the SAR, which measures survival from the smolt to the adult stage. Under either the passage strategy design or the passage experience design, returning adults will be tabulated and divided by the corresponding number of smolts to determine SARs. Comparing return rates over time will provide key information needed to improve understanding of the effects of environmental conditions and management strategies on the life-cycle survival rates of salmonids within and outside the Federal Columbia River Power System (Williams et al. 2005; Muir et al. 2006; Schaller et al. 2007).

Fish released using either the passage experience or passage strategy study design can include both surrogate and production subyearlings. However, based on observed behavior, production subyearling smolts are more likely to meet the requirements of the passage experience design (comparison of $C_0$, $C_1$, and $T_0$ groups). This is because the migration characteristics of production subyearlings are more similar to those of yearling spring Chinook salmon, for which the passage experience design was developed

Production subyearlings are cultured at Lyons Ferry, Nez Perce Tribal, Umatilla, Irrigon, and Oxbow Hatcheries. For production subyearlings, incubation and growth are controlled to produce fish sized 90-95 mm at the time of release. In some cases, rearing is followed by a few weeks of acclimation at sites along the Snake and Clearwater Rivers prior to release in May to June (Figure 1).

# INTRODUCTION

Numbers of naturally produced Snake River subyearling fall Chinook salmon are insufficient for either the passage strategy or passage experience study design (described above). Therefore, to make an informed choice between the two study designs, more information is needed on the life history strategies of both production and surrogate subyearling Chinook. To provide this information, scale pattern analyses were conducted and combined with juvenile PIT-tag detection histories to provide insight on the juvenile life history strategies of these fish.

Juvenile releases of surrogate subyearlings were made each year from 2005 to 2006 and from 2008 to 2011. Releases of production subyearlings were made in 2006 and from 2008 to 2011. From 2005 to 2011, late-season river-run subyearling Chinook salmon were collected at Lower Granite Dam and PIT tagged during September-October to evaluate late-season transport.

Beginning in 2006, we sampled scales from returning PIT-tagged adults at Lower Granite Dam to describe the juvenile migration histories of surrogate, production, and inriver migrants (i.e., transport vs. inriver) as well as their age at ocean entry, and age and size at maturity. The premise of this work was that data collected would be used to determine which group(s) of surrogate subyearlings would be most appropriate for the passage experience study design (i.e., to determine whether significant proportions of these fish were *not* overwintering in reservoirs during late fall and were primarily entering the ocean as subyearlings).

## METHODS

### Study Area

Scales were collected from adults entering the adult trap at Lower Granite Dam (rkm 695) and diverted via separation-by-code system. All adult study fish had been PIT-tagged and released as juveniles from areas above Lower Granite reservoir. These included natural subyearling fall Chinook salmon released in the Snake and Clearwater Rivers, surrogate subyearlings (reared at hatcheries as surrogates for natural subyearlings) released in the Snake and Clearwater Rivers, and hatchery production subyearlings released in the Snake and Clearwater Rivers (Figure 1). Scales were also collected from river-run subyearling Chinook salmon PIT tagged and released during fall at Lower Granite Dam to evaluate late-season transport.

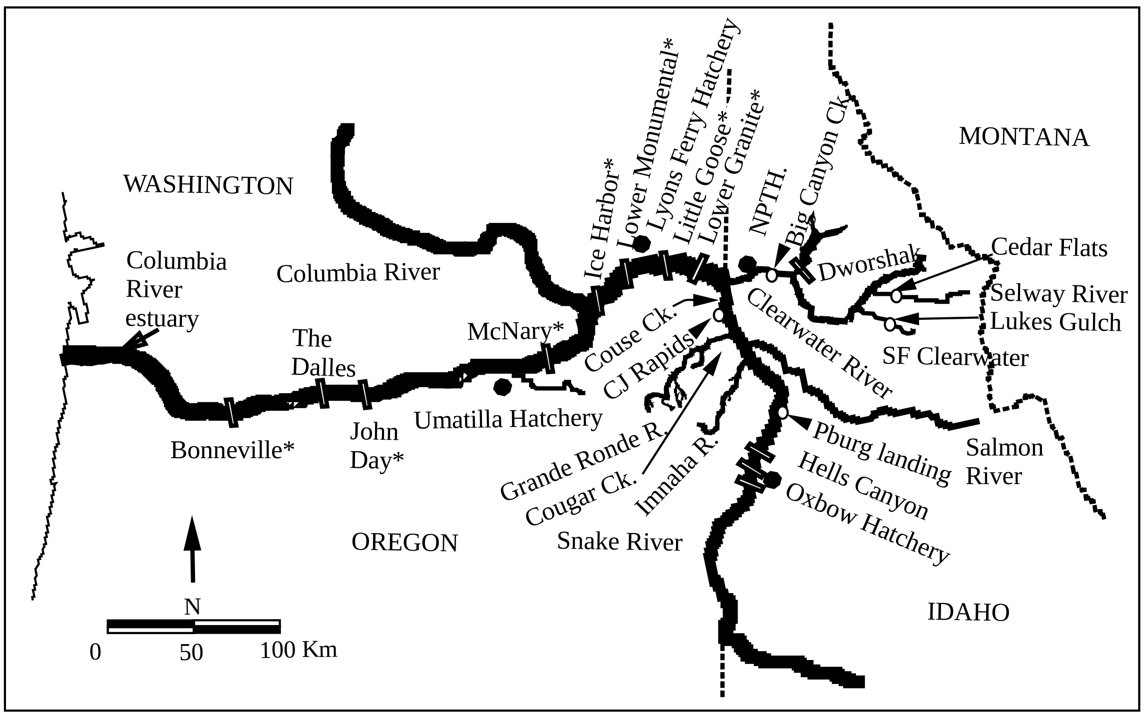


Figure 1. Map showing the collector dams, and juvenile release locations, as well as the four major spawning areas for fall Chinook salmon upstream from Lower Granite Reservoir. These are 1) upper reach of the Snake River from Hells Canyon Dam to the Salmon River, 2) lower reach of the Snake River from the Salmon River to the upper end of Lower Granite Reservoir, 3); The lower 83 km of the Grande Ronde River, and 4) the lower 65 km of the Clearwater River. Dams equipped with PIT-tag detection systems are indicated by asterisks.

Figure 1 shows the major spawning areas of Snake River subyearling Chinook, as well as the release points of all study fish groups. Surrogate subyearlings were released near the mouth of Couse and Big Canyon Creeks. Production subyearlings were released from the following nine locations: 1) Hells Canyon Dam, 2) Pittsburg Landing acclimation facility, 3) mouth of Cougar Creek, 4) Captain John Rapids acclimation facility, 5) mouth of Couse Creek, 6) Nez Perce Tribal Hatchery, 7) Big Canyon Creek acclimation facility, 8) Cedar Flats acclimation facility, and 9) Lukes Gulch acclimation facility. Also shown in Figure 1 are the four Snake River collector dams: Lower Granite, Little Goose, Lower Monumental and McNary. Study fish collected at any of these dams can be transported and released downstream of Bonneville Dam.

The Lyons Ferry Hatchery stock is the source of the Snake River hatchery fall Chinook salmon cultured for production or research purposes. This stock is cultured by the Nez Perce Tribal, Dworshak National, Oxbow, and Umatilla Hatcheries.

## Fish Collection and Sampling

We used the separation-by-code system at the Lower Granite Dam adult trap (Harmon 2003) during 2006–2008 to recapture adults returning from releases of natural, surrogate, production, and late-season river-run subyearlings made during 2005–2007. Once recaptured, we subjectively estimated gender, measured fork length to the nearest 1 cm, and collected scales. Scales from each fish were placed in an individual envelope marked with a sequential sample number, the recovery date, and the PIT-tag code of the sampled fish. Scales were analyzed by the Washington Department of Fish and Wildlife to determine age at ocean entry and total age (see Connor et al. 2005 for methods). A full analysis of age at ocean entry and age and size at maturity, including validation of scale pattern analysis, will be possible for releases made in 2005 through 2011 (excluding 2007) after scales collected in 2009 through 2015 are analyzed.

## RESULTS AND DISCUSSION

Using information from fish released as juveniles from 2005 to 2008, we programmed between 292,072 to 762,807 PIT-tag codes per study year into the separation-by-code system at Lower Granite Dam (Table 1). During collection of adults in 2006-2008, the majority of returning adults that had been programmed for recapture were successfully recaptured, and the majority of scales collected were readable (Table 2). Data collected in 2009 and 2010 will be reported when scale analyses are available. Adding these data will allow a full analysis of the releases made in 2005-2006.

Table 1. Number of fall Chinook salmon PIT-tag codes entered into the separation-by-code system of the adult trap at Lower Granite Dam for adult return years 2005-2008.

| | | Juveniles with PIT-tag codes | | |
|---|---|---|---|---|
| | | Hatchery rearing strategy | | Late-season |
| Return year | Total codes | Surrogate | Production | transport |
| 2005 | 292,072 | 172,156 | 112,288 | 7,628 |
| 2006 | 451,618 | 342,394 | 99,077 | 10,147 |
| 2007 | 854,550 | 595,231 | 246,864 | 12,455 |
| 2008 | 762,807 | 497,259 | 246,880 | 18,668 |

Table 2. Number of PIT-tagged adults from the 2005-2007 juvenile release years crossing Lower Granite Dam, the number sampled for scales, and the number of scales read for return years 2006-2008. The number of readable scale samples is based on assignment of an age at ocean entry.

| Release location | Subyearling group | Release year | Number crossing Lower Granite Dam | Number sampled* | Number of readable scale samples |
|---|---|---|---|---|---|
| Snake River | Surrogate | 2005 | 61 | 58 | 58 |
| | Surrogate | 2006 | 400 | 387 | 264 |
| | Production | 2006 | 277 | 269 | 209 |
| Clearwater River | Surrogate | 2005 | 111 | 107 | 93 |
| | Surrogate | 2006 | 223 | 213 | 138 |
| | Production | 2006 | 442 | 420 | 339 |
| Lower Granite | River-run | 2005 | 66 | 61 | 47 |
| Dam (late-season | River-run | 2006 | 68 | 62 | 27 |
| transport) | River-run | 2007 | 234 | 217 | 89 |

* Sampled either from the adult trap at Lower Granite Dam or in a hatchery.

Results presented here are for sampling of scales collected from adult fall Chinook salmon returning during 2006-2008 from juvenile releases beginning in 2005. These releases were made to evaluate migration strategies of surrogate and production subyearlings, as discussed above and in the consensus research proposal (Marsh et al. 2007). Analyses of scales collected from returning adults in 2009 through 2011 are not yet available. Therefore, we do not yet have a complete scale analysis from any single release year.

Results will likely vary among age classes in terms of the proportion of subyearling vs. yearling migrants returning from each age class. Therefore, we will report data on age-at-ocean entry when scale analyses are complete for all returning age classes from a given year class (release year). This information will be reported for all release years when scale analyses for all corresponding year classes are completed.

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