# MONITORING THE MIGRATIONS OF WILD SNAKE RIVER SPRING/SUMMER CHINOOK SALMON SMOLTS IN THE COLUMBIA RIVER BASIN, USA.

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## Abstract

Before 1989, information on the migrational characteristics of Snake River spring/summer chinook salmon smolts *Oncorhynchus tshawytscha* from individual wild populations was scarce. During summers 1988 through 1998, we PIT tagged wild parr in natal streams. Each subsequent spring and summer, tagged smolts were detected at juvenile bypass systems at dams on the lower Snake and Columbia Rivers. Study goals are to 1) characterize the migration timing of different wild stocks at traps and dams, 2) determine if consistent patterns are apparent, and 3) determine what environmental factors influence migration timing. At Lower Granite Dam, the first dam encountered by migrating smolts, annual migrational timings were consistently protracted and were highly variable among streams and years. By contrast, their hatchery counterparts exhibited compressed and consistent timings over the years. Some timing trends have been observed for a few wild stocks. In addition, for combined wild stocks, we observed 2- to 3-week migrational timing shifts between

relatively warm and cold years. Over all years, peak detections coincided with variable flows before 9 May, but coincided with peak flows from 9 to 31 May. Annually, since 1992, fishery managers have been using this real-time detection information on wild fish stocks to direct daily operations of the hydropower system.

## Introduction

In most years from 1966 to the late 1980s, migrations of Snake River yearling chinook salmon *Oncorhynchus tshawytscha* have been monitored by downstream recoveries of freeze-branded fish previously released from upstream hatcheries, river scoop traps, turbine intake gatewells at dams, or dam bypass systems (Bentley and Raymond 1968; Park and Ebel 1974; Raymond 1974, 1979; Ebel 1980). The brands identified groups of fish, but not individuals. The recent development of the passive integrated transponder (PIT) tag (Prentice et al. 1990b), permits identification of individual marked fish. This innovation has allowed the acquisition of more precise information on migrational timing as well as many other important juvenile salmonid behavioral characteristics.

In this paper, we provide summary information on the collection and PIT tagging of wild Snake River spring/summer chinook salmon parr as well as data on the detection and migration timing of the smolts as they migrated through the dams on the Snake and Columbia Rivers each spring and summer from 1989 through 1999. The goals of our study are to characterize migration timing of several individual stocks as well as combined populations of wild spring/summer chinook salmon smolts at traps and dams, determine if timing patterns are consistent, and examine what environmental factors influence or control this behavior.

## Methods

From 1988 to 1998, we collected and PIT-tagged wild spring/summer chinook salmon parr from 3 to 17 streams in Idaho and from 2 to 4 streams in Oregon during late summer. Since 1992, Oregon Department of Fish and Wildlife has collected and PIT tagged fish in their streams. During the study s first 3 years, we also PIT tagged from two to four stocks of hatchery spring/summer chinook salmon parr for comparative purposes (Achord et al. 1996).

Wild parr were PIT tagged in spawning and rearing areas that ranged from 172 to 770 river km upstream of Lower Granite Dam, and from 867 to 1,465 river km from the Pacific Ocean. The elevations of most of the natal rearing areas were between 1,524 and 2,134 m in elevation; however, the lowest tagging site was 719 m.

We used primarily two methods to collect wild fish--electrofishing and a seining technique that we developed specifically for this application (Achord et al. 1996). Prentice et al. (1990c) described in detail the components and setup of a typical PIT tagging station. However, for this study, we used portable PIT tagging stations that we designed specifically for use beside streams (Achord et al. 1996). After the fish were tagged, we held them for a minimum of 0.5 hours in live cages in the streams before releasing them as near as possible to the locations from where they were collected. From most streams a subsample of approximately 8-12%were retained for 24 hours in live cages to measure tag loss and delayed mortality.

During the springs and summers from 1989 through 1999, surviving spring/summer chinook salmon smolts PIT tagged the previous summers migrated downstream volitionally through the hydroelectric complex on the Snake and Columbia Rivers. Full PIT-tag monitoring systems were operational within smolt bypass systems at Lower Granite (1986-present), Little Goose (1987-present), and Lower Monumental (1993-present) Dams on the Snake River, and McNary (1986-present), John Day (1998-present), and Bonneville (1997-present) Dams on the Columbia River. Smolts were guided by submersible screens from turbine intakes into the juvenile bypass systems at these dams and subsequently monitored automatically for PIT tags. Prentice et al. (1990a) described in detail the monitoring systems at three of these dams.

## Results and Discussion

### *Fish Collection and Tagging*

From 1988 through 1998, we collected a total of 125,766 wild chinook salmon parr in Idaho and Oregon (first 4 years). Annual numbers of wild parr collected ranged from 1,455 in 1996 to 24,874 in 1994. Of those collected, 108,923 were PIT tagged and released. Over these 11 years, overall mortality from collection and tagging averaged 1.4% (annual ranges 0.5 to 2.6%). Overall mortality from collection over the years averaged 1.1% and overall mortality related to tagging (up to 24-hours) averaged 0.4%. The overall mortality from electrofishing averaged

1.8% and the overall mortality from collection by seining averaged 0.2%.Tag loss was virtually non-existent at 0.02%.

Over the above period, the overall fork length of tagged wild fish averaged 68 mm (annual averages ranged from 63 to 72 mm). The overall average length for wild fish that died after tagging was 64 mm (419 mortalities out of 109,342 tagged). This indicates that smaller fish died at a slightly higher rate than larger fish.

*Detections at Dams*

During the study period, a total of 13,909 first-time detections of wild smolts were made at dams. From 1993 to 1999, which were years when water was spilled at the dams, the first-time detection numbers were adjusted for spill. The percentage of released fish detected at the dams averaged 12.8% and ranged from 7.6% in 1989 to 32.3% in 1998. We caution against comparing detection rates among the study years because a number of variables differed through time including overall dam operations, the number of dams equipped with PIT-tag monitoring systems, surface bypass collection experiments at Lower Granite Dam in later years, the addition of extended length screens at various dams over various years, and the need to adjust numbers for spill at the dams in some years.

Over the course of the study, the percentages of PIT-tagged released fish from individual wild fish stocks that were detected at dams the following spring varied considerably, ranging from 1.5% to 58.5%. In general, the percentages increased over the years, in part, because of changing conditions at the monitoring dams noted above. However, some stocks consistently exhibited higher detection rates than other stocks. In all years, fish that were smaller at release (55 to 59 mm) were detected at significantly lower rates than fish that were larger at release (65 to 84 mm) ($P < 0.05$). However, the absolute differences in detection rates were not large between the two size groups of fish. For example, while one-third of all fish were 64 mm or smaller at release, they accounted for one-fourth of all detections at dams. Over the 8 to 10 month period between tagging and recovery (including the overwinter period), smaller fish likely had a higher natural mortality rate than larger fish, even in the absence of any handling and tagging. It is noteworthy that the smaller fish consistently exhibited significantly later timing at the dams ($P < 0.05$). Therefore, we feel it is important to continue tagging small fish (a 55 mm fork-length minimum), to acquire the most accurate and representative migration timing information for these wild stocks.

In 1994, we collected sufficient numbers of fish by both collection methods (electrofishing, seining) in two streams to compare their detections rates at the dams the following year. We found no significant difference in detection rates for fish released the previous year following collection by electrofishing (120/1,661=7.2%) or seining (101/1,460=6.9%) ($P > 0.05$). These data clearly demonstrated that electrofishing had little, if any, delayed effect on these fish compared to fish collected with our relatively benign seining technique which utilized water-to-water transfer techniques.

*Migration Timing at Lower Granite Dam*

The migration timing of individual wild stocks varied considerably among years and was usually protracted as measured at Lower Granite Dam, the first dam encountered by smolts between their natal rearing areas and the ocean. However, migration timing patterns are emerging for some stocks and groups of stocks, and range from early to late in the migration season. Attempting to relate distance (upstream from Lower Granite Dam) and elevation to the migration timing of wild stocks at the dam has yielded mixed results. In general, stocks from the farthest and highest elevations (from 2,000 to 2,134 m) had the latest timing at the dam. However, at short to intermediate distances from the dam and at elevations from 1,200 to 2,000 m, stock timings varied from early to late in the migration seasons. Most stocks from the lowest elevations (below 1,200 m) displayed the earliest migrational timing. Overall, the stocks displayed high variability in the middle 80% passage dates (10 to 90% passage period) over the years, ranging from 12 to 80 days, during April, May, June, and July.

Normally, large numbers of chinook salmon parr migrate downstream out of the upper tributaries in fall (Edmundson et al. 1968; Bjornn 1971; Raymond 1979). The magnitudes of these migrations differ annually and can result in many fish moving far downstream into larger tributaries, where quality overwintering habitat is more abundant. Factors such as stream discharge, temperature, turbidity, and habitat availability affect the migrations (Bjornn 1971). It is therefore not surprising that migrational timings of the wild stocks at the first dam would be variable and protracted. Raymond (1979) cited water temperature as one of the most important factors that triggers the downstream movement of hatchery-reared and wild chinook salmon smolts in spring. As water temperatures progressively warm from downstream to upstream in spring, the wild smolt migrations probably begin earlier in the lower elevations than in the higher elevation areas. However, in addition to water temperature, photoperiod plays an important role in smoltification of anadromous salmonids (Saunders and Henderson 1970; Wagner 1974; Ewing et al. 1979; Clarke and Shelbourn 1985; Duston and Saunders 1990; Solbakken et al. 1994).

The annual migrational timing patterns of the combined wild populations was also variable and protracted over the years. The middle 80% passage for these fish averaged 43 days (annual ranges 37 to 55 days), between mid-April and mid-June. By contrast, their hatchery counterparts (combined) exhibited a consistent and compressed migrational timing pattern at the dam. Their middle 80% passage period averaged 26 days between mid-April and mid-May, with little range variation in days. While appearing to exert little influence on the annual migrational patterns of hatchery fish, annual differences in climate (particularly temperature profiles) appear to influence the annual passage distribution shifts for wild fish populations.

Annual variation in climate is emerging as an important factor controlling the overall migrational timing of wild Snake River spring/summer chinook salmon smolts at Lower Granite Dam. In 1990, 1992, 1994, and 1998, we observed relatively warm late-winter and spring conditions and 50% of all wild fish passed this dam from 29 April to 4 May and 90% had passed by the end of May. In the relatively colder (late winter and spring) years of 1989, 1991, and 1993, 50% of all wild fish had not passed the dam until mid-May, and 90% had not passed until mid-June (except in 1993, when unusually high flows moved 90% through the dam by the end of May). During these 7 years, we observed a consistent 2- to 3-week shift in timing of wild fish at the dam between relatively warm and cold years. In 1995, intermediate weather conditions prevailed in late winter and spring (compared to the previous 6 years), and we observed intermediate passage times of 9 May and 5 June, for the 50 and 90% passage dates, respectively. We PIT-tagged wild fish in only three Idaho streams for the 1996 and 1997 smolt migrations. Therefore, we did not compare overall passage timing of wild fish in 1996 and 1997 to other years, since disproportionately high percentages (91 and 73.5%, respectively) of wild fish detections at the dam were from Oregon streams. In all other years 50% or less of wild fish detections were from Oregon streams. In 1999, we experienced different climatic conditions than in all other previous migration years. In late winter, a near-record snow pack in the Snake River basin resulted in high flows during the early spring period; however, the ensuing flows were moderated by very dry and cold conditions during the remaining spring and early summer period. The fluctuating medium to high flows throughout the spring moved the wild fish through Lower Granite Dam as observed in warmer years, with 50% passing by 3 May and 90% passing by 30 May.

We compared combined detection profiles of wild fish to river flows at Lower Granite Dam. Over all years, peak detections coincided with variable flows before about 9 May; however, between 9 and 31 May, peak detections coincided with peak flows. It appears that water reserved for fish migrations would provide more benefit to wild fish if it is utilized after the first week of May, particularly during years with low stream flows.

Our wild fish study is ongoing. To provide more information on the relationships between parr/smolt movements and environmental conditions, we have established environmental monitoring at five sites in natal rearing areas, four of which are located next to fish traps for juvenile salmonid migrants. Water quality sondes at these sites monitor water temperature, depth (flow), conductivity, dissolved oxygen, pH, and turbidity, continuously on an hourly basis. We have established a database of this environmental data that is available on the Internet at: http://bemdata.nwfsc.noaa.gov/baseline/intro.html. As additional environmental monitors and traps are installed in study streams, we can more accurately monitor fry, parr, and smolt movements out of rearing areas and examine the relationships between these movements and environmental parameters within the streams. Mapped over time, this information, along with weather and climate data, will be useful for accurately predicting on an annual basis the migrational characteristics of different wild stocks as they pass downstream through the Snake and Columbia River hydropower system.

Since 1992, fishery managers have been using real-time detection information on wild fish stocks to direct daily operations of the hydropower system, including reserved water releases, and a myriad of dam operations such as spill, bypass operations, power generation loads and schedules, and transportation of smolts. As more information on the migrational behavior of these wild fish stocks become available, decisions can be made to better protect these valuable threatened fish stocks.

More detailed information on this study can be found in our annual reports that are posted on the Internet at:

http://www.efw.bpa.gov/cgi-bin/FW/publications.cgi

Click on *Reports*, then *Downstream Migration* and *Water Budget*, then scroll down to project number *9102800*.

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## References

Achord, S., G. M. Matthews, O. W. Johnson, and D. M. Marsh. 1996. Use of Passive Integrated Transponder (PIT) tags to monitor migration timing of Snake River chinook salmon smolts. North American Journal of Fisheries Management 16:302-313.

Bentley, W. W., and H. L. Raymond. 1968. Collection of juvenile salmonids from turbine intake gatewells of major dams in the Columbia River system. Transactions of the American Fisheries Society 97:124-126.

Bjornn, T. C. 1971. Trout and salmon movements in two Idaho streams as related to temperature, food, stream flow, cover, and population density. Transactions of the American Fisheries Society 100:423-502.

Clark, W. C., and J. E. Shelbourn. 1985. Growth and development of seawater adaptability by juvenile fall chinook salmon (*Oncorhynchus tshawytscha)* in relation to temperature. Aquaculture 45:21-31.

Duston, J., and R. L. Saunders. 1990. The entrainment role of photoperiod on hypoosmoregulatory and growth related aspects of smolting in Atlantic salmon (*Salmo salar*). Canadian Journal of Zoology 68:707-715.

Ebel, W. J. 1980. Transportation of chinook salmon, *Oncorhynchus tshawytscha*, and steelhead, *Salmo gairdneri*, smolts in the Columbia River and effects on adult returns. Fishery Bulletin (U.S.) 78:491-505.

Edmundson, E., F. E. Everest, and D. W. Chapman. 1968. Permanence of station in juvenile chinook salmon and steelhead trout. Journal of the Fisheries Research Board of Canada 25:1453-1464.

Ewing, R. D., S. L. Johnson, H. J. Pribble, and J. A. Lichatowich. 1979. Temperature and photoperiod effects on gill (Na + K)-ATPase activity in chinook salmon (*Oncorhynchus tshawytscha)*. Journal of Fish Biology 36:1347-1353.

Park D. L., and W. J. Ebel. 1974. Marking fishes and invertebrates. II. Brand size and configuration in relation to long term retention on steelhead trout and chinook salmon. Marine Fisheries Review 36(7):7-9.

Prentice, E. F., T. A. Flagg, and C. S. McCutcheon. 1990a. PIT-tag monitoring systems for hydroelectric dams and fish hatcheries. American Fisheries Society Symposium 7:323-334.

Prentice, E. F., T. A. Flagg, C. S. McCutcheon, and D. F. Brastow. 1990b. Feasibility of using implantable passive integrated transponder (PIT) tags in salmonids. American Fisheries Society Symposium 7:317-322.

Prentice, E. F., T. A. Flagg, C. S. McCutcheon, D. F. Brastow, and D. C. Cross. 1990c. Equipment, methods, and an automated data-entry station for PIT tagging. American Fisheries Society Symposium 7:335-340.

Raymond, H. L. 1974. Marking fishes and invertebrates. I. State of the art of fish branding. Marine Fisheries Review 36(7):1-6.

Raymond, H. L. 1979. Effects of dams and impoundments on migrations of juvenile chinook salmon in the Columbia and Snake Rivers, 1966 to 1975. Transactions of the American Fisheries Society 108:505-529.

Saunders, R. L., and E. B. Henderson. 1970. Influence of photoperiod on smolt development and growth of Atlantic salmon (*Salmo salar)*. Journal of the Fisheries Research Board of Canada 27:1295-1311.

Solbakken, V. A., T. Hansen, and S. O. Stefansson. 1994. Effects of photoperiod and temperature on growth and parr-smolt transformation in Atlantic salmon (*Salmo salar L.)* and subsequent performance in seawater. Aquaculture 121:13-27.

Wagner, H. H. 1974. Photoperiod and temperature regulation of smolting in steelhead trout (*Salmo gairdneri)*. Canadian Journal of Zoology 52:219-234.