Emigration of Natural and Hatchery Chinook salmon; *Oncorhynchus tshawytscha* (Nacó'x in Nez Perce) and Steelhead; *Oncorhynchus mykiss* (Héeyey in Nez Perce) Smolts from the Imnaha River, Oregon from 2 October 2008 to 17 June 2009

2009 Annual Report for the Imnaha River Smolt Monitoring Project
and Lower Snake River Compensation Plan Hatchery Evaluation Studies in the Imnaha River, Oregon

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EXECUTIVE SUMMARY

This report summarizes the Nez Perce Tribe's Imnaha River juvenile Chinook salmon (Nacó'x in Nez Perce language; *Oncorhynchus tshawytscha*) and steelhead (Héeyey in Nez Perce language; *O. mykiss*) emigration studies conducted from October 2, 2008, to June 17, 2009 (migration year 2009). The studies have been ongoing for the past 18 years and have contributed information to the Fish Passage Center's Smolt Monitoring Program (SMP) for the past 16 years. The study collected and tagged emigrating smolts in the Imnaha River at rkm 7 during the fall and spring seasons. Tagged fish were detected downstream as they passed through Snake and Columbia River dams. The project evaluated the survival, biological characteristics, and migration performance of natural-origin (NO) and hatchery-origin (HO) spring/summer Chinook salmon and steelhead at Lower Granite Dam (LGR), Little Goose Dam (LGS), Lower Monumental Dam (LMD), and McNary Dam (MCN). This report represents a compilation of 16 of the past 18 years of SMP operations in addition to the MY 2009 results.

The two goals of the project are; 1) provide real-time data from juvenile Chinook salmon and steelhead tagged with passive integrated transponder (PIT) tags at the Imnaha River juvenile emigrant trap for the Fish Passage Center's SMP and; 2) compare performance measure metrics between natural- and hatchery-origin Chinook salmon and steelhead as part of the Lower Snake River Compensation Program (LSRCP) hatchery evaluations project. These goals will be accomplished by completing the following five objectives. 1) Quantify life-stage specific emigrant abundance of Imnaha River juvenile Chinook salmon and steelhead; 2) Quantify and compare life-stage specific emigration timing of Imnaha River juvenile Chinook salmon and steelhead, 3) Quantify and compare life-stage specific survival of juvenile Chinook salmon and steelhead within and from the Imnaha River to Lower Granite Dam on the Snake River and McNary Dam on the Columbia River, 4) Quantify and compare smolt to adult return rate indices (SARs) for fall- and spring-tagged NO Chinook salmon and HO and NO steelhead smolts and, 5) Describe life-stage specific biological characteristics of Imnaha River juvenile Chinook salmon and steelhead.

Project objectives were completed with the operation of a rotary screw trap in the Imnaha River approximately 7 river kilometers (rkm) above the confluence with the Snake River. The trap was operated during peak migration periods in the fall and spring, capturing emigrating natural-origin (NO) and hatchery-origin (HO) Chinook salmon and steelhead juveniles.

We estimated a minimum of 92,373 (95% C.I. 80,823 to 106,405) NO Chinook salmon juveniles emigrated past the trap, with 70% of the juveniles emigrating during the spring trapping period. An estimated minimum of 56,298 (95% C.I. 45,378 to 71,595) NO steelhead smolts emigrated past the trap, mainly in the spring. Survival of HO Chinook salmon and steelhead juveniles from the release site to the Imnaha trap was 89% (± 3.4%) and 88% (± 1.2%), respectively, indicating that fish were released in good condition and the rate of residualization was relatively low.

Significant differences in emigration timing was observed for NO compared to HO Chinook salmon and steelhead juveniles as determined by the cumulative proportion of juveniles captured at the screw trap. Arrival timing at Lower Granite Dam (LGR) was significantly earlier for fall

tagged NO Chinook salmon pre-smolts compared to spring-tagged smolts, and NO Chinook salmon arrival timing at LGR was significantly earlier than that of HO smolts. Arrival timing of HO steelhead at LGR was significantly earlier than that of NO steelhead juveniles. The differences in arrival timing had important implications for the proportion of each type that was available for transportation through the hydrosystem, with earlier arriving groups being less likely to be transported. These differences in transportation rates could influence adult survival estimates.

Analysis of travel time from the Imnaha River screw trap to LGR indicated that NO Chinook salmon smolt (spring-tagged) travel time to LGR was negatively correlated with Snake River flow. In contrast, there was no relationship between travel time and flow for HO Chinook salmon. Similarly, NO steelhead travel time was also negatively correlated with Snake River flow, whereas HO steelhead showed no relationship. These results suggested that NO Chinook salmon and steelhead respond to environmental cues during emigration, but HO juveniles were more dependent on release timing and migrated rapidly to LGR in variable environmental conditions. NO pre-smolts appear to have mixed with the general population in the spring and Snake River flow did not appear to influence travel time from the Imnaha River to LGR.

We estimated survival from the Imnaha River screw trap to LGR for NO pre-smolts (fall-tagged), smolts (spring-tagged) and HO Chinook salmon. Results demonstrated that survival of NO pre-smolts was 40.5% (± 2.6%), compared to 85.1% (± 1.9%) and 78.5% (± 6.4%) for NO and HO smolts, respectively. Survival from the trap to LGR was estimated to be 86.9% (± 2.6%) and 91.1 (± 4.7%) for NO and HO steelhead, respectively.

Juvenile survival from the Imnaha River trap to McNary Dam (MCN) was estimated to compare species- and origin-specific differences in survival through the migration corridor. Results demonstrated that NO and HO spring-emigrating Chinook salmon survival rates from the trap to LGR reach of 85.1% (± 1.9%) and 78.5% (± 6.4%) respectively, were similar to the survival rates estimated from LGR to MCN of 83.1% (± 5.1%) for NO and 83.7% (± 5.6%) for HO Chinook. In contrast, survival of NO and HO steelhead juveniles was significantly lower from LGR to MCN, 63.8% (± 7.3%) and 79.8% (± 5.7%) respectively, compared to the estimated survival rates of 86.9% (± 2.6%) for NO and 91.1% (± 4.7%) for HO steelhead from the Imnaha River trap to LGR. Results indicated that there are significant differences in survival between species and origin types in the reach from the trap to LGR versus LGR to MCN, with increased mortality of Chinook salmon juveniles occurring between the trap and LGR and increased mortality of steelhead juveniles occurring between LGR and MCN.

An analysis of the relationship between Snake River flow and survival from 1998 – 2009 revealed a significant correlation between flow and survival to LGR for NO, but not for HO steelhead juveniles. No significant relationship was found between Snake River flow and NO or HO Chinook salmon survival to LGR. In addition, a significant positive relationship was found between survival to MCN and NO Chinook salmon and steelhead juveniles, but not for HO juveniles of either species. Again these results suggested that NO juveniles respond to environmental conditions that maximize survival.

Adult returns in 2009 allowed for analyses of smolt to adult return (SAR) index rates through bood year 2004 for Imnaha River NO Chinook salmon, and through migration year 2007 for NO and HO steelhead. Results demonstrated that NO Chinook SARs have declined compared to previous years for both fall-tagged pre-smolts and spring-tagged smolts. Spring-tagged NO Chinook had a higher average (geometric mean) SAR index rate than fall-tagged Chinook when analyzed from the Imnaha River trap to LGR (0.61% and 0.36%, respectively). Overwinter mortality in Lower Granite Reservoir appears to be a major factor influencing SARs for fall-emigrating Chinook pre-smolts. Generally, SAR index rates were higher for HO compared to NO steelhead. Average (geometric mean) SAR index rates were 0.61% for HO and 0.45% for NO steelhead from the Imnaha River trap to LGR, and 0.71% (HO) and 0.54% (NO) from LGR to LGR. Results may vary due to different routes of passage between marked and unmarked fish. Fish marked with a passive integrated transponder (PIT) tag may not be treated the same as unmarked fish, in respect to being transported or bypassed back to the river. SAR index rates measured here represented fish that were bypassed to the river and may not represent the run at large fish that had additional options for traveling through the hydrosystem. Consequently, this analysis mainly served as a comparison between the two origin types for in-river survival.

We evaluated and compared NO and HO Chinook salmon and steelhead fork lengths, weights and condition factors. Generally HO fish were significantly larger than NO juveniles as measured by fork length and weight. Condition factors showed no differences. The larger size may confer survival benefits by reducing predation during the migration period and early ocean residency, and these may explain the higher SAR index rates for HO compared to NO fish. Completion of the project objectives resulted in meeting the goals indicated above. A large number of NO and HO Chinook salmon and steelhead were PIT tagged and evaluated as part of the Fish Passage Center’s Smolt Monitoring Program. In addition, data collected in 2009 provided long-term monitoring and evaluation trends for the LSRCP Imnaha River hatchery program.

ACKNOWLEDGMENTS

The Nez Perce Tribe extends the administrative support necessary to complete these projects and this report. Project funding from the U.S. Fish and Wildlife Service's Lower Snake River Compensation Plan program initiated the Imnaha River emigration project investigations in 1992 and the project continues today. The Bonneville Power Administration also provides significant project cost share funding for the Imnaha Smolt Monitoring Project. We wish to thank the following NPT employees for their hard work and dedication gathering the necessary data for this report: Cameron Albee, Mike Blenden, David Bright, Dirk Evans, Katie Frenyea, Justin Gould, Jim Harbeck, David Kane, Joe McCormack, Neal Meshell, Leland Mitchell, Jeff Nehls, and Cindy Sloan. Jay Hesse and Jason Vogel provided technical support and advice for these studies and reviews of the report. We also acknowledge the Oregon Department of Fish and Wildlife (ODFW) for PIT tagging under BPA program number 199602000 and for conducting the acclimation and releases of hatchery origin Chinook and steelhead. Appreciation is also extended to Joseph Feldhaus of ODFW for providing information on rearing and releases of hatchery fish. We extend our gratitude to the United States Forest Service for allowing us the use of the THOn Creek guard station facilities, and Scott and Vicki McClaran of McClaran Ranch Inc. for access to their land for trapping purposes. The Fish Passage Center's Data System Administrative Manager, and Senior Data Analyst, Sergei Rasskazov and Computer Specialist, Chris McCarty provided software that assisted with daily tasks.

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BACKGROUND

This report summarizes the Nez Perce Tribe (NPT) Department of Fisheries Resources Management (DFRM) juvenile emigration studies for the Imnaha River Smolt Monitoring Project and the Lower Snake River Compensation Plan Monitoring and Evaluation studies for the 2009 smolt migration year from the Imnaha River, Oregon. These studies are closely coordinated and provide information about juvenile natural and hatchery origin spring/summer Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) biological characteristics, survival, and emigration timing, including arrival timing at and travel time to the Snake River dams and McNary Dam on the Columbia River. These studies also provide biological information and smolt to adult return rate information on ESA listed Chinook salmon and steelhead for the Federal Columbia River Power System (FCRPS) Biological Opinion (NMFS 2000). Co-managers in the Imnaha River subbasin have identified the need to collect information on life history, migration patterns, juvenile emigrant abundance, reach specific smolt survivals, and smolt to adult return rates (SAR's) for both steelhead and Chinook salmon smolts (Ecovista 2004). The studies conducted during the fall of 2008 and spring of 2009 provided information related to the majority of the high priority data needs.

Population Status

The Grande Ronde-Imnaha Major Population Group (MPG) is an important contributor to the Snake River Basin Chinook salmon Evolutionarily Significant Unit (ESU) and has major cultural and social significance for tribal and non-tribal people of Northeast Oregon (Hesse et al 2004). Historically, the Imnaha subbasin supported one of the largest runs of spring/summer Chinook salmon in Northeast Oregon (Wallowa County and Nez Perce Tribe 1993). Prior to the construction of the four lower Snake River dams, an estimated 6,700 adult wild spring/summer Chinook salmon returned to the subbasin annually (USACE 1975). Since dam construction and other major anthropogenic factors, returns of Imnaha River natural origin adults have declined significantly and are currently part of the Snake River basin spring/summer Chinook salmon Evolutionary Significant Unit (ESU) that was listed as threatened under the United States Endangered Species Act (ESA) in 1992. The Imnaha Subbasin Management Plan maintains objectives of returning 5,740 adult Chinook (3,800 natural adults) to the Imnaha Basin annually (Ecovista 2004). The estimated adult abundance in 2009 was 432 wild and 1,530 hatchery spawners in the Imnaha River (Feldhaus et al. 2012).

Imnaha River summer steelhead are one of the six MPGs that are part of the Snake River Basin Steelhead Distinct Population Segment (DPS) that was listed as threatened under the ESA in 1997. Their listing status was reaffirmed in January 2006. Listed wild fish from Little Sheep Creek were incorporated into the Little Sheep hatchery broodstock; therefore, hatchery progeny (naturally produced fish and hatchery fish with an intact adipose fin) were considered part of the DPS and were covered by Section 4(d) protective regulations in the 2006 rule (ODFW 2011). Estimates of annual adult steelhead returns to the Imnaha River may have exceeded 4,000 steelhead in the 1960's. The Imnaha Subbasin Management Plan maintains objectives of returning 4,315 adult summer steelhead (2,100 natural adults) to the basin annually (Ecovista 2004). Currently steelhead returns are monitored in a few small tributaries including Camp, Cow, Lightning and Horse Creeks. Redd counts in Camp Creek estimated an adult spawner abundance ranging from 2 in 1976, to 159 in 2009 (NMFS 2010). Adult weirs in Lightening, Cow and Horse creeks have estimated adult spawner escapement ranging from 30 to greater than 200 for each stream (Young & Espinosa 2011; Young et al. 2011).

Project History

The vision of the Nez Perce Tribe DFRM is to recover and restore all species and populations of anadromous and resident fish within the traditional lands of the Nez Perce Tribe. The Nez Perce people have historically managed and fished throughout the Snake River basin and the mainstem Columbia River. The once abundant salmon runs were vital to supporting the Nez Perce way of life and served as a powerful cultural and social icon for the Nez Perce people. Due largely to hydroelectric power developments, habitat degradation, water quality impacts, and over-harvesting, those once robust salmon and steelhead runs have declined significantly.

The Lower Snake River Compensation Plan (LSRCP) was conceived and implemented by the United States Fish and Wildlife Service (USFWS) in 1976 to mitigate for spring, summer and fall Chinook salmon and steelhead losses to streams in the Snake River basin due to construction of the four Lower Snake River hydroelectric facilities. In 1985 the Tribe became involved in the program, and implemented the Nez Perce Tribe's Lower Snake River Compensation Plan Monitoring and Evaluation Studies (LSRCP M&E; project No. 141106J014). The LSRCP presently supports 11 hatchery programs in three states. This program is one approach to attempt to preserve and recover anadromous fish populations in the Snake River basin. One goal of the LSRCP Program is to maintain the hatchery production of 360,000 Chinook salmon smolts and 215,000 to 330,000 steelhead smolts for annual release in the Imnaha River (United States v. Oregon, 2008).

Juvenile spring/summer Chinook salmon and steelhead emigrant monitoring in the Imnaha River has been ongoing since 1992. The LSRCP funded the first two years of monitoring. In 1994, direct funding for the NPT Imnaha River Smolt Monitoring Project (IRSMP) to monitor hatchery and natural steelhead and Chinook was provided by BPA as part of the larger Smolt Monitoring by Non-Federal Entities Project (No. 198712700) and the Fish Passage Center's Smolt Monitoring Program (SMP). These larger projects provide data on smolt emigration from major tributaries to, and past hydroelectric facilities on the Snake and Columbia Rivers. Passive integrated transponder (PIT) tagged smolts are utilized to measure travel time and estimate survival through key index reaches. With the funding and support provided by BPA, FPC, and LSRCP, in-season indices of emigration strength and timing are provided to the Fish Passage Center by IRSMP for Imnaha River smolts at the Imnaha River trap and mainstem dams. Fish quality and descaling information are recorded at the Imnaha River trap to provide health indicators of emigrating smolts. This real-time tributary specific emigration data has been utilized in operational decisions relative to flow and spill management to improve smolt passage, and continues a collection of a time series of Chinook salmon and steelhead smolt arrival and survival information to mainstem dams.

One of the aspects of the LSRCP M&E studies in the Imnaha River is to quantify and compare natural origin return (NO) and hatchery origin return (HO) Chinook salmon and steelhead smolt performance, emigration characteristics and survival (Kucera and Blenden 1998). A long-term monitoring effort was established to document smolt emigrant timing and post release survival within the Imnaha River, estimate smolt survival downstream to McNary Dam, compare NO and HO smolt performance, and collect smolt to adult return information. In 2003 the studies began participation in the Separation by Code (SbyC) system. With the SbyC technology in operation at the hydrosystem bypass facilities it became possible to accurately represent non-PIT tagged fish migrating through the hydrosystem using a predetermined group of PIT tagged fish. The SbyC technology is further described in the METHODS section of this report under *Smolt to adult return rate indices*. The completion of trapping in the spring of 2009 marked NPT's 18th year of emigration studies on the Imnaha River, and the 16th year of participating in the FPC's Smolt Monitoring Program.

Imnaha River Juvenile Emigrant Monitoring &Evaluation Objectives

The IRSMP and Imnaha River LSRCP M&E studies assess the life-stage specific status and performance of NO and HO Chinook salmon and steelhead under a framework of M&E objectives listed below. A main goal of these studies is to provide real-time data from fish PIT tagged at the Imnaha River juvenile emigrant trap to the Fish Passage Center to inform in-season management decisions on hydrosystem operations.

M&E Objective 1: Quantify life-stage specific emigrant abundance of Imnaha River NO juvenile Chinook salmon and steelhead.

> Objective 1a: Quantify juvenile emigrant abundance for NO Chinook salmon emigrating past the Imnaha River trap during the fall and spring emigration seasons as well as a total emigrant abundance estimate for Migration Year 2009.
>
> Objective 1b: Quantify juvenile emigrant abundance for NO steelhead smolts emigrating past the Imnaha River trap in the spring.

M&E Objective 2: Quantify and compare life-stage specific emigration timing of Imnaha River juvenile Chinook salmon and steelhead.

> Objective 2a: Quantify the arrival timing of fall and spring emigrating NO Chinook salmon and spring emigrating HO Chinook salmon at the Imnaha River trap (represents timing of Chinook pre-smolt and smolt emigration from the Imnaha River basin) and compare the arrival timing between HO and NO fish during the spring emigration season. Describe the environmental parameters of discharge and temperature during peak Chinook emigration periods.
>
> Objective 2b: Quantify the arrival timing of spring emigrating NO and HO steelhead at the Imnaha River trap (represents timing of steelhead smolt emigration from the Imnaha River basin) and describe the environmental parameters of discharge and temperature during peak steelhead emigration periods.
>
> Objective 2c: Quantify and compare the arrival timing of NO Chinook salmon pre-smolts and smolts, HO Chinook salmon smolts, HO steelhead smolts and NO

steelhead smolts from the Imnaha River trap to: Lower Granite Dam (LGR), Little Goose Dam (LGS), Lower Monumental Dam (LMD), and McNary Dam (MCN).

Objective 2d: Quantify and compare the travel time of NO and HO juvenile Chinook salmon and steelhead from the tributary (Imnaha River trap) to LGR.

Objective 2e: Quantify status and trends of Imnaha and Snake River discharge and evaluate effects on juvenile emigrant travel time to LGR.

M&E Objective 3: Quantify and compare life-stage specific survival of juvenile Chinook salmon and steelhead within and from the Imnaha River to Lower Granite Dam on the Snake River and McNary Dam on the Columbia River.

Objective 3a: Quantify the in-river survival (post release survival) of PIT tagged HO Chinook salmon and steelhead smolts from release to the Imnaha River trap.

Objective 3b: Quantify and compare the survival of NO and HO fall emigrating Chinook presmolts and spring emigrating Chinook salmon and steelhead smolts from the Imnaha River trap to LGR and MCN.

Objective 3c: Quantify status and trends of Imnaha and Snake River discharge and evaluate effects on juvenile emigrant survival.

M&E Objective 4: Quantify and compare smolt to adult return (SAR) index rates for Imnaha River NO Chinook and NO and HO steelhead.

Objective 4a: Quantify and compare SAR index rates for PIT tagged NO Chinook salmon pre-smolts tagged at the Imnaha River trap during the fall and spring-tagged smolts for run-of-river release groups.

Objective 4b: Quantify and compare SAR index rates for PIT tagged HO and NO steelhead smolts tagged at the Imnaha River trap for run-of-river release groups.

M&E Objective 5: Describe life-stage specific biological characteristics of Imnaha River juvenile Chinook salmon and steelhead.

Objective 5a: Quantify and compare biological characteristics, including fork length (mm), weight (g), and condition factors, of NO Chinook salmon pre-smolts, and NO and HO Chinook salmon and steelhead smolts.

Description of Project Area

The Imnaha River subbasin is located in Northeastern Oregon (Figure 1) and encompasses an area of approximately 2,538 square kilometers. The mainstem Imnaha River flows in a northerly direction for 129 km from its headwaters in the Eagle Cap Wilderness Area to its confluence with the Snake River (James 1984; Kucera 1989). Elevations in the watershed vary from 3,048 m at the headwaters to about 260 m in lower elevations (Kucera 1989).

Reservoirs encountered by emigrating Imnaha River Chinook salmon and steelhead smolts are formed by Lower Granite Dam (LGR), Little Goose Dam (LGS), Lower Monumental Dam (LMD) and Ice Harbor Dam (IHD) in the Snake River and McNary Dam (MCN), John Day Dam (JDD), The Dalles Dam (TDD), and Bonneville Dam (BON) in the Columbia River (Figure 2). Juvenile emigration monitoring described in this report occurs at LGR, LGS, LMD, and MCN. Juvenile emigration at Ice Harbor Dam is not monitored because IHD lacks the necessary juvenile detection facilities.

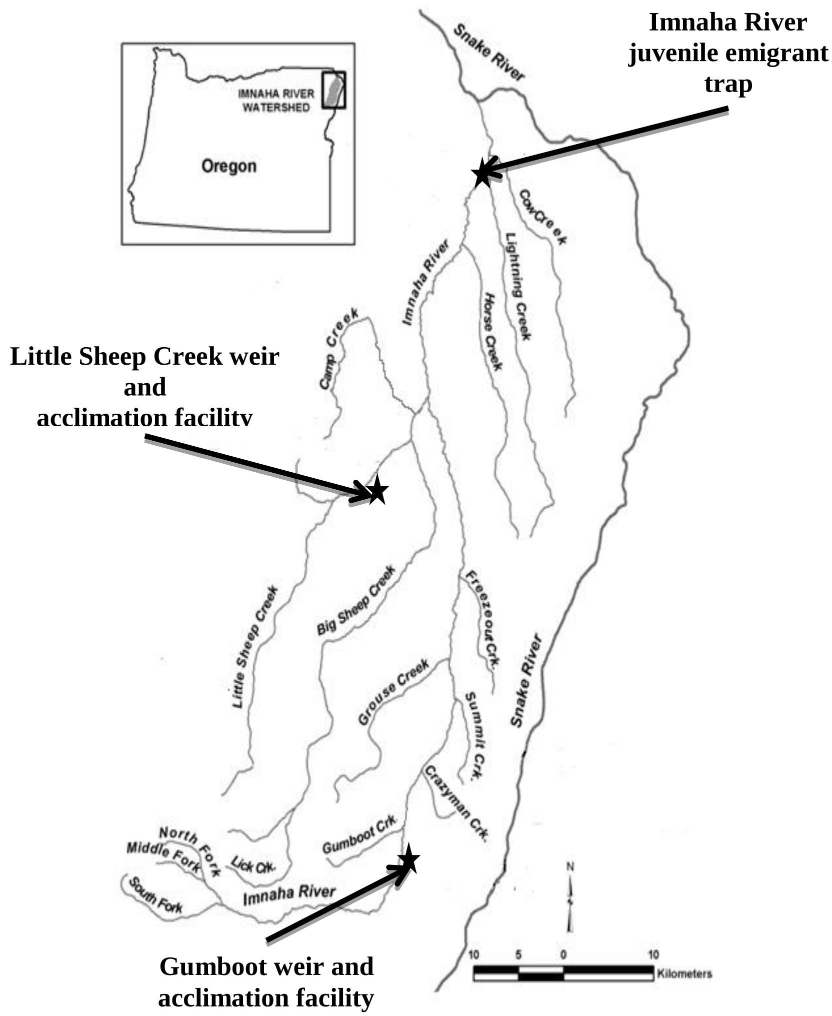

Figure 1. Map of the Imnaha River study area showing the location of the Imnaha River juvenile emigrant trap at N 45.76381 W 116.74802, the Gumboot Chinook salmon acclimation facility and the Little Sheep Creek steelhead acclimation facility.

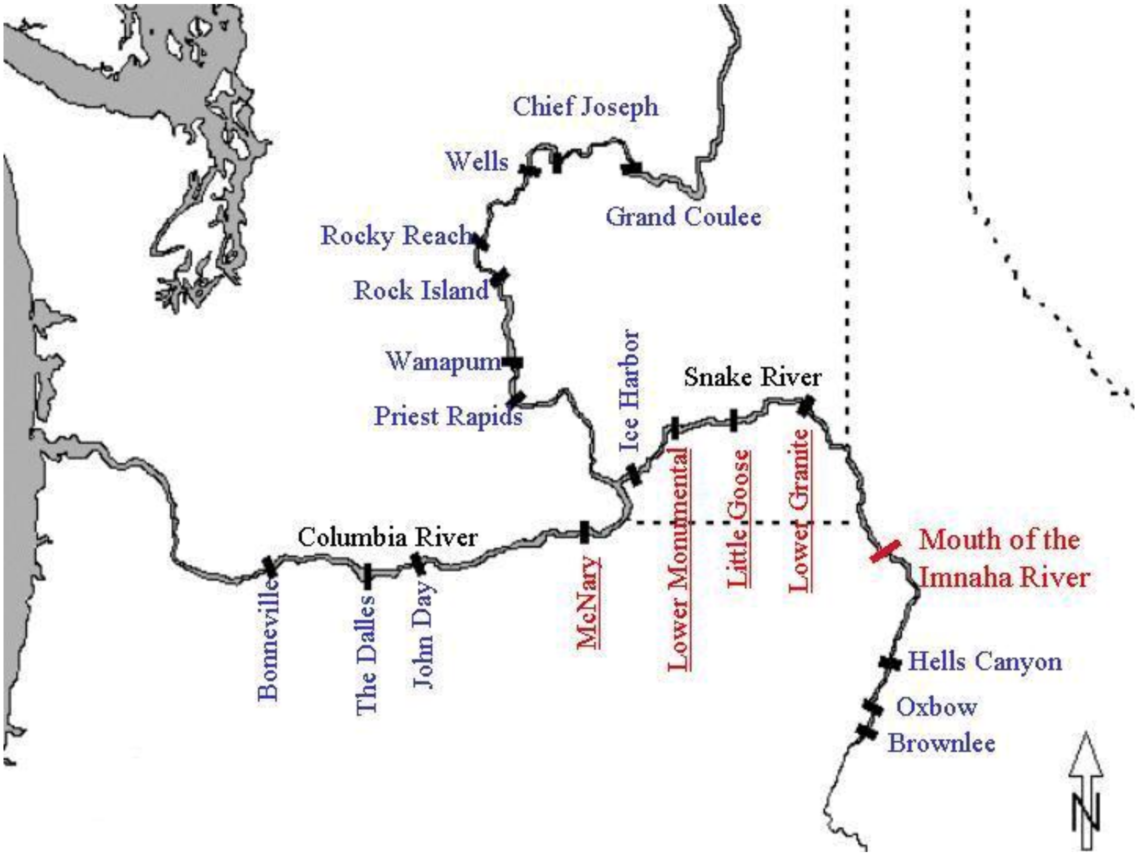

Figure 2. Map of the Columbia River Basin. Dams underlined indicate monitoring points for the Nez Perce Tribe Imnaha River Smolt Monitoring Project.

METHODS

Equipment Description

The primary field data collection method used to trap emigrating Chinook salmon and steelhead juveniles is the operation of a rotary screw trap. The Imnaha River juvenile emigrant trap is located at N 45.76381 W 116.74802, seven river kilometers (rkm) from the confluence with the Snake River. It is located as close to the confluence as possible and still accessible by road. The screw trap, manufactured by E.G. Solutions Inc., Corvallis, OR, has a rotating cone that is 2.1m in diameter and sits atop two or four (four during high spring flows) floating pontoons that are 6.7 m long, with a live box and debris drum (Figure 3).

Figure 3. The Imnaha River juvenile emigrant trap site with a rotary screw trap operating.

Trap Operations

Fish Handling

The trap was operated from October 2 to December 10, 2008 and from February 26 to June 17, 2009 in order to capture migration year 2009 Chinook salmon and steelhead emigrants. The trap was checked daily at 0800 and several times throughout each night and day, if warranted by large numbers of fish or excessive debris. Non-target piscivorous fish and large numbers of other non-target fish were removed from the live box first, then Chinook salmon and steelhead juveniles were netted into buckets and carried to the tagging tent and placed in aerated buckets.

Daily processing procedures were as follows. Fish were anaesthetized in a MS-222 bath (6 ml MS-222 stock solution (100 g/L) per 19 L of water) buffered with Propolyaqua until they could be effectively handled. All fish were examined for existing marks (e.g. fin clips and external tags) and Chinook salmon, steelhead, and large piscivorous fish were scanned with a Destron Fearing FS2001F PIT tag reader. A target number of each species was selected for PIT tagging based on the average daily catch and all other fish were enumerated and released 30-50 m downstream from the trap after recovering from the anesthetic. Fifty randomly selected NO Chinook salmon and 50 NO steelhead smolts were PIT tagged and released approximately one kilometer upstream of the trap for daily trap efficiency estimation. All other tagged fish were held in perforated recovery containers in the river and released after dark downstream of the trap and mortality due to trapping and tagging was recorded.

During peak emigration periods the trap often captured more smolts that can be safely processed in a reasonable time. To ensure that fish health was not compromised, two subsampling procedures were used to ensure a representative sample of juvenile fish trapped during both sampling and subsampling procedures. The first subsampling procedure was used when a moderate number of fish were entering the trap. Initially, a partition was placed in the trap to by-pass fish around the trap box and through a PIT tag antennae to monitor for recaptures (trap efficiency or previously tagged fish). Fish in the trap box were removed and processed as described above to get a composition of trapped fish captured prior to subsampling. After the trap box was cleared the partition was removed and fish were collected for a fixed period of time. After the set duration of trapping the partition is placed in the trap to isolate the collected fish from incoming fish and the fish in the box were processed. This is repeated until the number of fish entering the trap didn't exceed the ability of the crew to process all of the fish. Abundance and composition passing the trap during the subsampling procedure was estimated by multiplying the number of processed fish by an appropriate time ratio determined by the duration of the subsampling each hour. For example, if fish were collected for 15 minutes and then bypassed for 45 minutes the ratio would be 1:4. The estimated total number of fish passing would equal the total processed multiplied by four and the composition of the handled fish (origin, recapture, length, etc.) would be expanded to the total abundance estimate for each species. The second subsampling routine was used when the number of fish in the trap was so large that all fish could not be processed in a reasonable amount of time. Similar to above, the partition was placed in the trap box to isolate all trapped fish within the live box and divert captured fish through the PIT tag detector. The composition of fish in the trap box was determined by subsampling and processing net-fulls of fish. This was accomplished by scooping one or more net-fulls of fish from the live box for processing then scooping equally-sized net-fulls of the remaining fish to determine the total number of net-fulls that were in the box at time the subsampling began. All net-fulls were passed through a separate PIT tag antenna to interrogate any previously PIT tagged fish. This estimate was expanded in a similar way to the first routine except "net-fulls" becomes the multiplier. The subsample consisted of a remote monitoring (RM) file of PIT tag numbers and a text file recording the expanded fish numbers. The PIT tag data collected were incorporated into recapture numbers and trap efficiency calculations. The expanded fish numbers were included in the number of fish handled and incidental species counts. All other pertaining calculations within this document were based on the actual PIT tag numbers, not the expanded numbers of fish handled.

PIT tagging and PIT tag recaptures of juvenile NO and HO Chinook salmon and steelhead

The NO Chinook salmon and steelhead juveniles selected for PIT tagging were examined for existing PIT tags, percent of descaling and general health. All fish were measured for fork length to the nearest millimeter and weighed to the nearest 0.1gram. Only Chinook salmon greater than 60 mm were selected for tagging. Fish were PIT tagged using hand injector units following the methods described by Prentice et al. (1986, 1990) and Matthews et al. (1990, 1992). Hypodermic injector units and PIT tags were sterilized after each use in ethanol for at least 10 minutes and allowed to dry prior to reuse. Tagging was discontinued when water temperatures exceeded 15° C. PIT tagged fish were held in perforated recovery containers in the river and released after dark. All previously PIT tagged fish of either hatchery or natural origin were recorded as recaptures at the trap, and released downstream immediately upon recovering from the anesthetic.

PERFORMANCE MEASURE EVALUATIONS

Life-stage specific estimates of natural origin juvenile emigrant abundance

Spring and fall juvenile emigrant abundance for NO Chinook salmon and spring NO steelhead were estimated for the tributary using the weekly catch numbers by species and life-stage and expanded by the weekly trap efficiency rate. Data analysis was performed using the Gauss program (Aptech Systems Inc., Maple Valley, Washington) with a Bailey trap efficiency estimation method (Steinhorst et al. 2004). The Bailey estimate is a version of the Lincoln-Peterson method. The Gauss program utilizes a bootstrap method with 1000 iterations to provide a distribution of population estimates, then calculates the point estimate, the 95% confidence intervals, and standard error and utilizes stratified data when appropriate. To maintain robustness for analysis, we set a lower limit of seven mark recaptures for any period when assessing trap efficiencies (Steinhorst et al. 2004). Coefficients of variation (C.V.) were calculated by dividing the standard error by the population estimate (point estimate) as an indicator of precision.

Trap efficiencies

Daily trap efficiency (TE) trials were conducted across the entire trapping period using PIT tagged NO Chinook salmon and steelhead smolts. The daily goal was to randomly PIT tag 50 NO Chinook salmon and 50 NO steelhead. Fish marked for TE trials were held in perforated containers in the river during daylight hours (up to 12 h) and then transported upstream approximately one kilometer and released after dark. Daily TE trials were grouped into weekly periods if at least seven marked fish were recaptured and flow conditions were relatively stable during a weekly period. Weeks with less than seven recaptures were grouped with either the preceding week or the following week depending on similarity of flow conditions. Trap efficiency was determined by $E = R/M$; where E is estimated trap efficiency, R is number of marked fish recaptured, and M is number of fish marked and released.

Hatchery releases

In 2009 HO Chinook salmon and steelhead were released by LSRCP facilities managed by the Oregon Department of Fish and Wildlife (LSRCP, 2009). In 2009 two HO steelhead groups were released. First a volitional release from the Little Sheep Acclimation Facility occurred during the period from March 31 to April 28 following a 3 week acclimation period. Second, a direct release into Big Sheep Creek occurred on April 7, 2009 (Appendix H, Warren et al. 2011). HO Chinook salmon were volitionally released from the Gumboot Acclimation Facility from March 30 to April 15, 2009. An unplanned direct release of HO Chinook occurred on March 12 to liberate diseased fish that were not to be acclimated with the remaining brood year 2007 smolts (Joseph Feldhaus, Oregon Department of Fish and Wildlife, personal communication.) This release group is not included in any of the analyses in this report.

Life-stage specific emigration timing of Imnaha River juvenile Chinook salmon and steelhead

Timing of juvenile emigration from the Imnaha River

Due to the proximity of the Imnaha River trap to the confluence with the Snake River (seven river kilometers) it was assumed that juvenile emigrant arrival timing at the trap represented emigration timing from the tributary to the Snake River. Consequently, cumulative emigration timing from the Imnaha River was quantified for each group of NO and HO Chinook salmon and steelhead juveniles. Capture timing of NO Chinook salmon was compared to the timing of recaptures of HO fish that had been PIT tagged prior to release. Similarly, comparisons were made between two different hatchery steelhead release methods (direct release and acclimated volitional release) and NO steelhead to determine patterns of emigration timing. Tests for differences in emigrant timing using the cumulative proportion of each release group caught over time were conducted with a Kolmogrovov-Smirnov (K-S) test (Steel et al. 1997 and STATGRAPHICS 1995). The PIT tag interrogation data used for these comparisons were queried from the Pacific States Marine Fisheries Commission (PSMFC's) PIT Tag Information System database (PTAGIS).

Arrival timing of Imnaha River juvenile emigrants at mainstem dams

Arrival timing at Lower Granite Dam (LGR), Little Goose Dam (LGS), Lower Monumental Dam (LMD), and McNary Dam (MCN) was quantified for NO and HO Chinook salmon and steelhead using PIT tag interrogation data queried from PTAGIS and the proportion of emigrant passage over time. Detections and arrival timing at each dam for this report period were based on first-time observations of individual tag codes at each dam. The cumulative distribution of arrival times between fall- and spring-tagged juvenile NO Chinook salmon, as well as NO and HO Chinook and steelhead spring smolts were compared using a Kolmogrovov-Smirnov test (Steel et al. 1997). The cumulative proportion that arrived before the May 1, 2009 initiation date of full collections for juvenile transportation at LGR was calculated for each release group by species and origin to determine the proportion of juvenile emigrants that had passed the dam before transportation was initiated.

Travel time from the Imnaha River Trap to LGR in relation to Snake River flow

We calculated travel time from the trap to LGR as the number of days from release or interrogation at the trap to the first detection at LGR for PIT tagged juveniles. Mean travel time for all fish detected at LGR by week was determined and compared for HO, spring-tagged NO smolts and fall-tagged NO pre-smolts. In addition, we determined the relationship between weekly mean travel time and Snake River flow using a regression analysis. Snake River water discharge was provided by the USGS gauge 13334300 at Anatone, Washington at http://waterdata.usgs.gov/usa/nwis/uv?site_no=13334300. Measurements of outflow and spill at LGR were obtained online from DART at http://www.cbr.washington.edu/dart/.

Life-stage specific estimates of juvenile emigrant survival

Survival estimates from the Imnaha River to LGR and MCN were calculated for HO and NO steelhead and Chinook salmon smolts and NO Chinook salmon pre-smolts. Release groups of HO and NO Chinook salmon juveniles were evaluated independently by season and also as a combined release group by migration year. NO and HO steelhead smolts were evaluated for a spring release group only since insufficient numbers of NO steelhead are tagged in the fall, and there are no fall releases of HO fish. The assumptions for the methodology can be found in Smith et al. (1994) and Burnham et al. (1987).

In-river survival (post release survival in the tributary) was also calculated for HO Chinook and steelhead smolts from their point of release to the Imnaha River juvenile emigrant trap at rkm 7. HO release groups were evaluated separately according to their release location and method. Hatchery releases occurred as acclimated volitional releases from the LSRCP Gumboot Acclimation Facility on the Imnaha River (Chinook), acclimated volitional releases from the LSRCP Little Sheep Creek Acclimation Facility (steelhead), or direct releases into Big Sheep Creek (steelhead) and the Imnaha River at Summit Creek bridge (please note that this was an early liberation of diseased HO Chinook, and not a planned conventional release.) In order to minimize bias, the 2009 direct release of Chinook salmon (disease mitigation fish) were not evaluated independently for post release survival or survival to mainstem dams. Survival probabilities were estimated by the Cormack, Jolly and Seber methodology (1964, and 1965, respectively, as cited in Smith et al. 1994) with the Survival Using Proportional Hazards (SURPH) model (Smith et. al. 1994) used for comparison. The data files for season- and migration year-wide release groups were created using the program PITPRO version 4.10 (Westhagen and Skalski, 2007). Data for PITPRO and SURPH was obtained directly from PTAGIS.

The relationship between juvenile survival and Imnaha or Snake River discharge provides information about the environmental conditions that maximize survival to LGR and may provide useful information important for the management of hatchery release strategies. Imnaha River discharge data was obtained online from USGS gauge 13292000 at Imnaha, Oregon at http://waterdata.usgs.gov/usa/nwis/uv?site_no=13292000. Snake River water discharge and temperature information was provided by the USGS gauge 13334300 at Anatone, Washington at http://waterdata.usgs.gov/usa/nwis/uv?site_no=13334300.

Smolt to adult return (SAR) index rates

The smolt to adult return index rates quantified for this report are a measure of the number of PIT tagged adults from a given brood year that return to LGR divided by the number of PIT tagged smolts that left the juvenile collection facility at LGR one to three years prior, integrated over all return years. For this report, PIT tagged juveniles and adults were used for SAR index rate analyses. For LGR – LGR SAR index rates, adult PIT tag detections at LGR are totaled by their juvenile release group and brood year (Chinook salmon) or migration year (steelhead), and divided by the number of PIT tagged-juveniles detected at LGR from that brood or juvenile migration year. For Imnaha – LGR SAR index rates, adult PIT tag detections at LGR are divided by the number of juveniles from the corresponding brood or migration year PIT tagged at the Imnaha River trap.

Smolt to adult return index rates were quantified for two groups of PIT tagged NO Chinook salmon from the Imnaha River, the fall-tagged survival mode pre-smolts and spring-tagged survival mode smolts for brood years 1996 through 2004. Steelhead SAR index rates were calculated for both HO and NO steelhead for survival mode PIT tagged release groups. HO steelhead SAR index rates were evaluated by brood year from HO steelhead captured and PIT tagged at the Imnaha River juvenile emigrant trap for migration years 2000 through 2007 (brood years 1999 – 2006.) Natural-origin steelhead SAR index rates were calculated by migration year from 2000 through 2007, as the PIT tagged release groups from the Imnaha River trap include juveniles of unknown brood years, making analysis by brood year impossible for NO steelhead.

Fish marked with PIT tags migrating downstream from the Imnaha River will travel through the hyrdorsystem in one of two predetermined designations; monitor mode or survival mode. The Separation by Code (SbyC) system allows PIT tagged fish interrogated at the hydrosystem juvenile bypass facilities to be segregated by these two actions depending on specific PIT tag codes. Survival mode fish are always bypassed back to the river in an effort to assess in-river survival of emigrating juveniles. The monitor mode group are treated as the run-at-large fish (non-PIT tagged) and barged or bypassed depending on the management actions at any given time at each hydrosystem facility. The survival mode is the default action for PIT tagged fish even when the run-at-large fish are being transported. Consequently, default action fish do not represent the non-PIT tagged fish migrating through the hydrosystem and do not accurately represent the SAR rate for the entire coHOt. Monitor mode codes provide a more useful evaluation of SAR rates because they more closely represent the run-at-large group. We plan to use monitor mode and survival mode codes in the future to more accurately calculate SAR rates for Imnaha River Chinook and steelhead; however, prior to migration year 2010, insufficient numbers of monitor mode tags were distributed by this project to perform SAR rate analyses on that particular SbyC mode. For this report, SAR index rates were calculated for survival mode (in-river migration) release groups only.

Life-stage specific evaluation of biological characteristics

Juvenile emigrants were evaluated for life-stage specific biological characteristics of fork length (mm), weight (g), and condition across the spring and fall emigration periods. Length frequency distributions and condition factors were calculated for each fish species by origin. Length frequencies were based on five millimeter classes. Condition factors were calculated using Fulton's condition factor: $(W/L^3) \times 10^5$ (Bagenal and Tesch 1978). NO *O. mykiss* less than 120 mm or that had the morphological characteristics of resident rainbow trout were assumed not to be actively migrating and therefore were not PIT tagged or used in length, weight and condition factor calculations and were reported as rainbow trout.

All statistical evaluations that compared fish captured and tagged were performed with STATISTIX7 developed by Analytical Software (2000). A student t-test was used to test for significant differences in mean fork length between various groups of fish. Differences were considered significant at $p < 0.05$. Median fork lengths were compared with the Wilcoxon rank sum test (Ott, 1984). Differences were considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

Trap operations

The emigrant trap was operated for a total of 172 days during migration year 2009 (MY2009). Fall trapping spanned from October 2 until ice-in on December 10, 2008 (70 days), with no inoperable periods due to icy conditions. Spring trapping commenced on February 26 and operated through June 17, 2009 (114 days) with a total of 12 inoperable days resulting from high flows and debris (11) and staffing conflicts (1). Subsampling procedures were used to estimate juvenile abundance for 6 of the 114 days during the spring trapping period. Please refer to Appendix A for a summary of total hours fished and total catch by day.

Target catch

The catch of MY2009 NO Chinook salmon totaled 9,222 fish including 2,754 pre-smolts trapped in the fall of 2008, and 6,468 smolts trapped in spring (Table 1). A total of 8,812 NO Chinook salmon were PIT tagged at the Imnaha trap for MY2009, of which 3,155 were marked and released above the trap for trap efficiency trials (Table 1, Appendix B). A total of 14 of the 1,000 NO Chinook salmon that were previously PIT tagged by Oregon Department of Fish and Wildlife's (ODFW) Early Life History Program during September of 2008 were recaptured at the Imnaha River trap. Please refer to Appendix C for trap date and travel time data for these fish.

The catch of MY2009 NO steelhead totaled 5,857 fish including 154 trapped in fall and 5,703 trapped in spring (Table 2). A total of 5,164 NO steelhead were PIT tagged, of which 1,362 were marked and released above the trap for trap efficiency trials (Table 2, Appendix B). NO steelhead were not tagged in the fall since the number of fish captured was typically too small to produce an accurate abundance estimate.

A total of 36,674 HO Chinook smolts representing brood year 2007 were captured at the Imnaha River trap during the MY2009 spring trapping period (Appendix A). HO Chinook captures were from two release groups totaling approximately 293,802 smolts. A volitional release group of approximately 234,963 smolts was released from the Imnaha River Gumboot acclimation facility at rkm 74 beginning March 30, 2009 until April 15 when all remaining smolts were forced out. A direct release of approximately 58,839 Chinook smolts occurred at the Summit Creek Bridge in the Imnaha River on March 12, 2009. These smolts were supposed to be acclimated at the Gumboot Facility but disease concerns resulted in an early released (Feldhaus, J. personal communication, July 2012). A total of 1,760 previously PIT tagged HO Chinook salmon were recaptured at the Imnaha juvenile emigrant trap. Please refer to Appendix H for additional information on these two release groups of HO Chinook.

A total of 16,365 HO steelhead smolts representing brood year 2007 were captured at the Imnaha River trap during the MY2009 spring trapping period (Appendix A). HO steelhead captures were from two release sites in the Imnaha River subbasin totaling 187,401 smolts (Appendix H). A volitional release of 142,103 HO steelhead from the LSRCP Little Sheep Creek acclimation facility began March 31 and ended April 28 when all remaining fish were forced out. The second was a direct release group of 45,298 HO steelhead into Big Sheep Creek that occurred April 7, 2009 (Warren et al. 2011). A total of 1,987 previously PIT tagged HO steelhead released from the Little Sheep Creek and Big Sheep Creek acclimation facilities were recaptured at the Imnaha River trap. Please refer to Appendix H for additional information on these two release groups of HO steelhead.

Table 1. Gauss population estimates by release group and totals for natural-origin Chinook salmon captured in the Imnaha River juvenile emigrant trap during migration year 2009 (MY 2009; fall 2008 and spring 2009). Table includes the date that the trap efficiency trail started (Date), total fish captured by the screw trap (Caught), total marked (Mark), total recaptured (Recap), trap efficiency for the period (T.E.), total population estimate (Pop), lower 95% confidence interval (Lower C.I.), upper 95% confidence interval (Upper C.I.) and standard error (S.E.).

Date	Caught	Mark	Recap	T.E. (%)	Pop	Lower C.I.	Upper C.I.	S.E.
9/28	1,518	323	27	8.4	17,565	12,348	26,187	3,615.2
11/16	882	292	35	12.0	7,179	5,346	9,787	1,148.9
11/23	354	168	20	11.9	2,849	2,094	3,888	472.8
Fall totals	2,754	783	82	10.8	27,593	21,981	36,906	3,698.6
2/22	412	213	26	12.2	3,266	2,281	4,771	640.8
3/8	382	154	30	19.5	1910	1443	2,555	287.5
3/22	1201	374	35	9.4	12,510	8,461	19,046	2,732.0
3/29	644	305	47	15.4	4,106	2,991	5,732	713.1
4/5	890	268	30	11.2	7,723	5,266	11,596	1,594.2
4/12	1,409	398	25	6.3	21,623	13,156	35,711	6,330.1
4/26	641	292	43	14.7	4,269	3,110	6,019	714.0
5/3	889	368	34	9.2	9,373	6,328	14,606	2,168.2
Spring totals	6,468	2,372	270	12.2	64,780	55,444	77,474	5,732.4
MY 2009 Totals	9,222	3,155	352	11	92,373	80,823	106,105	6,455.3

Table 2. Gauss population estimates by release group and totals for natural-origin steelhead captured in the Imnaha River juvenile emigrant trap during spring 2009. Table includes the date that the trap efficiency trial started (Date), total fish captured by the screw trap (Caught), total marked (Mark), total recaptured (Recap), trap efficiency for the period (T.E.), total population estimate (Pop), lower 95% confidence interval (Lower C.I.), upper 95% confidence interval (Upper C.I.) and standard error (S.E.).

Date	Caught	Mark	Recap	T.E. (%)	Pop	Lower C.I.	Upper C.I.	S.E.
2/22	400	187	15	8.0	4,700	2,918	7,812	1,256.0
4/26	856	308	46	14.9	5,628	4,072	7,736	952.2
5/10	2,166	365	49	13.4	15,855	11,219	23,080	3,061.5
5/17	1,564	183	13	7.1	20,555	12,515	33,911	5,573.3
5/24	717	319	23	7.2	9,560	5,978	16,074	2,630.3
Totals	5,703	1,362	146	10.1	56,298	45,378	71,595	6,661.0

Incidental catch

The incidental catch during the fall and spring of migration year 2009 was estimated to total 1,583 fish comprising of seven families of fishes: Salmonidae, Centrarchidae, Catostomidae, Cyprinidae, Cottidae, and Ictaluridae, and Petromyzotidae (Appendix D). The catch of Salmonidae consisted of 80 adult steelhead, 4 adult Chinook salmon, 481 rainbow trout, 242 mountain whitefish (*Prosopium williamsoni*), and 198 bull trout (*Salvelinus confluentus*). Bull trout were divided into adults 300 mm and greater (n=60), and juveniles less than 300 mm (n=138). The juvenile rainbow trout were determined to be resident fish based on morphological characteristics and are not enumerated as NO steelhead juveniles in this report. The catch of Centrarchidae consisted of 18 smallmouth bass (*Micropterus dolomieui*). The catch of the Catostomidae family consisted of 19 bridgelip suckers (*Catostomus columbianus*), 41 largescale suckers (*Catostomus macrocheilus*), and 320 unidentified sucker species. The catch of Cyprinidae included 2 chislemouth (*Acrocheilus alutaceus*), 88 longnose dace (*Rhinichthys cataractae*), 18 Northern pikeminnow (*Ptychocheilus oregonensis*), and 5 redside shiner (*Richardsonius balteatus*). The catch of the Cottidae family consisted of 31 sculpins of unidentified species. The catch of the Ictaluridae family consisted of 14 bullhead of unidentified species. A total of 22 juvenile Pacific Lamprey (*Lampetra tridentata*) of the family Petromyzotidae were caught in the spring of 2009. Lamprey were categorized by their developmental stage as either ammocoetes (larvae) or macropthalmia (juveniles). Please refer to Appendix D for a summary table of the MY2009 Incidental Catch data and Appendix E for detailed Pacific Lamprey catch and biological data.

Trapping and tagging mortality

A total of 25 NO Chinook salmon, 8 HO Chinook salmon, 33 NO steelhead, and 13 HO steelhead mortalities occurred during trapping in MY2009. Eight NO Chinook salmon mortalities occurred during the fall of 2008, accounting for 0.29 % of the NO Chinook salmon fall catch (Appendix F). Of these eight mortalities, seven were from trapping and one was from handling. Seventeen NO Chinook salmon mortalities occurred during the spring: seven due to trapping, two from handling, five from PIT tagging and three that were dead on arrival at the Imnaha trap (Appendix G). The 17 mortalities accounted for 0.26 % of the NO Chinook salmon captured in the spring of 2009. Eight HO Chinook mortalities were recorded in the spring of 2009. Of these eight, three were attributed to trapping, four to handling, and one that was dead on arrival. These eight mortalities accounted for 0.02% of the total catch of HO Chinook in MY2009. There were 31 NO steelhead mortalities during the spring of 2009, and two during the fall of 2008. Of the 31 spring mortalities, eight were from trapping, four from handling, and 19 from PIT tagging, accounting for 0.53% of the total NO steelhead catch in the spring of 2009. The two NO steelhead mortalities recorded in the fall of 2008 were a result of handling and accounted for 1.30% of the total fall catch of NO steelhead during MY2009. A total of 13 HO steelhead mortalities were recorded in MY2009, all during the spring trapping season. Nine of these 13 were attributed to trapping, four to handling, accounting for 0.08% of the total HO steelhead catch.

Twenty-seven incidental catch mortalities occurred during the MY2009 trapping seasons. Twelve of these 27 occurred during fall 2008 trapping. Trapping caused the mortality of one sculpin, handling caused one bridgelip sucker, three juvenile bull trout, and six mountain white fish mortalities, and one rainbow trout was dead on arrival at the Imnaha trap. During spring 2009, a total of 15 mortalities occurred at the trap, with trapping causing the mortalities of 10 sculpins and two suckers of unknown species. One adult steelhead kelt of unknown origin and two suckers of unknown species were dead on arrival at the trap.

PERFORMANCE MEASURE EVALUATIONS

Life-stage specific estimates of NO juvenile emigrant abundance

Gauss population estimates generated from mark/recapture analysis of the trap efficiency fish estimated the spring juvenile emigrant abundance for NO Chinook salmon to be 64,780 smolts, (95% C.I. 55,444 to 77,474; Table 1), with a C.V. of 8.9%. Spring 2009 trap efficiencies for NO Chinook smolts averaged 12.2% and ranged from 6.3% to 19.5% through the season (Table 1). The fall juvenile emigrant abundance estimate for NO Chinook salmon pre-smolts was 27,593 (95% C.I. 21,981 to 36,906; Table 1) with a C.V. of 13.4%. Trap efficiencies averaged 10.8% and ranged from 8.4% to 12.0% through the 2008 fall season (Table 1). The MY 2009 combined juvenile emigrant abundance estimate (fall and spring total) for NO Chinook salmon was 92,373 (95% C.I. 80,823 to 106,405) with a C.V. of 7.0%. Our results indicate that 70% of Chinook salmon juveniles emigrated past the trap during the spring 2009 trapping period (Table 1).

The spring juvenile emigration abundance estimate for NO steelhead smolts in 2009 was 56,298 (95% C.I. 45,378 to 71,595; Table 2) with a C.V. of 11.8%. Trap efficiencies for NO steelhead averaged 10.1% and ranged from 7.1% to 14.9% (Table 2).

These juvenile emigration abundance estimates do not represent a total annual abundance estimate, as trapping was limited to the peak emigration periods in the spring and fall seasons only. In addition, trap efficiency trials were limited by low marking and recapture rates during periods with fewer emigrating juveniles and when the trap was removed during periods of high flows or icy conditions. The number of juveniles that emigrated when the trap was not operational was not determined for migration year 2009. Consequently, abundance estimates presented here represented a minimum NO estimate of juvenile emigrant abundance for migration year 2009 Chinook salmon and steelhead.

Life-stage specific emigration timing of Imnaha River juvenile Chinook salmon and steelhead

Timing of juvenile emigration from the Imnaha River

Arrival timing at the Imnaha River trap, assumed to represent emigration from the Imnaha River, was compared between NO and HO smolt release groups of Chinook and steelhead as well as between NO fall-tagged Chinook pre-smolts and spring-tagged smolts using the cumulative proportion of juveniles captured over time and a Kolmogrovov-Smirnov (K-S) test (Steel et al. 1997). First, 10 percent, median, 90 percent and last arrivals for each release group by species and origin are presented in Table 3.

In 2009 very few HO Chinook salmon were trapped until after the force out from the acclimation facility indicating that juveniles did not immediately emigrate downstream. Although median arrival timing at the trap occurred on the same day, April 10, for both HO and NO Chinook smolts, results of the K-S test demonstrated significant differences in cumulative arrival (emigration) timing between NO and HO fish with the maximum difference occurring early in the emigration season on April 6 (MaxD = 0.3942 $p < 0.05$; Figure 4). The 90 percentile arrival date for HO Chinook was April 17, compared to May 10 for NO Chinook, indicating that the HO emigration was much more contracted than the NO emigration.

Comparing the emigration timing of MY2009 NO and HO steelhead evaluated by the cumulative proportion of each release group captured at the Imnaha River trap indicated that HO steelhead emigration timing was significantly different than that of NO steelhead. Results of the K-S test demonstrated that the maximum difference in emigration timing between NO and HO steelhead occurred on May 5 (MaxD for direct release = 0.6462, MaxD for acclimated release = 0.3445, $p < 0.05$; Figure 5). Similarly, the median and 10 percent arrival dates were significantly different among the origin types (Table 3). Acclimated-volitional released fish from the Little Sheep Acclimation Facility began arriving at the Imnaha River trap on April 2, two days after release, with 10 percent of the PIT tagged fish arriving by April 11. The median arrival date for this release group was May 5, and the 90 percent arrival date was May 18. Direct released fish from Big Sheep Creek began arriving at the trap on April 8, one day after release, with 10 percent of the PIT tagged fish arriving by April 8. The median arrival date of PIT tagged fish from this release group was April 11, with a 90 percent date of May 16. NO steelhead were trapped from February 26 (first day of spring trapping) until June 17 (last day of spring trapping) with 10 percent, median, and 90 percent arrival dates being April 27, May 15, and May 25, respectively. Results demonstrated that peak emigration of NO steelhead did not occur until early May whereas a majority of the HO steelhead had already passed the trap by then. Consequently, neither hatchery release method mimicked the emigration timing of NO steelhead in 2009.

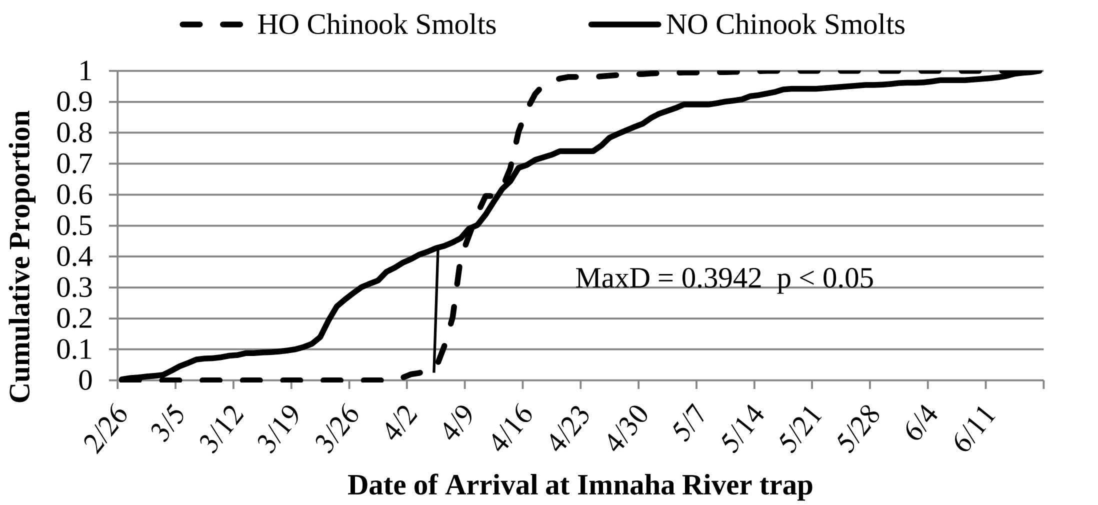

Figure 4. Comparison of emigration timing of natural-origin (NO) and hatchery-origin (HO) Chinook smolts from the Imnaha River presented as the cumulative capture proportion of each origin type at the Imnaha River trap during the spring 2009 trapping season, 26 February to 17 June. Maximum difference in emigration timing (MaxD, represented as the solid vertical line) between the origin types occurred on April 6, 2009.

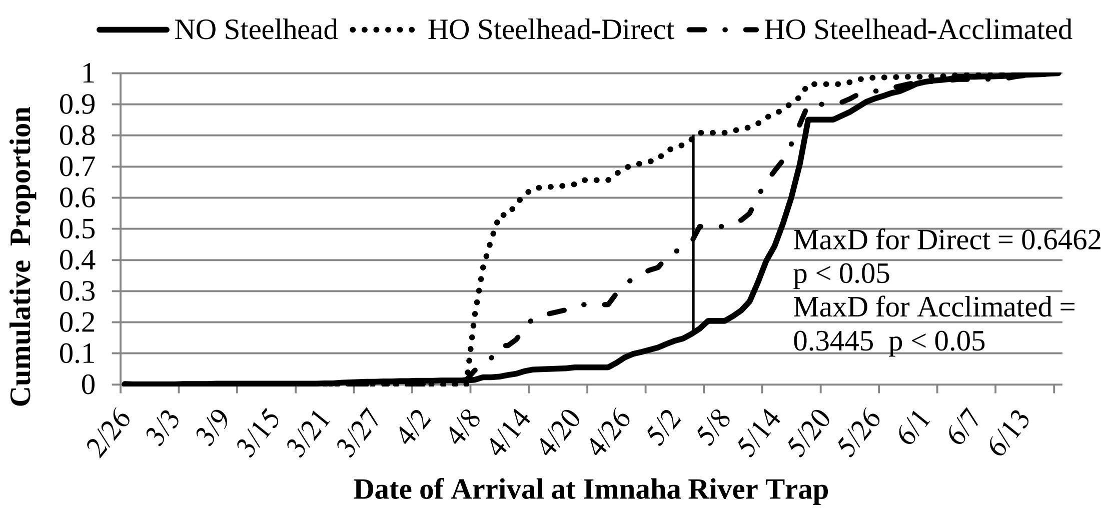

Figure 5. Comparison of emigration timing of natural-origin (NO) and hatchery-origin (HO) steelhead from the Imnaha River presented as the cumulative capture proportion of each origin type at the Imnaha River trap during the spring 2009 trapping season, 26 February to 17 June. Maximum difference in emigration timing (MaxD, represented as the solid vertical line) between the origin types occurred on May 5, 2009 and was the same for both direct release and acclimated HO steelhead.

Table 3. First, 10th percentile, median, 90th percentile, and last arrival dates for natural-origin (NO) and hatchery-origin (HO) Chinook and steelhead smolt release groups captured at the Imnaha River trap during the 2009 spring trapping period, 26 February to 17 June.

Origin species	First Arrival	10th percentile	Median	90th percentile	Last Arrival
NO Chinook salmon	26-Feb	19-Mar	10-Apr	10-May	17-Jun
HO Chinook salmon	1-Apr	6-Mar	10-Apr	17-Apr	15-May
NO Steelhead	26-Feb	27-Apr	15-May	25-May	17-Jun
HO Steelhead-Acclimated	2-Apr	11-Apr	5-May	18-May	17-Jun
HO Steelhead-Direct	8-Apr	8-Apr	11-Apr	16-May	15-Jun

Arrival timing of Imnaha River juvenile emigrants at mainstem dams

Arrival timing at three dams on the Snake River (LGR, LGS, and LMD) and one on the Columbia River (MCN) was calculated for NO and HO juvenile emigrants. First, last and median arrival dates as well as 10 percent and 90 percent arrival dates to LGR, LGS, LMD and MCN are presented in Table 4 for all MY2009 juvenile emigrants. The K-S test was used to determine where significant maximum differences occurred between HO and NO emigration timing as well as between NO Chinook pre-smolts and smolts and NO and HO steelhead smolts

Table 4. Arrival timing for natural-origin (NO) Chinook salmon pre-smolts (fall tagged), NO Chinook salmon smolts (spring tagged), hatchery-origin (HO) Chinook salmon smolts, and NO and HO steelhead smolts determined by Passive Integrated Transponder (PIT) tag detections at Lower Granite Dam (LGR), Little Goose Dam (LGS), Lower Monumental Dam (LMD) and McNary Dam (MCN) in MY2009. Dates include first detection (first), 10th percentile (10%), median, 90th percentile (90%) and last detection (last).

Release Group	Dam	First	10%	Median	90%	Last
NO Chinook Pre-smolts	LGR	29-Mar	6-Apr	18-Apr	29-Apr	20-May
	LGS	7-Apr	14-Apr	21-Apr	3-May	22-May
	LMD	11-Apr	19-Apr	23-Apr	3-May	28-May
	MCN	16-Apr	24-Apr	4-May	12-May	24-May
NO Chinook Smolts	LGR	30-Mar	11-Apr	27-Apr	19-May	6-Jul
	LGS	8-Apr	19-Apr	30-Apr	22-May	8-Jul
	LMD	10-Apr	21-Apr	30-Apr	23-May	7-Jul
	MCN	17-Apr	29-Apr	8-May	21-May	5-Jul
HO Chinook Smolts	LGR	13-Apr	29-Apr	14-May	19-May	7-Jun
	LGS	17-Apr	3-May	16-May	21-May	5-Jun
	LMD	23-Apr	6-May	19-May	22-May	1-Jun
	MCN	25-Apr	12-May	19-May	24-May	1-Jun
NO Steelhead Smolts	LGR	6-Apr	7-May	19-May	30-May	23-Jun
	LGS	9-Apr	9-May	20-May	2-Jun	29-Jun
	LMD	5-Apr	11-May	21-May	1-Jun	27-Jun
	MCN	10-Apr	9-May	22-May	25-May	23-Jun
HO Steelhead Smolts	LGR	9-Apr	20-Apr	8-May	21-May	12-Jul
	LGS	12-Apr	22-Apr	10-May	26-May	6-Jul
	LMD	14-Apr	24-Apr	15-May	26-May	1-Jul
	MCN	17-Apr	29-Apr	15-May	25-May	3-Jul

Chinook salmon arrival timing at LGR

Results indicated that fall-tagged NO Chinook arrived at LGR and lower river dams significantly earlier than spring-tagged NO Chinook salmon smolts as demonstrated by the earlier median and cumulative arrival timing at LGR ($p < 0.05$). The maximum difference in the proportion of arrivals between fall-tagged and spring-tagged smolts occurred on April 24, 2009 (MaxD = 0.4359, $p < 0.05$; Figure 6). By the May 1, 2009 date of full collections for smolt transportation through the hydrosystem, 97.79% of fall-tagged Chinook smolts had already passed LGR and were not available for transportation, as opposed to only 58.06% of spring-tagged smolts. Due to the difference in passage route between these two life-history types, trends in the difference in smolt to adult return rates between fall-emigrating and spring-emigrating juvenile Chinook salmon would be expected.

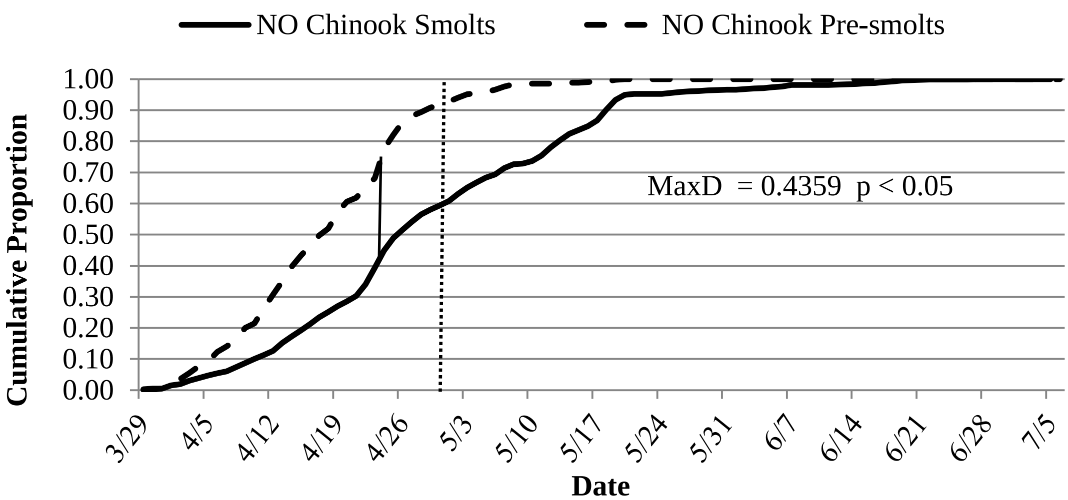

Figure 6. Arrival timing of natural-origin (NO) fall-tagged Chinook (pre-smolts) and spring-tagged smolts at Lower Granite Dam (LGR) during the 2009 migration year. Maximum difference (MaxD, represented by the solid vertical line) in arrival timing between the two release groups occurred on April 24, 2009. The dotted vertical line indicates the initiation date of full collections for juvenile transportation at LGR, May 1, 2009.

Natural-origin Chinook salmon smolts demonstrated earlier arrival timing throughout the majority of the run compared to HO smolts; however, arrival times converged near the end of the run as indicated by the same 90th percentile arrival timing date (May 19, 2009, Table 4). K-S test results revealed a significant difference in overall cumulative arrival timing at LGR with a maximum difference occurring on May 5 when 68.80% of NO fish passed LGR compared to only 17.48% of HO (MaxD = 0.5117, $p < 0.05$; Figure 7). By May 1, 2009, when full collections for transportation began, over 58% of NO fish had already passed LGR but only 11% of HO Chinook had passed LGR, leaving almost 90% of HO Chinook available for transportation. Again this could have a significant effect on the smolt-to-adult return rates for NO compared to HO Chinook salmon smolts.

Interestingly the median emigration timing from the tributary (median arrival timing at the Imnaha River trap) occurred on the same day (April 10, Table 3) for both HO and NO Chinook smolts, while there is a two week delay in median arrival timing of HO fish at LGR compared to NO fish. There appeared to be a significant delay in the emigration of HO Chinook upon entering the Snake River and encountering the first of the reservoirs created by the hydrosystem from a factor that does not affect NO Chinook in the same way. Please refer to the *Travel time of juvenile emigrants from the Imnaha River Trap to LGR* section below for discussion of the relationship between Snake River flow and travel time to LGR. Possible factors causing the delay in emigration timing of HO Chinook specifically within the Snake River should be further evaluated.

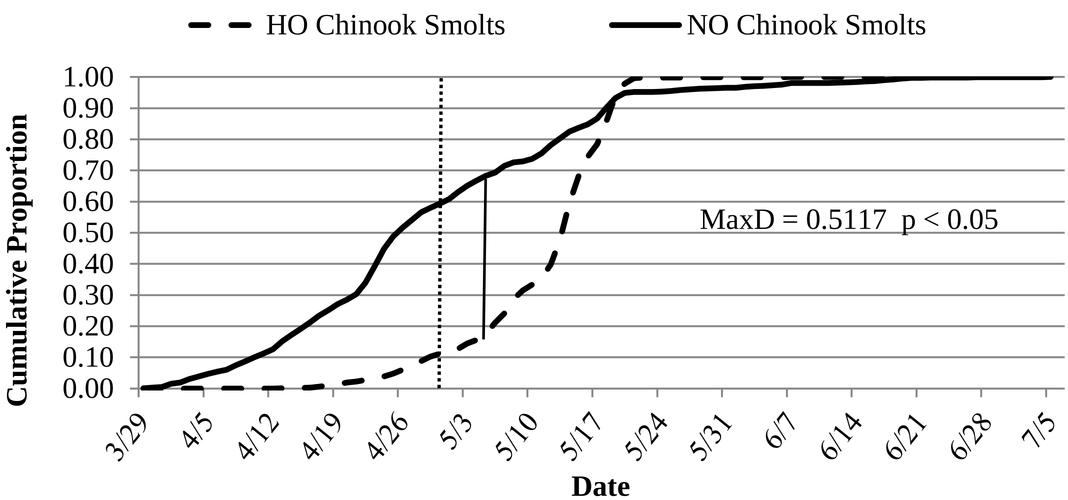

Figure 7. Arrival timing at Lower Granite Dam (LGR) of natural-origin (NO) and hatchery-origin (HO) Chinook smolts emigrating during spring of 2009. Maximum difference (MaxD, represented by the solid vertical line) in arrival timing between the origin types occurred on May 5, 2009. The dotted vertical line indicates the initiation date of full collections for juvenile transportation at LGR, May 1, 2009.

<u>*Steelhead arrival timing at LGR*</u>

Comparisons of NO and HO steelhead smolt emigration timing revealed significant differences in median and cumulative arrival timing at LGR with the maximum difference occurring on May 15, 2009 (MaxD = 0.4815, $p < 0.05$; Figure 8). By that date, 72.8% of HO steelhead had reached LGR compared to only 29.2% of NO steelhead. Over 38% of the HO steelhead reached LGR when full collections for juvenile transportation began on May 1, but only 5.1% of the NO steelhead had reached the dam. Consequently, a significantly higher proportion of NO steelhead were available for transportation and this may influence results of smolt to adult returns comparisons.

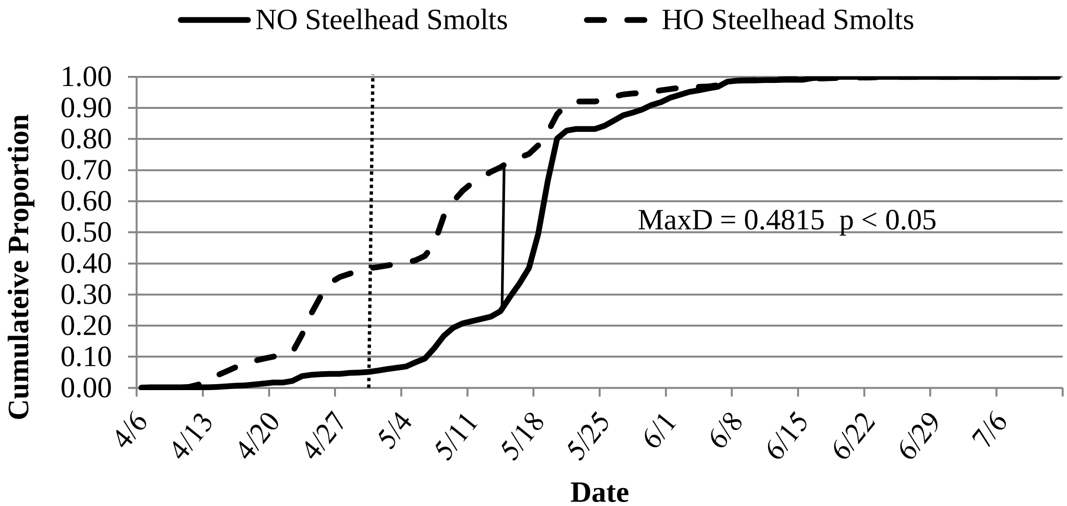

Figure 8. Arrival timing at Lower Granite Dam (LGR) of natural-origin (NO) and hatchery-origin (HO) steelhead smolts emigrating during spring of 2009. Maximum difference (MaxD, represented by the solid vertical line) in arrival timing between the origin types occurred on May 15, 2009. The dotted vertical line indicates the initiation date of full collections for juvenile transportation at LGR, May 1, 2009.

Arrival timing at dams below LGR

Arrival timing results must be considered with caution due to variations in detection probabilities and transportation rates at the dams. Often times, dams further downstream will have earlier arrival times than those upstream. Detection probabilities were highly influenced by varying flow conditions at each dam and this may significantly affect arrival timing data. Early in the monitoring season dams will have a lower detection probability due to high spring flow. As the migration season progresses the detection probabilities will increase as the flows decrease. A significant number of smolts passed through the upper three dams undetected until McNary dam. In situations where origin types differ in their arrival timing at Lower Granite Dam, as with NO and HO steelhead, higher transportation rates on later-arriving fish (NO) at the upper dams can result in earlier median, 90th percentile, and last arrival dates of fish from that release group at the lower dams. If a higher proportion of NO fish are transported, and thus become unavailable for detection lower in the hydrosystem, then NO steelhead could appear to have earlier arrival dates at McNary than their HO counterparts. This could simply be due to the fact that the majority of the PIT tagged fish were removed from the river at upstream dams and the majority of NO smolts that will be detected at McNary are the ones that arrived before the initiation of transportation. First, 10th percentile, median, 90th percentile and last arrival dates are summarized above in Table 4 for each release group.

Travel time from the Imnaha River trap to LGR in relation to Snake River flow

Chinook salmon juvenile emigrant travel time

Travel time for NO spring-tagged Chinook salmon smolts generally decreased as the trapping period progressed, and decreased significantly when flows increased in late May (Table 5; Figure 9). Regression analysis indicated that NO travel time was negatively correlated with Snake

River flow (R^2 = 0.363; P = 0.029). In contrast, HO juvenile Chinook salmon travel times increased as the trapping period progressed (Table 5) and there was no significant relationship with Snake River flow (R^2 = 0.202; P = 0.371; Figure 9). These results suggested that because HO Chinook salmon were released over a relatively sHOt period of time and rapidly migrated as a group, flow had little impact on travel time from the trap to LGR. Regression analysis indicated a positive relationship between travel time and Snake River flow for NO fall-tagged Chinook salmon (R^2 = 0.59; P = 0.025; Table 5; Figure 9). Similar to HO juveniles, increasing travel times over the spring trapping period was a consequence of the progression of time from tag/release date and the NOmally increasing river flows during spring. This suggested that the NO fall-tagged pre-smolts population completely mixed during the winter period, then began migrating in the spring and there was no relationship between tag date and detection date. In other words, fish tagged early or late in the fall were not detected early or late at LGR.

Table 5. Weekly mean travel time from the Imnaha River trap to Lower Granite Dam (LGR) for hatchery-origin (HO) Chinook salmon, natural-origin (NO) Chinook salmon spring-tagged smolts and NO Chinook salmon fall-tagged pre-smolts in 2009. The table includes LGD detection week, number of HO Chinook salmon detected (HO count), HO Chinook salmon mean travel time (HO mean travel time), HO smolt range of travel times (10% and 90% bounds), number of NO Chinook salmon detected (NO smolt count), NO Chinook salmon smolt mean travel time (NO smolt mean travel time), NO smolt range of travel times (10% and 90% bounds), number of NO Chinook salmon pre-smolts detected (NO pre-smolt count), NO Chinook salmon pre-smolt mean travel time (NO pre-smolt mean travel time), NO pre-smolt range of travel times (10% and 90% bounds) and mean Snake River flow in cubic feet per second (cfs).

LGD detection week	HO smolt count	HO smolt mean travel time (days)	HO smolt range of travel times (10% - 90%)	NO smolt count	NO smolt mean travel time (days)	NO smolt range of travel times (10% - 90%)	NO pre-smolt count	NO pre-smolt mean travel time (days)	NO pre-smolt range of travel times (10% - 90%)	Snake River Flow (cfs)
3/29/2009	--	--	--	69	16	(8 - 29)	187	137	(119 - 150)	30,943
4/5/2009	1	27	--	159	18	(9 - 34)	437	145	(134 - 156)	40,243
4/12/2009	17	17	(6 - 30)	307	18	(6 - 39)	621	151	(136 - 162)	50,286
4/19/2009	39	19	(9 - 36)	492	18	(7 - 32)	727	159	(149 - 171)	72,057
4/26/2009	51	22	(13 - 42)	364	22	(11 - 37)	288	164	(157 - 175)	56,300
5/3/2009	83	28	(21 - 37)	270	22	(8 - 41)	110	171	(164 - 182)	62,600
5/10/2009	155	33	(26 - 39)	253	20	(9 - 37)	11	181	(180 - 182)	56,086
5/17/2009	125	33	(30 - 39)	266	18	(4 - 36)	24	180	(170 - 195)	89,486
5/24/2009	--	--	--	25	7	(2 - 13)	--	--	--	102,814
5/31/2009	--	--	--	24	5	(2 - 5)	--	--	--	103,343
6/7/2009	--	--	--	18	4	(2 - 5)	--	--	--	91,829
6/14/2009	--	--	--	32	5	(3 - 6)	--	--	--	70,329
6/21/2009	--	--	--	7	7	(4 - 9)	--	--	--	65,300

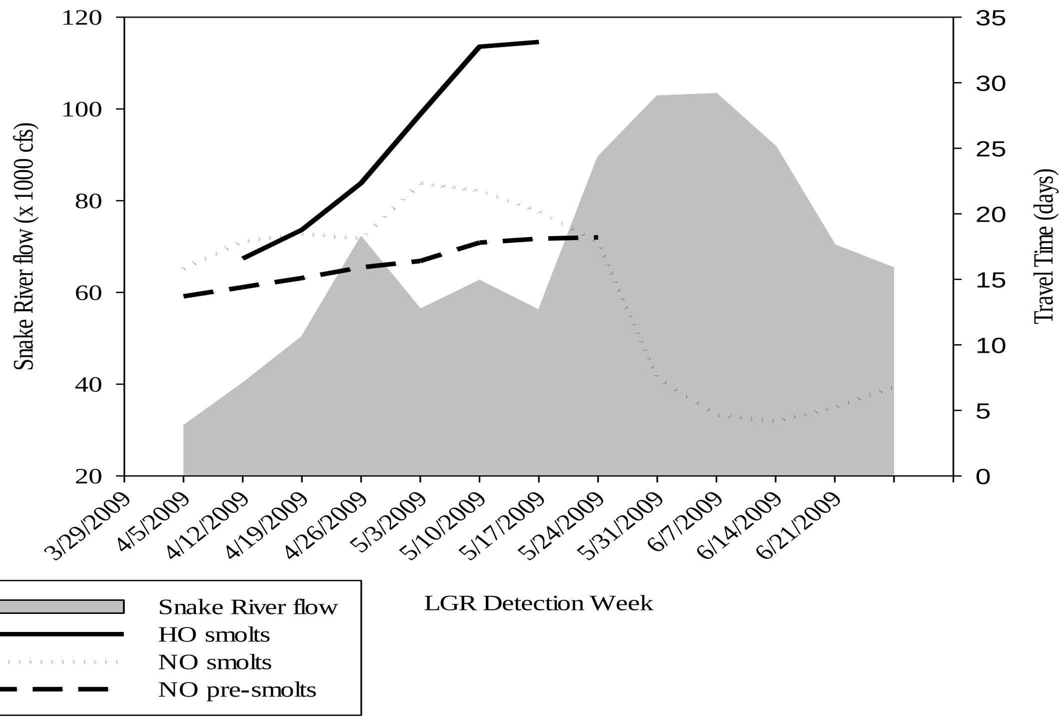

Figure 9. Weekly mean travel time from the Imnaha River trap to Lower Granite Dam (LGR) for hatchery-origin (HO) Chinook salmon (HO smolts) and natural-origin (NO) Chinook salmon spring-tagged smolts (NO smolts), NO Chinook salmon fall-tagged pre-smolts (NO pre-smolts) and Snake River flow in thousands of cubic feet per second (cfs). NO pre-smolt travel times were transformed by dividing by 10.

Steelhead juvenile emigrant travel time

Travel time for NO steelhead juveniles generally decreased as the trapping period progressed (Table 6; Figure 10). Regression analysis indicated that travel time was negatively correlated with Snake River flow (R^2 = 0.390; P = 0.051). In contrast, travel time for HO steelhead juveniles was not related to increasing flows (R^2 = 0.033; P = 0.613; Table 6), but remained similar across the migration period (Figure 10). These results demonstrated increased travel times for HO compared to NO steelhead juveniles. In addition, it appeared that flow positively influenced NO steelhead travel times but had little impact on travel time for HO steelhead.

Table 6. Weekly mean travel time from the Imnaha River trap to Lower Granite Dam (LGR) for hatchery-origin (HO) steelhead and natural-origin (NO) steelhead juveniles in 2009. The table includes LGR detection week, number of HO steelhead detected (HO count), HO steelhead mean travel time (HO mean travel time), HO steelhead range of travel times (10% and 90% bounds), number of NO steelhead detected (NO count), NO steelhead mean travel time (NO mean travel time), NO steelhead range of travel times (10% and 90% bounds) and mean Snake River flow in cubic feet per second (cfs).

LGD detection week	HO smolt count	HO smolt mean travel time (days)	HO smolt range of travel times (10% - 90%)	NO smolt count	NO smolt mean travel time (days)	NO smolt range of travel times (10% - 90%)	Snake River Flow (cfs)
3/29/2009	--	--	--	--	--	--	30,943
4/5/2009	--	--	--	2	13	(11 - 15)	40,243
4/12/2009	46	5	(3 - 7)	18	4	(3 - 6)	50,286
4/19/2009	95	11	(6 - 15)	60	10	(3 - 19)	72,057
4/26/2009	65	15	(9 - 21)	31	6	(3 - 12)	56,300
5/3/2009	146	13	(3 - 27)	245	7	(2 - 12)	62,600
5/10/2009	80	15	(3 - 32)	262	5	(3 - 11)	56,086
5/17/2009	188	10	(2 - 25)	921	5	(2 - 7)	89,486
5/24/2009	25	6	(1 - 12)	142	3	(1 - 4)	102,814
5/31/2009	18	13	(1 - 30)	109	4	(2 - 7)	103,343
6/7/2009	11	11	(2 - 14)	41	5	(1 - 12)	91,829
6/14/2009	6	6	(2 - 13)	--	--	--	70,329
6/21/2009	--	--	--	--	--	--	65,300

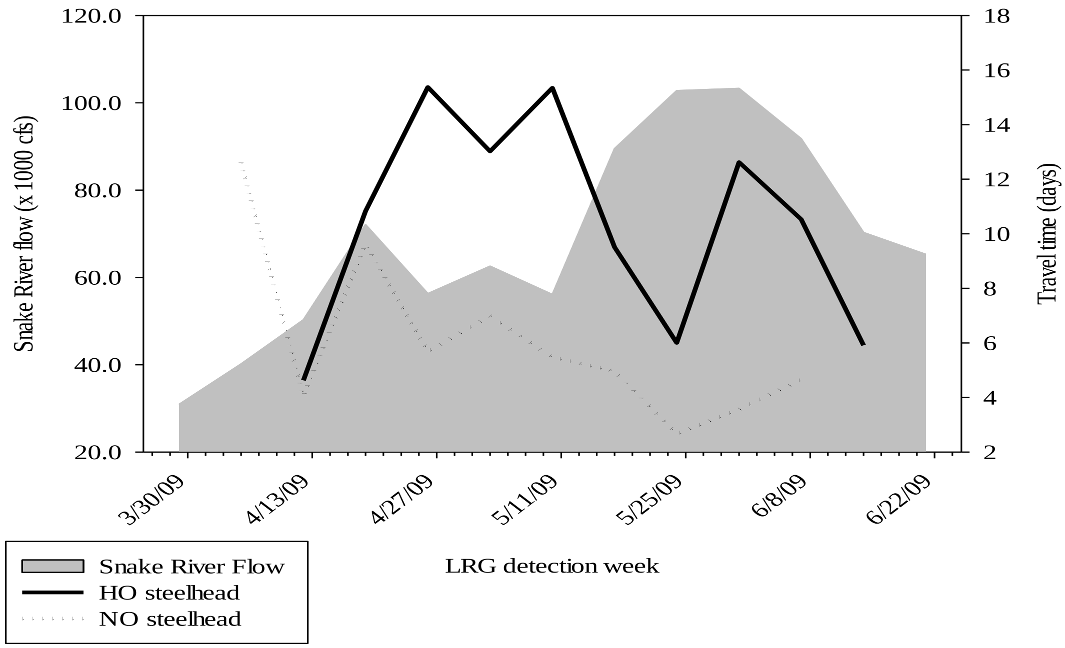

Figure 10. Mean weekly travel time from the Imnaha River trap to Lower Granite Dam (LGR) for hatchery-origin (HO) and natural-origin (NO) steelhead juveniles and Snake River flow in thousands of cubic feet per second (cfs).

Life-stage specific estimates of juvenile emigrant survival

Post release survival of HO Chinook

Post release survival from release to the trap of acclimated HO Chinook salmon was 89% ± 3.4% (95% C.I.). This resulted in an estimated 260,602 ± 8,822 (95% C.I.) HO Chinook salmon emigrating past the Imnaha River juvenile emigrant trap during the spring of 2009. Survival was similar to previous estimates that have ranged from 63% ± 2.1% (95% C.I.) in 2006 to 100% ± 14.3% (95% C.I.) in 1994 (Figure 11). The relatively low mortality from release to the Imnaha River confluence with the Snake River suggested that the fish were released in good condition and few fish residualized as precocial parr.

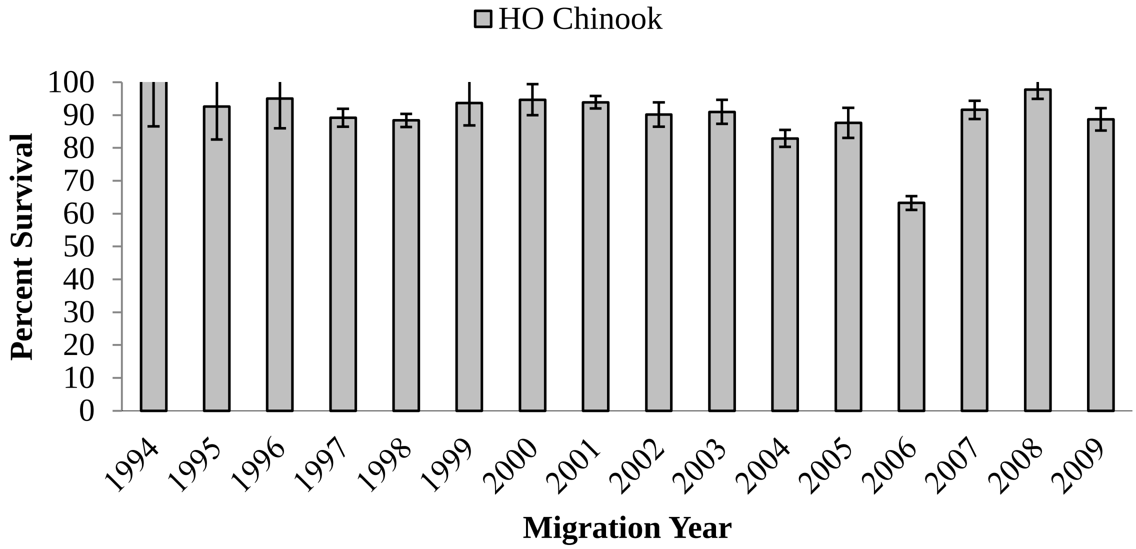

Figure 11. Estimated post release survival of hatchery-origin (HO) Chinook salmon from release at the Imnaha River Gumboot acclimation facility to the Imnaha River juvenile emigrant trap during the spring from 1994 to 2009. The error bars indicate 95% confidence intervals.

Post release survival of HO steelhead

Survival from release to the trap of the combined HO release groups (direct-stream and volitional releases) was 88% ± 1.2% (95% C.I.). This resulted in an estimated 165,663 ± 1,988 (95% C.I.) HO steelhead emigrating past the Imnaha River juvenile emigrant trap during the spring of 2009. Survival was similar to previous estimates that have ranged from 56% ± 7.97% (95% C.I.) in 1994 to 100% ± 9.19% (95% C.I.) in 2003 (Figure 12). This suggested that steelhead smolt residualization was likely low from these release groups.

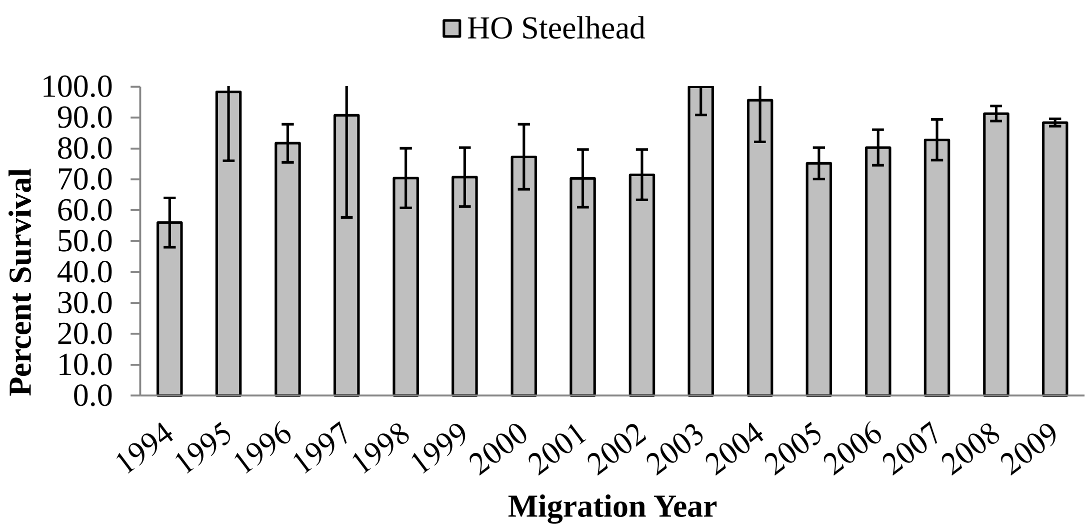

Figure 12. Estimated post release survival of hatchery-origin (HO) steelhead from release to the Imnaha River juvenile emigrant trap during the spring from 1994 to 2009. The error bars indicate 95% confidence intervals.

Estimated survival from the Imnaha River trap to Lower Granite Dam (LGR)

Survival from the trap to LGR was estimated for both fall-tagged NO Chinook pre-smolts and spring-tagged smolts independently, as well as for a combined release group of all NO Chinook tagged during MY2009. Survival of these groups was compared to that of HO Chinook salmon based on PIT tag interrogations at the trap. The MY2009 survival estimate of fall-tagged NO Chinook salmon pre-smolts from the trap to LGR was 40.5% (± 2.6%), compared to 85.1% (± 1.9%, Table 7 and Figure 13) for spring-tagged NO Chinook salmon. The significantly higher survival observed in the spring-tagged Chinook salmon smolts may be more a result of the shorter travel time to LGR for spring-tagged fish compared to fall-tagged pre-smolts and the overwinter mortality of the pre-smolt group. Combining the two NO groups provided an overall estimate of survival from the trap to LGR for NO Chinook salmon emigrating from the Imnaha River equal to 71.6% (± 1.6%). Comparing overall NO survival with that of the HO release group demonstrated a similar survival rate to LGR. However, the survival estimate of the spring-tagged Chinook salmon smolts was significantly higher than that of the HO fish emigrating in the spring (t-test, $P < 0.001$). From 1994 through 2009 the average survival rate from the trap to LGR for spring-tagged NO smolts was significantly higher than that observed for HO Chinook salmon (t-test, $P = 0.0003$; Table 7).

Survival from the trap to LGR was estimated to be 86.9% (± 2.6%) and 91.1 (± 4.7) for NO and HO steelhead, respectively for MY2009 (Table 7, Figure 14). Survival for HO fish was calculated using only PIT tag recaptures from the Imnaha River trap, or HO fish tagged at the trap as a tagging release group. Average survival comparisons from 1995 through 2009 revealed no significant difference for NO compared to HO steelhead (Table 7; t-test, $P = 0.56$).

Table 7. Estimates of survival from the Imnaha River juvenile migration trap to Lower Granite Dam for spring-tagged juvenile natural-origin (NO) and hatchery-origin (HO) Chinook salmon and steelhead from 1993 to 2009. Ninety-five percent confidence intervals are shown in parentheses and average, standard deviation (S.D) and coefficient of variation (C.V.) across years is presented at the bottom of the table.

Migration Year	NO Chinook (%)		HO Chinook (%)		NO Steelhead (%)		HO Steelhead (%)	
1993	80.9	(11.8)						
1994	76.2	(5.3)	67.1	(10.2)				
1995	90.9	(6.7)	72.1	(6.3)	83.7	(7.1)	77.5	(3.1)
1996	81.2	(5.3)	71.4	(9.4)	86.5	(3.9)	64.6	(4.7)
1997	89.5	(12.9)	80.4	(8)	90.1	(3.9)	81.4	(2)
1998	85.2	(2)	75.7	(3.1)	86.0	(2.2)	82.9	(2.35)
1999	88.5	(2)	71.6	(4.7)	87.7	(3.1)	85.4	(2)
2000	84.8	(2.3)	74.4	(4.3)	84.4	(2.7)	85.8	(2.4)
2001	83.7	(0.8)	80.3	(1.6)	82.7	(1.4)	82.0	(1.6)
2002	86.9	(4.4)	77.3	(4.4)	83.0	(5.4)	81.8	(3.5)
2003	75.9	(2.3)	72.4	(6.8)	82.0	(2.5)	89.4	(3.3)
2004	73.3	(1.2)	61.0	(0.9)	79.0	(2.2)	86.0	(1.3)
2005	73.9	(1.7)	60.8	(3.7)	80.8	(1.4)	82.8	(1.2)
2006	76.7	(8.2)	68.7	(5.0)	91.9	(5.1)	86.1	(3.8)
2007	77.5	(2.7)	70.5	(4.7)	78.8	(4.4)	97.0	(8.82)
2008	84.2	(4.2)	70.1	(2.6)	89.7	(4.0)	82.7	(4.9)
2009	85.1	(1.9)	78.5	(6.4)	86.9	(2.6)	91.1	(4.7)
Average	82.0		72.0		84.9		83.8	
S.D.	5.6		5.9		4.0		7.1	
C.V.	0.07		0.08		0.05		0.08	

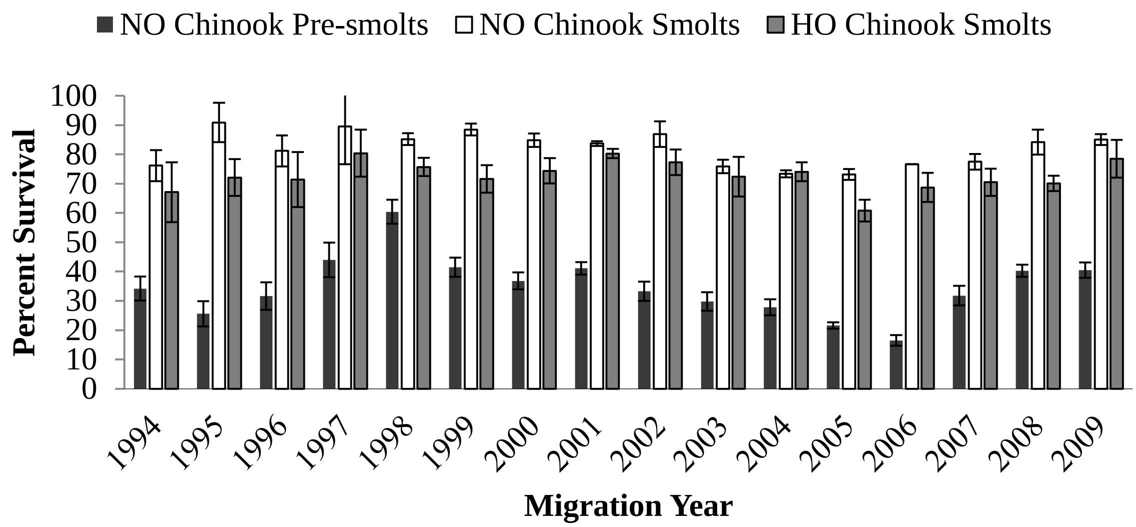

Figure 13. Estimated survival of natural-origin (NO) Chinook salmon pre-smolts and smolts, and hatchery-origin (HO) smolts from the Imnaha River juvenile emigrant trap to Lower Granite Dam (LGR) from 1994 to 2009. The error bars indicate 95% confidence intervals.

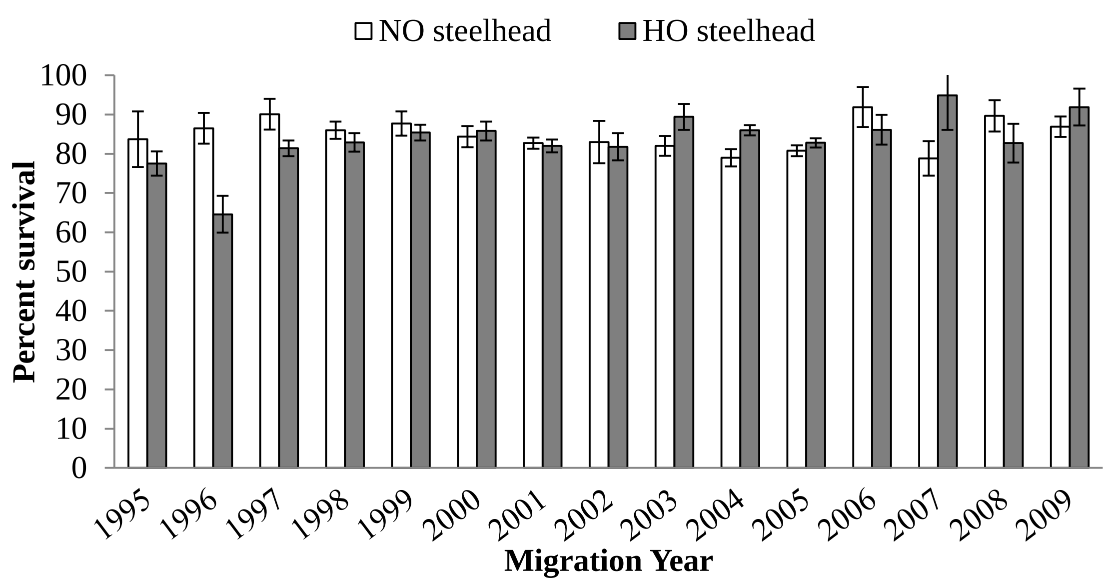

Figure 14. Estimated survival of natural-origin (NO) and hatchery-origin (HO) steelhead smolts from the Imnaha River juvenile emigrant trap to Lower Granite Dam (LGR) during the spring from 1995 to 2009. The error bars indicate 95% confidence intervals.

Estimated survival from the Imnaha River to MCN for MY2009 Imnaha River juvenile emigrants

Our analysis provides estimates of juvenile survival to the Imnaha River trap, LGR, and MCN but will not provide detailed results of juvenile survival through the entire hydrosystem. A more comprehensive analysis of in-river and transportation migration route effects on juvenile survival and resulting adult returns can be found in the Fish Passage Center's Comparative Survival Report (Comparative Survival Study, 2011).

It is important to note that the fish used to evaluate juvenile survival from LGR to MCN did not represent the run-at-large and should not be used as an indication of overall group survival or subsequent adult returns. Because transported juveniles cannot be used to evaluate in-river survival past LGR, only fish that arrived at LGR prior to the start of transportation, were by-passed at the juvenile collection facility (designated "survival mode" for PIT tagged fish), or passed without encountering the juvenile collection facility (spillway, turbines or locks) could be used to calculate survival from LGR to MCN. Given the timing and magnitude of transportation, variable capture probabilities at the juvenile bypass facilities of each dam (Comparative Survival Study, 2012) and the flow and spill levels (see Arrival Timing section above), our analysis demonstrated that each group would have experienced significantly different emigration conditions. For example, approximately 60% of NO Chinook salmon arrived at LGR prior to the start of transportation compared to only 10% of the HO Chinook salmon juveniles. Once transportation started the average capture probability was 30%, so even after the start of juvenile transport activities the majority of juveniles passed each dam without being collected for transport. However, the cumulative effects of collection facilities at each of the four lower Snake River dams (LGR, LGO, LMN, MCN) would have resulted in a majority of the later emigrating juvenile groups (HO) being captured and transported, while a significantly smaller proportion of the earlier emigrating groups would have been transported. Consequently, it was likely that these groups experienced significantly different passage conditions and this could have a significant impact on adult returns.

Survival estimates from the Imnaha River trap to McNary Dam on the Columbia River provide information on the survival of Imnaha River juvenile emigrants through the Snake River hydrosystem. Similar to arrival timing, survival throughout the hydrosystem should be considered with caution, as it is possible to have higher survival estimates at dams further downstream. We chose to evaluate survival to MCN as it provided a metric assessing hydrosystem effects on early life history. Survival from the trap to MCN was estimated for NO Chinook salmon pre-smolts, NO Chinook salmon smolts, a combined group of NO Chinook salmon pre-smolts and smolts (NO Chinook total), HO Chinook salmon smolts, and NO and HO steelhead smolts to allow for comparisons among the groups.

Results demonstrated similar survival for the combined group of NO Chinook to that of HO Chinook salmon (Table 8). Separating the combined NO Chinook salmon group demonstrated that survival of the spring-tagged smolts (69.4% ± 5.3%) was significantly higher than that of fall-tagged pre-smolts (33.6% ± 5.9%). Survival from LGR to MCN was highest for fall-tagged Chinook pre-smolts, with slightly lower but similar survival for NO and HO Chinook salmon (Table 8). These results suggested that the higher mortality rates observed in the pre-smolts occurred as they overwintered in the Snake River.

Estimated survival from the trap to MCN for NO steelhead was10% lower compared to that observed for HO steelhead, 58.8% (± 8.0) and 68.2% (± 19.1), respectively (Table 8). Similarly, survival of NO steelhead from LGR to MCN was 16% lower than that of HO steelhead juveniles. These results indicated that overall survival from the trap to MCN was significantly lower for

NO steelhead than for HO steelhead. However, both groups demonstrated poorer survival from LGR to MCN than any of the Chinook salmon release groups. Together these results provide interesting species- and origin-specific differences in survival. Juvenile Chinook salmon mortality was greater above LGR (trap to LGR), whereas steelhead mortality was greater in the river section below LGR (LGR to MCN); survival effects of origin (NO compared to HO) was not a factor in Chinook salmon survival, but did impact steelhead survival.

We also investigated the pattern of annual survival to MCN for each species by origin and results supported our conclusions that survival differences existed between Chinook salmon and steelhead. Analyzing the 1998–2009 average annual survival from the trap to MCN revealed that survival was significantly higher for spring-tagged NO smolts compared to HO Chinook salmon smolts ($t = 2.47$, $P = 0.022$; Table 9). In contrast, there was no significant difference in average annual survival to MCN for NO and HO steelhead ($t = 2.07$, $P = 0.88$; Table 9).

Regression analysis demonstrated no relationship in annual survival estimates to MCN for NO and HO Chinook salmon ($P = 0.48$, $R^2 = 0.05$; Figure 15). In spite of the fact that average annual survival to MCN was greater for NO compared to HO juvenile Chinook salmon (Table 9), a lack of relationship of annual survival from 1998 – 2009 indicated that survival did not follow a consistent pattern and suggested that Chinook salmon juvenile survival was independent of the effects of annual environmental variation. If environmental factors acted similarly you would expect to see a similar pattern of high and low survival years in the two groups. In contrast, there was a significant positive relationship between annual survival to MCN of NO and HO steelhead ($P = 0.006$, $R^2 = 0.53$; Figure 15), suggesting that the effects of annual environmental variation were similar between the two groups.

Table 8. Estimated survival probabilities for all passive integrated transponder (PIT) tagged release groups of natural-origin (NO) and hatchery-origin (HO) Chinook salmon and steelhead juveniles released from the Imnaha River trap from October 2, 2008 to June 17, 2009. Estimates are from release at the trap to Lower Granite Dam, from Lower Granite Dam to McNary Dam and from the trap to McNary Dam. NO Chinook salmon pre-smolts were fall-tagged juvenile Chinook salmon, NO Chinook smolts were spring-tagged juvenile Chinook salmon and NO Chinook total were a combination of fall- and spring-tagged Chinook salmon. Abbreviations: LGR – Lower Granite Dam, MCN – McNary Dam, 95% C.I. – 95% confidence intervals.

	Number Released	Trap to LGR (95% C.I.)	Trap to MCN (95% C.I.)	LGR to MCN (95% C.I.)
NO Chinook pre-smolt	2,676	40.5 (2.6)	33.6 (5.9)	94.8 (14.1)
NO Chinook smolt	6,139	85.1 (1.9)	69.4 (5.3)	83.1 (5.1)
NO Chinook total	8,815	71.6 (1.6)	58.5 (4.1)	84.9 (4.9)
HO Chinook	1,760	78.5 (6.4)	67.1 (14.1)	83.7 (5.6)
NO Steelhead	5,165	86.9 (2.6)	58.8 (8.0)	63.8 (7.3)
HO Steelhead	1,795	91.1 (4.7)	68.2 (19.1)	79.8 (5.7)

Table 9. Survival estimates of natural-origin (NO) and hatchery-origin (HO) Chinook salmon and steelhead from the Imnaha River trap to McNary Dam from 1998 to 2009; table includes spring-emigrants only. Ninety-five percent confidence intervals are shown in parentheses and average, standard deviation (S.D) and coefficient of variation (C.V.) across years is presented at the bottom of the table.

Migration Year	NO Chinook %		HO Chinook %		NO Steelhead %		HO Steelhead %	
1998	78.7	(6.8)	54.3	(8.0)	64.0	(10.1)	63.8	(10.5)
1999	68.5	(4.3)	53.8	(9.8)	71.6	(12.0)	58.8	(7.6)
2000	67.9	(6.3)	54.1	(9.7)	49.9	(12.2)	40.2	(12.5)
2001	47.4	(1.5)	52.1	(5.3)	18.4	(3.1)	13.9	(3.9)
2002	61.9	(5.3)	56.0	(5.6)	37.0	(4.8)	48.7	(13.2)
2003	57.1	(5.6)	49.0	(11.8)	42.0	(5.6)	63.0	(14.5)
2004	52.7	(5.1)	51.4	(16.5)	47.4	(25.3)	29.4	(11.2)
2005	53.9	(7.8)	65.8	(30.8)	41.6	(8.7)	44.7	(7.4)
2006	76.3	(24.6)	44.5	(3.5)	61.8	(16.2)	64.2	(13.5)
2007	64.5	(3.4)	66.1	(6.2)	60.3	(12.4)	79.5	(33.2)
2008	70.9	(13.1)	51.8	(4.4)	64.5	(10.0)	55.5	(9.1)
2009	69.4	(5.3)	67.1	(14.1)	58.8	(8.0)	68.2	(19.1)
Average	64.1		55.5		51.4		52.5	
S.D.	9.7		7.2		15.0		18.2	
C.V.	0.15		0.13		0.29		0.35	

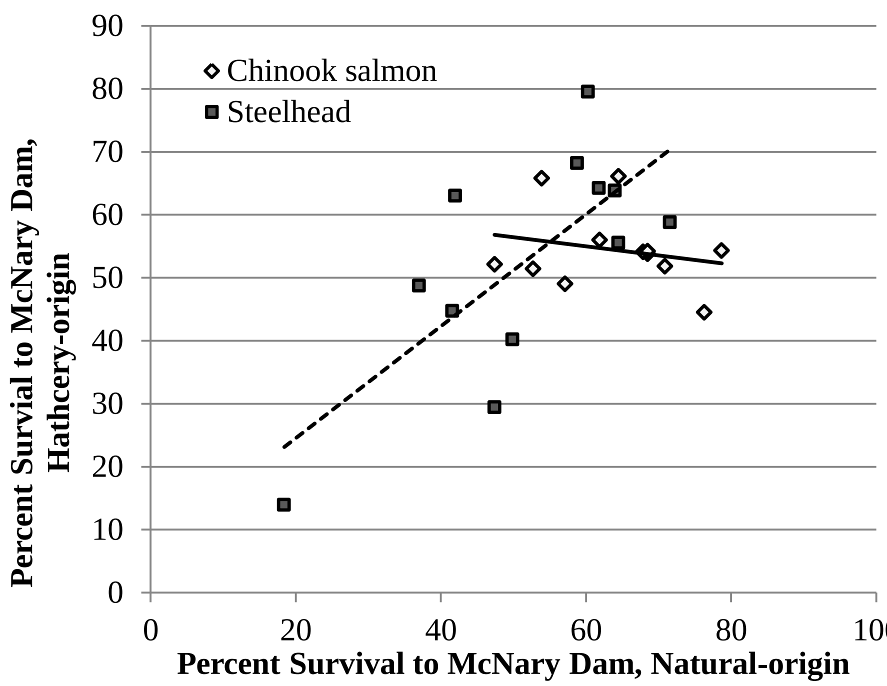

Figure 15. Relationship between estimated percent survival of natural-origin and hatchery-origin Chinook salmon (solid line) and steelhead (dashed line) smolts from the Imnaha River juvenile emigrant trap to McNary Dam (MCN) from 1998 to 2009.

Juvenile emigrant survival in relation to Imnaha and Snake River flow

Possible environmental factors influencing juvenile survival include flow, spill and temperature. We did not find a significant relationship between survival to LGR or MCN and temperature (data not shown), but did find a significant relationship between survival to MCN and flow and spill. We will focus our analysis on flow, as increased flow would be expected to significantly impact travel time and survival to LGR and MCN. Average daily flow in April (peak Chinook salmon emigration period) and May (peak steelhead emigration period) provided the metrics used to determine the relationship between river flow and juvenile survival to LGR and MCN. Average daily Imnaha River and Snake River flows (Anatone gage http://waterdata.usgs.gov/id/nwis) were significantly correlated ($P < 0.01$, $R^2 = 0.74$) so we used Snake River flow because fish captured at the trap experience more time in the Snake compared to the Imnaha River. Results demonstrated no significant relationship between juvenile survival from the Imnaha River trap to LGR and average daily Snake River flow in April for NO ($P = 0.25$, $R^2 = 0.09$) or HO ($P = 0.34$, $R^2 = 0.07$) Chinook salmon (Figure 16). Analyzing steelhead survival to LGR revealed a significant positive relationship between average daily flow in May and survival for NO steelhead ($P = 0.02$, $R^2 = 0.30$), but not HO steelhead ($P = 0.36$, $R^2 = 0.06$).

A significant positive relationship between survival to MCN and flow was found for NO Chinook salmon ($P = 0.01$, $R^2 = 0.48$), and steelhead ($P = 0.01$, $R^2 = 0.50$) but not HO Chinook salmon ($P = 0.07$, $R^2 = 0.29$) or steelhead ($P = 0.09$, $R^2 = 0.26$). Scatter plots showing the relationship between survival to MCN and flow are presented by Figure 16 and Figure 17. These results suggest that NO juveniles from both species are more heavily influenced by environmental variables, such as flow, and this may explain some of the survival differences that we have observed.

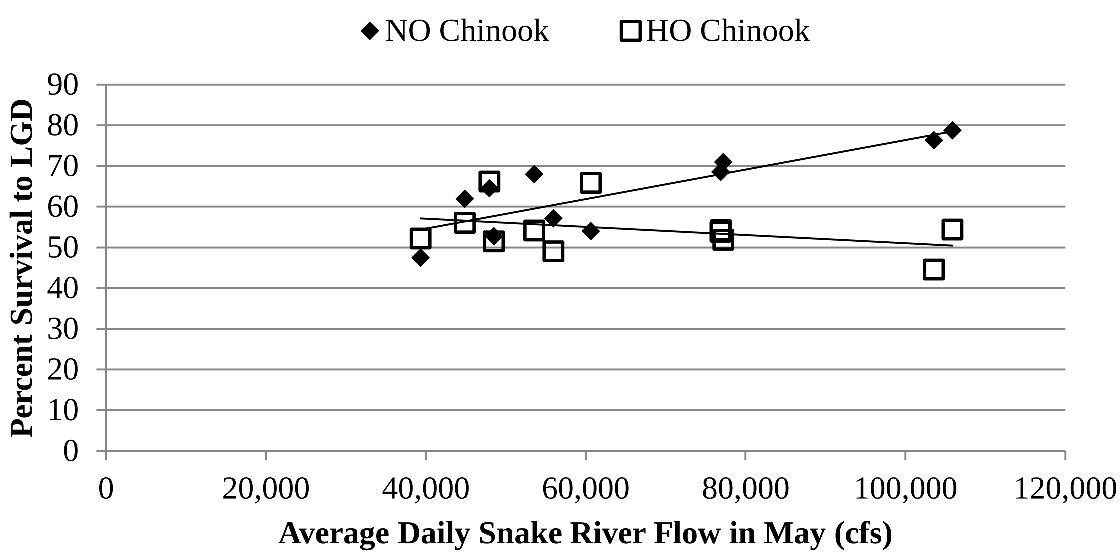

Figure 16. Relationship between annual survival of natural-origin (NO Chinook) and hatchery-origin (HO Chinook) Chinook salmon to McNary Dam and average Snake River flow in April measured at the stream flow gage in Anatone, Washington. cfs – cubic feet per second.

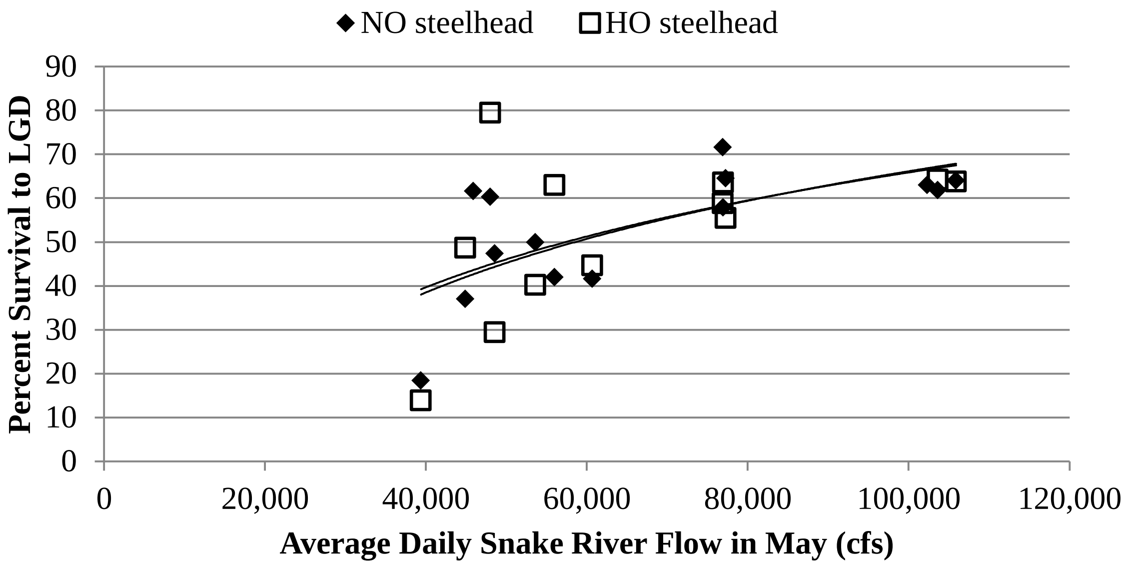

Figure 17. Relationship between annual survival of natural-origin (NO, solid line) and hatchery-origin (HO; dashed line) steelhead to McNary Dam and average Snake River flow in May measured at the stream flow gage in Anatone, Washington. cfs – cubic feet per second.

Smolt to adult return (SAR) index rates

Smolt to adult return index rates for NO Chinook salmon

Adult returns in 2009 allowed for the estimation of SAR index rates for brood years 1996 through 2004 for Chinook salmon and migration years 2000 through 2007 for steelhead. Smolt to adult return (SAR) index rates were calculated from the Imnaha River trap to LGR and from LGR to LGR. The SAR index rates calculated here were not representative of the total PIT tagged adult returns as they do not include fish that were transported as juveniles. However, they are useful as a means to compare survival to the adult life stage and return of PIT tagged HO and NO Chinook salmon and steelhead that migrated through the hydrosystem (were designated as survival mode smolts and left in-river.)

Relying on PIT tag interrogations resulted in small sample sizes (few adult PIT tag detections) during some years and this precluded a more comprehensive analysis utilizing estimated smolt equivalents and total adult returns at LGR. With the installation of in-river PIT tag arrays in the Imnaha River it will be possible to calculate SAR rates from the Imnaha trap back to the Imnaha River for future return years. In the future, we plan to estimate smolt to adult survival rates (SARs) using juvenile emigrant abundance estimates at the Imnaha River trap, smolt equivalents at LGR, total adults back to LGR, and the Imnaha River using the in-stream PIT tag arrays and population expansions for a more comprehensive analysis. We also plan to analyze HO Chinook salmon SARs utilizing similar methods as stated above, for comparisons to NO Chinook salmon from the Imnaha River.

Adult detections in 2009 completed the estimation of SAR index rates for brood year 2004 Chinook salmon with results presented in Table 10. The decreased number of tags combined with low returns of PIT tagged adults limited the ability to draw conclusions regarding SAR index rates for BY2004, but it was clear that SAR index rates had declined compared to previous years. A comparison of SAR index rates for fall- and spring-tagged NO Chinook salmon revealed a higher Imnaha trap to LGR average (geometric mean) SAR index for spring-tagged juveniles, but a higher LGR to LGR average (geometric mean) SAR index for fall-tagged juveniles (Table 10). SAR index rates for Chinook salmon tagged in the fall were greater when analyzed from LGR to LGR, after accounting for mortality between the Imnaha River trap and LGR. SAR index rates from the Imnaha River trap were greater for spring-tagged fish compared to those tagged in the fall and this is a better comparison since migration timing through the hydrosystem was not a factor.

Table 10. Smolt to adult return (SAR) index rates for survival mode (in-river migration) Imnaha River natural-origin Chinook salmon to Lower Granite Dam (LGR) and LGR to LGR for brood years 1996 to 2004. Brood year included fish tagged in the fall of one year and spring of the following year (i.e. Brood year 1996 were tagged in migration year 1998 during the fall of 1997 and spring of 1998).

Brood Year and Season Tagged	Number PIT Tagged	PIT Tagged Smolts at LGR	Number of Adult Detections at LGR	Age at Return			SAR Index Imnaha to LGR (%)	SAR Index LGR to LGR (%)
Fall				III	IV	V		
1996	3,449	876	42	9	24	9	1.22	4.79
1997	4,001	845	35	3	29	3	0.87	4.14
1998	3,952	701	42	2	23	17	1.06	5.99
1999	3,867	823	9	0	7	2	0.23	1.09
2000	3,228	662	22	4	17	1	0.68	3.32
2001	2,053	599	8	0	6	2	0.39	1.34
2002	1,190	346	2	0	1	1	0.17	0.58
2003	2,034	433	2	0	1	1	0.10	0.46
2004	1,264	209	1	0	1	0	0.08	0.48
Geomean							0.36	1.61
Spring								
1996	3,956	3,429	59	3	41	15	1.49	1.72
1997	5,306	4,686	105	8	69	28	1.98	2.24
1998	4,369	3,666	98	3	56	39	2.24	2.67
1999	10,005	1,886	41	1	32	8	0.41	2.17
2000	2,321	2,030	25	6	17	2	1.08	1.23
2001	5,145	3,914	11	1	8	2	0.21	0.28
2002	3,220	2,416	10	0	9	1	0.31	0.41
2003	1,611	1,174	2	0	0	2	0.12	0.17
2004	944	724	5	0	5	0	0.53	0.69
Geomean							0.61	0.90

Smolt to adult return index rates for NO and HO steelhead

Juvenile NO steelhead emigrate at unknown age and thus it was impossible to analyze brood year SAR index rates. For this analysis we evaluated migration year (MY) SAR index rates assuming that these largely represented a single cohort as they passed the trap. As with Chinook salmon, tagged steelhead were segregated into survival mode and monitor mode groups for survival analysis through the hydrosystem. Analyses were performed on survival mode (in-river migration) groups only, due to insufficient numbers of monitor-mode tags being distributed.

Adult returns in 2009 completed the migration year 2007 SAR index rate analyses for HO and NO steelhead. The HO steelhead PIT tagged at the Imnaha River trap and designated as survival mode (in-river migration) had LGR to LGR SAR index rates ranging from 0.11% to 1.55 % (Table 11). Similar SAR index rates were observed for survival mode NO steelhead (range from 0.08% – 1.73%). Average (geometric mean) SAR index rates for survival mode NO and HO steelhead from migration years 2000 – 2007 demonstrated that HO steelhead had higher SAR index rates (Table 11). All of these SAR index rates are similar to what Buchanan et al. (2007) found for Snake River Basin hatchery steelhead from LGR to LGR during the same time period.

Table 11. Smolt to adult return (SAR) index rates for passive integrated transponder (PIT) tagged, survival mode (in-river juvenile migration) Imnaha River natural-origin (NO) and hatchery-origin (HO) steelhead tagged at the Imnaha River trap to Lower Granite Dam (LGR) and from LGR to LGR for migration years 2000 to 2007.

Brood Year	Migration Year	Number PIT Tagged	PIT Tagged Smolts at LGR	Number of Adult detections at LGR	Ocean Age at Return I	II	III	SAR Index Imnaha to LGR %	SAR Index LGR to LGR (%)
HO Steelhead tagged at Imnaha River Trap									
1999	2000	5,846	5,016	65	49	16	0	1.11	1.30
2000	2001	3,463	2,840	3	3	0	0	0.09	0.11
2001	2002	2,153	1,787	25	18	7	0	1.16	1.40
2002	2003	5,227	4,673	38	26	12	0	0.73	0.81
2003	2004	4,487	3,854	16	11	5	0	0.36	0.42
2004	2005	6,570	5,440	21	19	2	0	0.32	0.39
2005	2006	1,494	1,286	20	17	3	0	1.34	1.55
2006	2007	1,492	1,416	22	17	5	0	1.47	1.55
	Geomean							0.61	0.71
NO Steelhead tagged at Imnaha River Trap									
	2000	4,737	3,998	69	51	18	0	1.46	1.73
	2001	3,680	3,043	10	1	9	0	0.27	0.33
	2002	4,809	3,934	37	21	16	0	0.77	0.94
	2003	6,302	5,168	34	18	16	0	0.54	0.66
	2004	1,506	1,190	1	0	1	0	0.07	0.08
	2005	4,400	3,555	5	3	2	0	0.11	0.14
	2006	2,063	1,896	26	21	5	0	1.26	1.37
	2007	3,238	2,552	32	18	14	0	0.99	1.25
	Geomean							0.45	0.54

Life-stage specific evaluation of biological characteristics

The biological characteristics of length, weight, and condition factor at emigration were evaluated for NO and HO juveniles for MY2009. Comparisons were made between spring-emigrating smolt groups only to illustrate the differences between hatchery-reared smolts and naturally-produced smolts in terms of size and condition at emigration. HO Chinook and HO steelhead were significantly larger at emigration than NO smolts ($p < 0.05$; Table 12 and Figures 18 and 19). A total of 1,923 previously PIT tagged steelhead released from the Little Sheep

Creek and Big Sheep Creek acclimation facilities represented HO steelhead release groups. HO steelhead smolts had a mean fork length of 218.4 mm, a mean weight of 110.2 g, and a mean condition factor of 1.02; whereas, the mean fork length of NO steelhead smolts was 172.9 mm, mean weight was 54.5 g, and mean condition factor was 1.03 for a sample size of 6,115 PIT tagged fish (Table 12). The mean fork length of HO Chinook salmon was significantly greater than that of NO Chinook salmon ($p < 0.05$; Table 12). Fall-tagged NO Chinook salmon pre-smolts averaged 84.6 mm in fork length, 7.2 g in weight, and had an average condition factor of 1.15 (Table 12). Appendix I provides a weekly summary of mean fork lengths and condition factors for NO and HO Chinook salmon and steelhead smolts captured at the Imnaha River juvenile emigrant trap during the spring of 2009.

Table 12. Sample sizes, means, ranges, and standard deviations of fork lengths (mm), weights (g), and condition factors (K) for natural-origin (NO) and hatchery-origin (HO) Chinook salmon and steelhead captured during the 2009 migration year, 2 October 2008 to 17 June 2009, at the Imnaha River juvenile emigrant trap.

		Fall 2008	Spring 2009			
Attribute	Statistic	NO Chinook Pre-smolts	NO Chinook Smolts	HO Chinook Smolts	NO Steelhead Smolts	HO Steelhead Smolts
Fork Length (mm)	Sample Size (n)	2680	6115	1957	5163	1923
	Mean	84.6	99.7	123.2	172.9	218.4
	Minimum	50	50	100	120	130
	Maximum	123	140	163	257	315
	Standard Deviation	9.8	10.0	8.1	17.6	23.4
Weight (g)	Sample Size (n)	2680	6115	1957	5163	1923
	Mean	7.2	11.6	22.6	54.5	110.2
	Minimum	1.7	1.1	11.4	14.9	20.2
	Maximum	20.1	32.2	58.3	174.7	376.3
	Standard Deviation	2.4	3.5	4.5	16.9	38.6
Condition Factor (K)	Sample Size (n)	2680	6115	1957	5163	1923
	Mean	1.15	1.14	1.2	1.03	1.02
	Minimum	0.75	0.66	0.62	0.64	0.76
	Maximum	1.78	1.51	1.69	1.52	1.42
	Standard Deviation	0.12	0.10	0.10	0.08	0.08

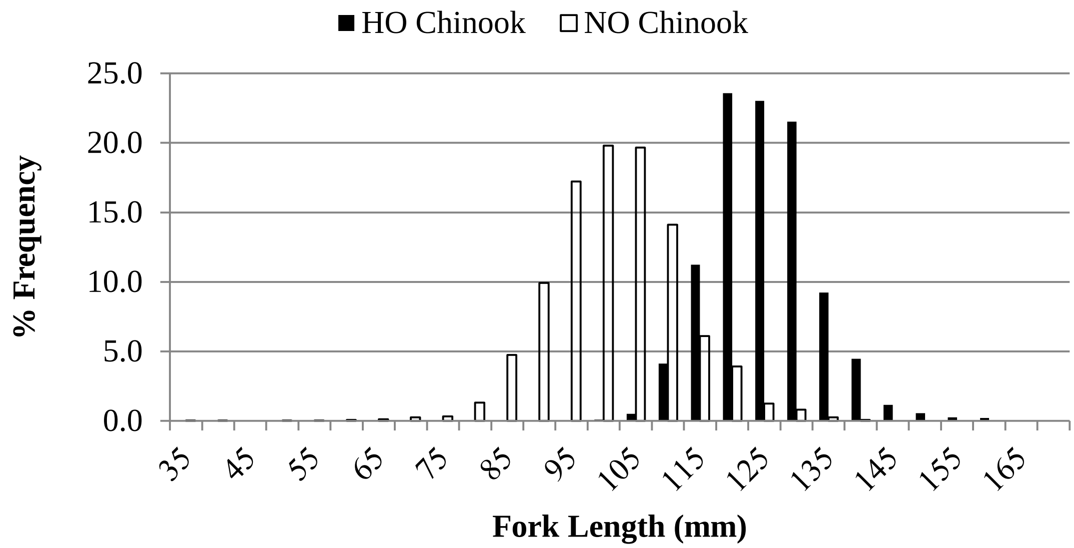

Figure 18. Length frequency distribution of natural-origin (NO) and hatchery-origin (HO) Chinook salmon smolts trapped in the Imnaha River juvenile emigrant trap from February 26 to June 17, 2009.

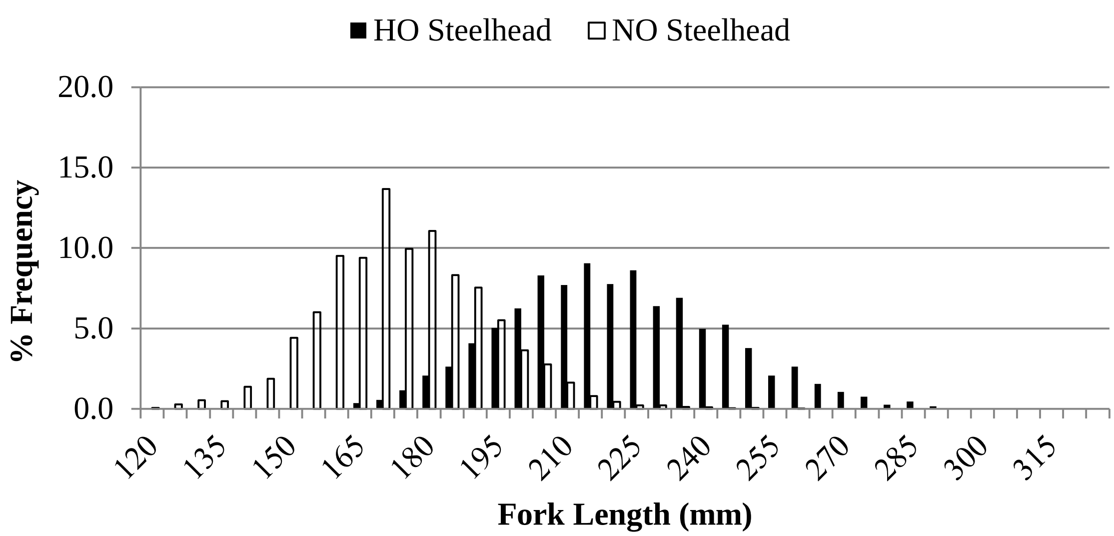

Figure 19. Length frequency distribution of natural-origin (NO) and hatchery-origin (HO) steelhead smolts trapped in the Imnaha River juvenile emigrant trap, February 26 to June 17, 2009.

LSRCP hatchery programs for the Imnaha River have produced significantly larger smolts than in nature from 1994 to 2009. The differences in size between HO and NO smolts has been a management concern regarding both freshwater and marine survival, increased tendency to residualize or become precocial, and an earlier age at maturity for larger smolts.

Survival of both Chinook salmon and steelhead juvenile emigrants from the Imnaha River may have been heavily affected by predation, which has been shown to be inversely related to fish size in both freshwater and marine environments (Ward et al. 1989; Bond et al. 2008; Holtby et al. 1990; Neilson and Green 1986, Muir et al. 2006). Size-selective predation in the estuary by Northern pikeminnow *Ptychocheilus oregonensis* and other piscivorous fishes has been evaluated and demonstrated to be higher on juveniles less than 150 mm in total length (Muir et al. 2006; Emmett and Krutzikowsky 2008). Muir et al. (2006) found that barge-transported Chinook salmon juveniles were at a greater risk for predation in the estuary than juveniles that migrated in-river. They concluded that this was due to the smaller size at release from the barge caused by the lack of growth opportunity prior to arrival at the estuary.

For Imnaha River Chinook salmon, both size at emigration and probability of being transported may affect survival. HO and NO Chinook averaged 123.2 mm and 99.7 mm fork length, respectively when interrogated at the Imnaha River trap. At this size, both were at higher risk of predation. However, by the initiation date of full transportation at LGR (May 1, 2009) only about 10% of the HO group had passed the dam compared to 60% of the NO Chinook salmon smolts. It is possible that if a higher proportion of HO smolts were barged (therefore, not allowing additional time for growth prior to arriving at the estuary), those fish were potentially at a higher risk of predation in the estuary. In contrast, NO Chinook salmon smolts would have the benefit of additional growth during in-river emigration and reduced predation risk in the estuary. Both NO and HO steelhead smolts were already above the 150 mm total length threshold when captured at the Imnaha River trap (Table 12) so it is logical to assume that lost growth opportunity as a result of barging had minimal impact on the size-selective predation pressures in the estuary and ocean entrance for Imnaha River steelhead.

Residualism, or failure to migrate to the ocean, can partially be evaluated for HO Chinook and steelhead by assessing the survival from release at the acclimation facilities to the Imnaha River trap. Results demonstrated relatively high post-release survival rates from release to the trap for both HO Chinook salmon (89%; Figure 11) and HO steelhead (88%; Figure 12), suggesting a low tendency to residualize as either precocial Chinook parr or resident rainbow trout. Consequently, the hatchery programs for both Chinook salmon and steelhead appear to be successful in limiting the level of residualism in the Imnaha River.

Studies have shown that larger size at release, at time of ocean entry, and following the first ocean year of hatchery Chinook salmon smolts resulted in earlier age at maturity, with higher proportions of adults returning at age three and four and lower proportions of adults returning at age five than their natural counterparts (Claiborne et al. 2011; Ewing and Ewing 2002; Nielson and Geen 1986). Scheuerell (2005) found significant relationships between juvenile size at tagging and the proportion of adults returning at age four versus age five in wild adult Snake River Chinook salmon; however, results varied amongst watersheds, suggesting that local environmental conditions as well as genetics have an effect on age at maturity.

Our results suggested that size at release for both HO Chinook and steelhead was not a major factor causing decreased downstream or ocean survival. There also appeared to be no indication of an increased tendency for these hatchery smolts to residualize beyond expected and acceptable measures. Further investigation into the relationship of smolt size at migration and age at maturity for Imnaha River NO Chinook salmon and steelhead could provide useful information necessary to meet LSRCP goals of managing the hatchery broodstocks in a way that mimics the genetic and life history characteristics of their wild counterparts.

MANAGEMENT RECOMMENDATIONS AND FUTURE ANALYSIS

1. Extend trapping seasons in 2010 to better assess the emigration timing of Imnaha River juvenile Chinook salmon and steelhead. Utilize year-round trapping efforts until the pre-smolt and smolt emigration periods can be identified with precision, and modify future trapping efforts accordingly.
2. Coordinate with the Fish Passage center to distribute PIT tags in a way that maximizes representation of the entire emigrating populations of Imnaha River juveniles for the basin-wide Smolt Monitoring Program, and also increases the potential to analyze SARs for all juvenile release groups by passage route through the Snake and Columbia River hydrosystem.
3. Continue to monitor and evaluate emigration patterns (emigration timing from the Imnaha River, arrival timing at LGR in relation to transportation schedules, and travel time to LGR) and survival of Imnaha River HO and NO Chinook salmon and steelhead.
4. Evaluate the environmental conditions as they relate to emigration patterns and survival of HO and NO Chinook salmon and steelhead emigrating from the Imnaha River.
5. Provide a more comprehensive analysis of SARs for both NO and HO Chinook salmon and steelhead from the Imnaha River trap back to the Imnaha River utilizing juvenile abundance estimates and proportions of PIT tagged fish and the adult PIT tag arrays installed in the Imnaha River in 2010.
6. Provide analyses on smolt to adult survival (SAS) for Imnaha River NO and HO Chinook salmon and steelhead.
7. Further investigate the effects of smolt size differences between NO and HO Chinook salmon and steelhead on juvenile survival and adult returns, and make recommendations for the Imnaha River LSRCP hatchery programs.
8. Evaluate the use of the Imnaha River PIT tag arrays to assess residualism of both NO and HO Chinook salmon and steelhead, as well as possible delays in smolt emigration of juveniles PIT tagged at the Imnaha River trap.
9. Evaluate sources of mortality of juveniles handled at the Imnaha River trap with consideration to juvenile size, temperature, experience of tagging personnel, and time after tagging, as well as predation on fish released above the trap for trap efficiency trials.

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APPENDICES

Appendix A. The number of hours sampled and the catch, including subsample estimates, of natural-origin (NO) and hatchery-origin (HO) Chinook salmon and steelhead at the Imnaha River juvenile emigrant trap from 2 October 2008 to 17 June 2009. Sampling periods exceeded 24 hours when trapping continued past the hour the trap was started from the previous day (e.g. 0800 on October 17 to 0845 on October 18). N/A indicates the trap was not operated on that date.

Sample End Date	Hours Fished	NO Chinook	HO Chinook	NO Steelhead	HO Steelhead
10/2/2008	16.5	1	0	1	0
10/3/2008	23	0	0	0	0
10/4/2008	25.5	1	0	2	0
10/5/2008	24	10	0	2	0
10/6/2008	24	22	0	4	0
10/7/2008	24	8	0	2	0
10/8/2008	23	0	0	1	0
10/9/2008	26	0	0	0	0
10/10/2008	24.5	0	0	5	0
10/11/2008	23	1	0	8	0
10/12/2008	24.5	0	0	21	0
10/13/2008	22.5	0	0	6	0
10/14/2008	25	0	0	4	0
10/15/2008	24	5	0	4	0
10/16/2008	24	0	0	0	0
10/17/2008	24	8	0	0	0
10/18/2008	24	2	0	8	0
10/19/2008	24	2	0	0	0
10/20/2008	24	2	0	0	0
10/21/2008	24	16	0	0	0
10/22/2008	23.5	36	0	0	0
10/23/2008	24	4	0	9	0
10/24/2008	24	2	0	11	0
10/25/2008	24	2	0	2	0
10/26/2008	24	6	0	0	0
10/27/2008	24	4	0	4	0
10/28/2008	23.5	0	0	1	0
10/29/2008	24	0	0	2	0
10/30/2008	25	0	0	0	0
10/31/2008	24	5	0	0	0
11/1/2008	24	15	0	0	0
11/2/2008	24	0	0	0	0
11/3/2008	25.5	182	0	0	0
11/4/2008	25.5	530	0	0	0

Sample End Date	Hours Fished	NO Chinook	HO Chinook	NO Steelhead	HO Steelhead
11/5/2008	20.5	6	0	0	0
11/6/2008	22.5	4	0	6	0
11/7/2008	24	8	0	11	0
11/8/2008	25	102	0	3	0
11/9/2008	24	5	0	3	0
11/10/2008	24	1	0	1	0
11/11/2008	23.5	1	0	0	0
11/12/2008	24.5	1	0	0	0
11/13/2008	25	0	0	0	0
11/14/2008	26	236	0	0	0
11/15/2008	24	290	0	3	0
11/16/2008	23.5	239	0	3	0
11/17/2008	23.25	146	0	7	0
11/18/2008	25	232	0	4	0
11/19/2008	21.5	40	0	6	0
11/20/2008	24	83	0	2	0
11/21/2008	23.5	142	0	2	0
11/22/2008	24	0	0	3	0
11/23/2008	24	35	0	2	0
11/24/2008	24	50	0	1	0
11/25/2008	24	34	0	0	0
11/26/2008	24.25	7	0	0	0
11/27/2008	25	54	0	0	0
11/28/2008	24	3	0	0	0
11/29/2008	24	8	0	0	0
11/30/2008	23.5	31	0	0	0
12/1/2008	24	38	0	0	0
12/2/2008	24	22	0	0	0
12/3/2008	24	1	0	0	0
12/4/2008	23.5	7	0	0	0
12/5/2008	25	17	0	0	0
12/6/2008	23	18	0	0	0
12/7/2008	24	16	0	0	0
12/8/2008	24	8	0	0	0
12/9/2008	23.5	5	0	0	0
12/10/2008	24	0	0	0	0
2/26/2009	16	19	0	1	0
2/27/2009	23	25	0	1	0

Sample End Date	Hours Fished	NO Chinook	HO Chinook	NO Steelhead	HO Steelhead
2/28/2009	24	17	0	1	0
3/1/2009	24	15	0	0	0
3/2/2009	24	15	0	0	0
3/3/2009	23.5	16	0	2	0
3/4/2009	14.5	87	0	4	0
3/5/2009	23.5	85	0	0	0
3/6/2009	24	65	0	3	0
3/7/2009	24	68	0	1	0
3/8/2009	23.5	25	0	1	0
3/9/2009	24	1	0	0	0
3/10/2009	23.5	22	0	2	0
3/11/2009	24	32	0	0	0
3/12/2009	14	16	0	0	0
3/13/2009	19	35	0	1	0
3/14/2009	11	0	0	0	0
3/15/2009	21	32	3,709	0	0
3/16/2009	23.25	19	3,927	0	0
3/17/2009	25.75	43	1,806	0	0
3/18/2009	23.5	20	365	0	0
3/19/2009	24	29	310	0	0
3/20/2009	24	43	230	2	0
3/21/2009	24	65	143	2	0
3/22/2009	24.5	136	221	3	0
3/23/2009	25	331	380	9	0
3/24/2009	20.5	276	246	7	0
3/25/2009	25	145	126	7	0
3/26/2009	25.5	126	109	5	0
3/27/2009	23.75	116	62	2	0
3/28/2009	23.75	71	51	5	0
3/29/2009	23.75	62	40	1	0
3/30/2009	24.75	172	94	4	0
3/31/2009	23	89	49	2	0
4/1/2009	24.5	102	881	4	0
4/2/2009	24.5	72	364	1	23
4/3/2009	23.5	87	218	0	63
4/4/2009	24.5	60	401	3	84
4/5/2009	23.5	68	376	1	44
4/6/2009	25.5	47	1,968	0	46
4/7/2009	24.5	65	2,832	1	30

Sample End Date	Hours Fished	NO Chinook	HO Chinook	NO Steelhead	HO Steelhead
4/8/2009	20.5	85	1,130	11	134
4/9/2009	27	189	3,485	46	1,845
4/10/2009	20.25	228	2,469	2	904
4/11/2009	18.5	208	1,621	12	568
4/12/2009	23.5	266	1,038	29	656
4/13/2009	27.75	249	724	26	282
4/14/2009	20.5	157	1,216	43	680
4/15/2009	24	265	1,928	29	461
4/16/2009	14	83	1,684	7	245
4/17/2009	24	104	1,098	7	79
4/18/2009	24	50	477	2	55
4/19/2009	26	54	212	7	57
4/20/2009	24.5	67	180	19	106
4/21/2009	20	0	0	0	0
4/22/2009	N/A	N/A	N/A	N/A	N/A
4/23/2009	N/A	N/A	N/A	N/A	N/A
4/24/2009	N/A	N/A	N/A	N/A	N/A
4/25/2009	9.25	114	85	84	498
4/26/2009	27.75	154	63	100	360
4/27/2009	24	80	41	60	299
4/28/2009	23.25	73	22	40	178
4/29/2009	22.75	70	22	39	115
4/30/2009	25.5	63	28	41	181
5/1/2009	26	114	28	67	338
5/2/2009	23	87	22	57	222
5/3/2009	23.5	56	14	44	179
5/4/2009	24	58	27	82	301
5/5/2009	24	45	16	95	256
5/6/2009	6.5	25	19	142	398
5/7/2009	N/A	N/A	N/A	N/A	N/A
5/8/2009	N/A	N/A	N/A	N/A	N/A
5/9/2009	20	27	11	89	225
5/10/2009	24.25	27	5	106	281
5/11/2009	23.75	24	7	162	279
5/12/2009	21.25	25	12	342	501
5/13/2009	24.25	63	31	393	611
5/14/2009	15.5	20	10	276	373
5/15/2009	21.5	26	13	408	498
5/16/2009	24.5	36	12	479	596

Sample End Date	Hours Fished	NO Chinook	HO Chinook	NO Steelhead	HO Steelhead
5/17/2009	25.5	47	11	617	827
5/18/2009	21	29	1	809	1,286
5/19/2009	N/A	N/A	N/A	N/A	N/A
5/20/2009	N/A	N/A	N/A	N/A	N/A
5/21/2009	N/A	N/A	N/A	N/A	N/A
5/22/2009	14	11	1	70	61
5/23/2009	24.25	16	1	68	79
5/24/2009	24.5	16	0	93	127
5/25/2009	23.5	10	0	99	112
5/26/2009	24	12	0	55	78
5/27/2009	23.75	16	0	51	62
5/28/2009	13.5	1	1	49	89
5/29/2009	23.5	3	0	37	69
5/30/2009	13	12	0	68	74
5/31/2009	14	22	0	71	6
6/1/2009	14	4	0	34	38
6/2/2009	23.5	3	0	24	35
6/3/2009	24	5	0	12	52
6/4/2009	24.5	19	0	18	40
6/5/2009	24	21	0	40	43
6/6/2009	N/A	N/A	N/A	N/A	N/A
6/7/2009	N/A	N/A	N/A	N/A	N/A
6/8/2009	11.5	2	0	2	3
6/9/2009	24	11	0	2	10
6/10/2009	24	14	0	4	13
6/11/2009	24.5	13	0	6	26
6/12/2009	13	20	0	8	28
6/13/2009	25.25	29	0	15	36
6/14/2009	22.25	43	0	3	26
6/15/2009	24.25	17	1	8	48
6/16/2009	24	13	0	8	31
6/17/2009	24	48	0	10	15
Fall Total	1,672	2,754	0	154	0
Spring Total	2,255.25	6,468	36,674	5,703	16,365
MY Total	3,927.25	9,222	36,674	5,857	16,365

Appendix B. The number of natural-origin (NO) and hatchery-origin (HO) Chinook salmon and steelhead administered passive integrated transponder tags weekly at the Imnaha River juvenile emigrant trap from 28 September 2008 to 20 June 2009.

Week	NO Chinook	HO Chinook	NO Steelhead	HO Steelhead
9/28/2008	2	0	0	0
10/5/2008	38	0	0	0
10/12/2008	15	0	0	0
10/19/2008	62	0	1	0
10/26/2008	30	0	0	0
11/2/2008	765	0	0	0
11/9/2008	531	0	0	0
11/16/2008	877	0	0	0
11/23/2008	190	0	0	0
11/30/2008	134	0	0	0
12/7/2008	29	0	0	0
2/22/2009	61	0	3	0
3/1/2009	351	0	10	0
3/8/2009	130	0	4	0
3/15/2009	184	1	4	0
3/22/2009	1199	1	38	0
3/29/2009	642	0	15	0
4/5/2009	729	0	47	0
4/12/2009	1145	0	138	0
4/19/2009	234	0	109	0
4/26/2009	640	1	402	0
5/3/2009	210	0	448	0
5/10/2009	217	0	2163	0
5/17/2009	89	0	1073	0
5/24/2009	59	0	447	0
5/31/2009	69	0	197	0
6/7/2009	86	0	37	0
6/14/2009	94	0	29	0
Fall Totals	2,673	0	0	0
Spring Totals	6,139	3	5164	0
Season Totals	8,812	3	5164	0

Appendix C. Recaptures of passive integrated transponder tagged natural-origin Chinook salmon, tagged by the Oregon Department of Fish and Wildlife Early Life History Program, at the Imnaha River juvenile emigrant trap during the fall of 2008 and spring 2009.

Migration Year	Tagging Agency	Recapture file	Tag ID	Date Tagged	Date Recaptured	Travel Time (Days)
2009	ODFW	BDM08304.NT1	3D9.1C2CA82410	9/4/2008	10/30/2008	56
2009	ODFW	BDM08320.NT1	3D9.1C2CA49D85	9/3/2008	11/15/2008	73
2009	ODFW	BDM08323.NT1	3D9.1C2CA8A021	9/4/2008	11/18/2008	75
2009	ODFW	BDM09063.NT1	3D9.1C2CA4BBF3	9/4/2008	3/4/2009	181
2009	ODFW	BDM09064.NT1	3D9.1C2CA85F7B	9/4/2008	3/5/2009	182
2009	ODFW	BDM09065.NT1	3D9.1C2C8CDDF2	9/4/2008	3/6/2009	183
2009	ODFW	BDM09096.NT1	3D9.1C2C97CB2D	9/3/2008	4/6/2009	215
2009	ODFW	BDM09099.NT1	3D9.1C2CA899EC	9/4/2008	4/10/2009	218
2009	ODFW	BDM09100.NT1	3D9.1C2CA35FDE	9/4/2008	4/11/2009	219
2009	ODFW	BDM09103.NT1	3D9.1C2CA8A011	9/4/2008	4/13/2009	221
2009	ODFW	BDM09110.NT1	3D9.1C2CA35AE8	9/4/2008	4/20/2009	228
2009	ODFW	BDM09130.NT1	3D9.1C2C97DB3B	9/5/2008	5/10/2009	247
2009	ODFW	BDM09133.NT1	3D9.1C2CA8345E	9/3/2008	5/13/2009	252
2009	ODFW	BDM09137.NT1	3D9.1C2CA7A94B	9/3/2008	5/17/2009	256
2009	ODFW	BDM09151.NT1	3D9.1C2C8CCF94	9/5/2008	5/31/2009	268

Appendix D. The catch of incidental fish during the fall, 2 October to 10 December 2008, and the spring, 26 February to 17 June 2009, at the Imnaha River juvenile emigrant trap for the 2009 migration year. Catch totals include subsampling estimates.

Family	Common Name	Fall 2008	Spring 2009
Salmonidae	Adult Steelhead	1	79
	Adult Chinook	4	0
	Rainbow Trout / Steelhead	462	19
	Mountain Whitefish	231	11
	Bull Trout	136	2
	Adult Bull Trout	56	4
Centrarchidae	Smallmouth Bass	13	5
Catostomidae	Bridgelip Sucker	9	10
	Largescale Sucker	0	41
	Sucker (unidentified species)	97	223
Cyprinidae	Chislemouth	0	2
	Long Nose Dace	0	88
	Northern Pikeminnow	6	12
	Redside Shiner	4	1
Cottidae	Sculpin (unidentified species)	1	30
Ictaluridae	Bull Head	0	14
Petromyzotidae	Pacific Lamprey macropthalmia	0	9
	Pacific Lamprey ammocoetes	0	13
	Total Catch	1020	563

Appendix E. Pacific Lamprey, *Lampetra tridentate*, caught during the migration year 2009 trapping season, 2 October 2008 to 17 June 2009. Table includes the trap date, developmental stage, total length in millimeters (mm), and weight in grams (g).

Trap Date	Developmental Stage	Length (mm)	Weight (g)
2/26/2009	Ammocoete	160	7.2
2/27/2009	Ammocoete	150	5.8
3/4/2009	Ammocoete	140	8.4
3/4/2009	Ammocoete	140	8.2
3/7/2009	Ammocoete	140	5.8
3/17/2009	Ammocoete	-	-
4/10/2009	Macropthalmia	144	6.3
4/10/2009	Macropthalmia	150	6.4
4/10/2009	Ammocoete	-	5.8
4/10/2009	Macropthalmia	-	-
4/10/2009	Macropthalmia	-	-
4/10/2009	Macropthalmia	-	-
4/10/2009	Macropthalmia	-	-
4/10/2009	Macropthalmia	-	-
4/10/2009	Macropthalmia	-	-
4/12/2009	Macropthalmia	130	4.8
4/12/2009	Ammocoete	160	7.2
4/12/2009	Ammocoete	160	8.7
4/14/2009	Ammocoete	150	6.5
4/14/2009	Ammocoete	146	5
4/16/2009	Ammocoete	150	5.5
5/22/2009	Ammocoete	-	-

Appendix F. The weekly mean discharge in cubic feet per second (cfs), temperature in Celsius (°C), and catch, including subsample estimates, of natural-origin (NO) and hatchery-origin (HO) Chinook salmon and steelhead at the Imnaha River juvenile emigrant trap from September 28, 2008 to 20 June 2009. The temperature recorder was lost during spring of 2009.

Week	Average Discharge (cfs)	Average Temperature (°C)	NO Chinook	HO Chinook	NO Steelhead	HO Steelhead
9/28/2008	123	14.6	2	0	3	0
10/5/2008	151	10.3	41	0	22	0
10/12/2008	144	8.3	15	0	43	0
10/19/2008	146	8.4	64	0	22	0
10/26/2008	136	7.6	30	0	7	0
11/2/2008	218	7.5	832	0	20	0
11/9/2008	240	7.4	534	0	7	0
11/16/2008	211	5.5	882	0	27	0
11/23/2008	177	7.0	191	0	3	0
11/30/2008	170	5.0	134	0	0	0
12/7/2008	159	3.2	29	0	0	0
2/22/2009	232	4.4	61	0	3	0
3/1/2009	341	5.7	351	0	10	0
3/8/2009	261	N/A	131	0	4	0
3/15/2009	278	N/A	251	10,490	4	0
3/22/2009	459	N/A	1,201	1,195	38	0
3/29/2009	429	N/A	644	2,047	15	170
4/5/2009	700	N/A	890	13,881	73	3,571
4/12/2009	885	N/A	1,174	8,165	143	2,458
4/19/2009	1538	N/A	235	477	110	661
4/26/2009	864	N/A	641	226	404	1,693
5/3/2009	1540	N/A	211	87	452	1,359
5/10/2009	1297	N/A	221	90	2,166	3,139
5/17/2009	1814	N/A	103	14	1,564	2,253
5/24/2009	1804	N/A	70	1	452	611
5/31/2009	1903	N/A	74	0	199	214
6/7/2009	1476	N/A	89	0	37	116
6/14/2009	1247	N/A	121	1	29	120
Fall Totals			2,754	0	154	0
Spring Totals			6,468	36,674	5,703	16,365
Season Totals			9,222	36,674	5,857	16,365

Appendix G. Mortality of natural-origin (NO) and hatchery-origin (HO) Chinook salmon and steelhead smolts due to trapping, handling, passive integrated transponder (PIT) tagging and those that were dead on arrival (DOA) at the Imnaha River juvenile emigrant trap from 2 October to 10 December, 2008. N = sample size.

	Chinook				Steelhead			
	NO		HO		NO		HO	
Source of Mortality	(N)	(%)	(N)	(%)	(N)	(%)	(N)	(%)
Trapping	7	0.25	0	0	0	0	0	0
Handling	1	0.04	0	0	2	1.3	0	0
Tagging	0	0	0	0	0	0	0	0
DOA	0	0	0	0	0	0	0	0
Number Captured	2,754		0		154		0	
Total Mortality	8	0.29	0	0	2	1.3	0	0

Appendix H. Mortality of natural-origin (NO) and hatchery-origin (HO) Chinook salmon and steelhead smolts due to trapping, handling, passive integrated transponder (PIT) tagging and those that were dead on arrival (DOA) at the Imnaha River juvenile emigrant trap from 26 February to 17 June, 2009. N = sample size.

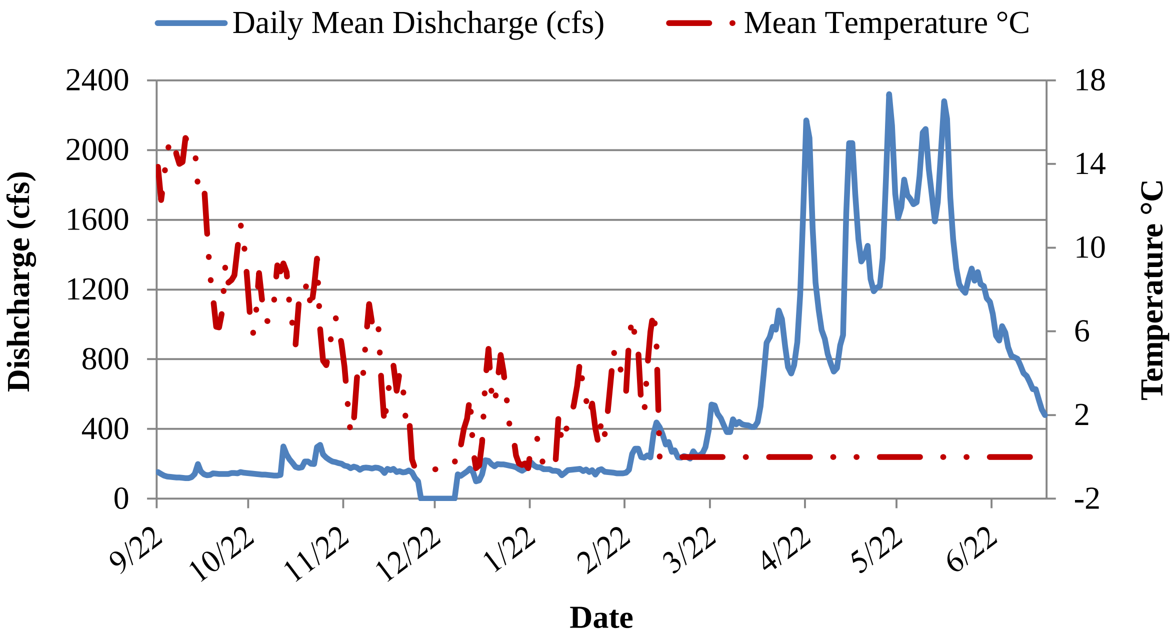
	Chinook				Steelhead			
	NO		HO		NO		HO	
Source of Mortality	(N)	(%)	(N)	(%)	(N)	(%)	(N)	(%)
Trapping	7	0.1	3	0.01	8	0.14	9	0.06
Handling	2	0.03	4	0.01	4	0.07	4	0.02
Tagging	5	0.08	0	0	19	0.32	0	0
DOA	3	0.05	1	0	0	0	0	0
Number Captured	6,468		36674		5857		16365	
Total Mortality	17	0.26	8	0.02	31	0.53	13	0.08

Appendix I. Releases of hatchery-origin Chinook salmon and steelhead smolts to the Imnaha River subbasin and the number of smolts released with a passive integrated transponder (PIT) tag during migration year 2009 (Chinook data from J. Feldhaus, ODFW, personal communication, July 2012; steelhead data from Warren et al. 2011; Table 3).

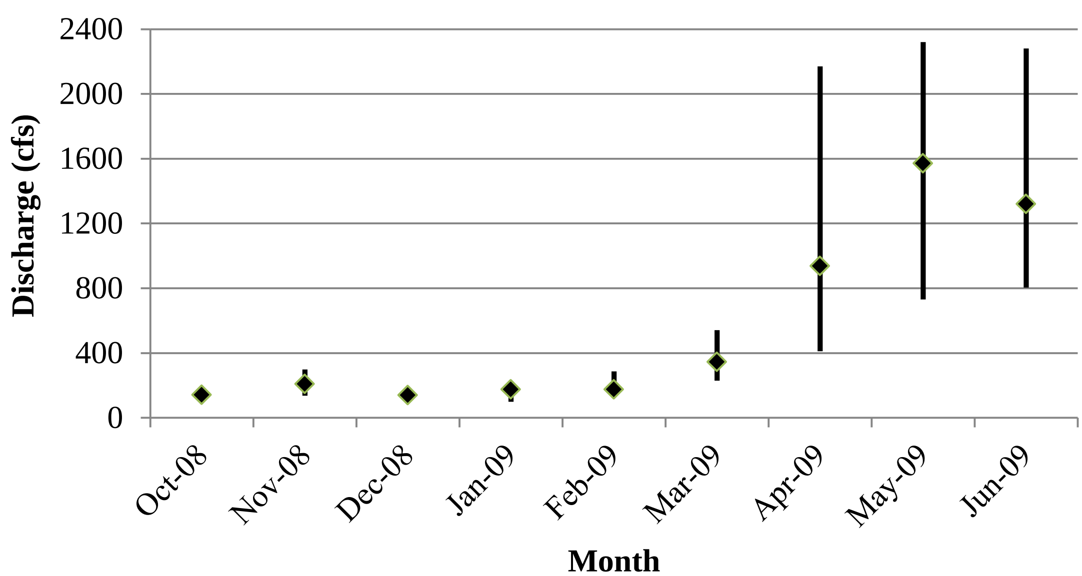
Release Year	Species	Arrival at Acclimation Site	Number Released	Release Dates	Total PIT Tags Released	Release Site
2009	Chinook salmon	March 11 - 14	234,963	March 30 – April 15	16,697	Imnaha River (Gumboot)
2009	Chinook salmon	Direct Stream	58,839	March 12	4,166	Imnaha River (Summit Cr. Bridge)
2009	Steelhead	March 2 - 4	142,103	March 31 – April 28	15,990	Little Sheep Creek
2009	Steelhead	Direct Stream	45,298	7-Apr	4,860	Big Sheep Creek

Appendix J. Weekly mean fork lengths (FL) in millimeters (mm) and condition factors (K) for natural-origin (NO) and hatchery-origin (HO) Chinook salmon and steelhead smolts captured at the Imnaha River juvenile emigrant trap during the spring of 2009.

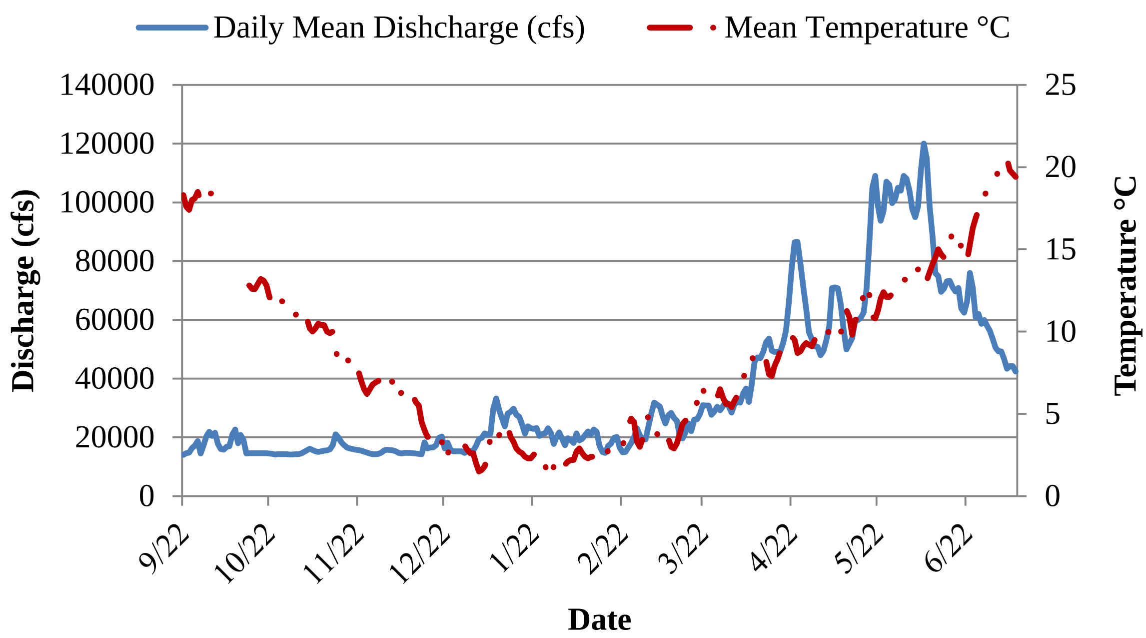
	NO Chinook smolts		HO Chinook smolts		NO steelhead smolts		HO steelhead smolts	
Week	FL (mm)	K	FL (mm)	K	FL (mm)	K	FL (mm)	K
2/22/2009	93.8	1.19			151.7	1.02		
3/1/2009	95.2	1.12			147.0	1.03		
3/8/2009	95.7	1.14			162.8	0.98		
3/15/2009	97.1	1.08	119.9	1.18	152.5	0.96		
3/22/2009	96.9	1.13	119.7	1.17	150.5	0.99		
3/29/2009	98.6	1.13	121.7	1.20	164.5	0.99	219.4	1.07
4/5/2009	102.3	1.14	123.7	1.21	173.5	1.01	220.3	1.08
4/12/2009	100.0	1.16	123.6	1.21	173.4	1.02	224.1	1.07
4/19/2009	100.9	1.15	124.3	1.17	177.3	1.05	228.6	1.05
4/26/2009	101.1	1.16	125.6	1.13	170.5	1.03	221.3	1.02
5/3/2009	104.4	1.18	132.1	1.16	176.1	1.02	223.9	0.99
5/10/2009	106.3	1.13	133.0	1.11	174.7	1.03	217.8	0.98
5/17/2009	109.0	1.14	129.5	1.09	174.0	1.01	213.4	0.96
5/24/2009	107.1	1.17			164.8	1.04	204.7	0.97
5/31/2009	106.6	1.23			168.2	1.06	203.8	0.99
6/7/2009	96.7	1.23			172.8	1.08	211.8	1.01
6/14/2009	95.0	1.20			174.5	1.07	217.1	1.00



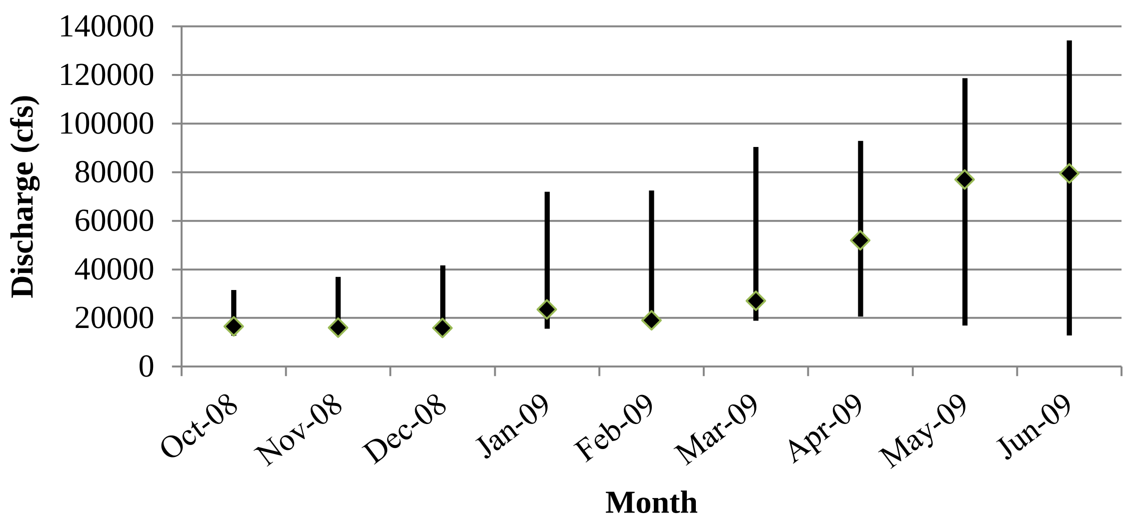
Appendix K. The average daily discharge in cubic feet per second (cfs) at the Imnaha River USGS gauge 13292000 and the average daily temperature in Celsius (^{o}C) from September 22, 2008 through July 9, 2009 at the Imnaha River juvenile emigrant trap. The temperature recorder was lost during early spring of 2009.



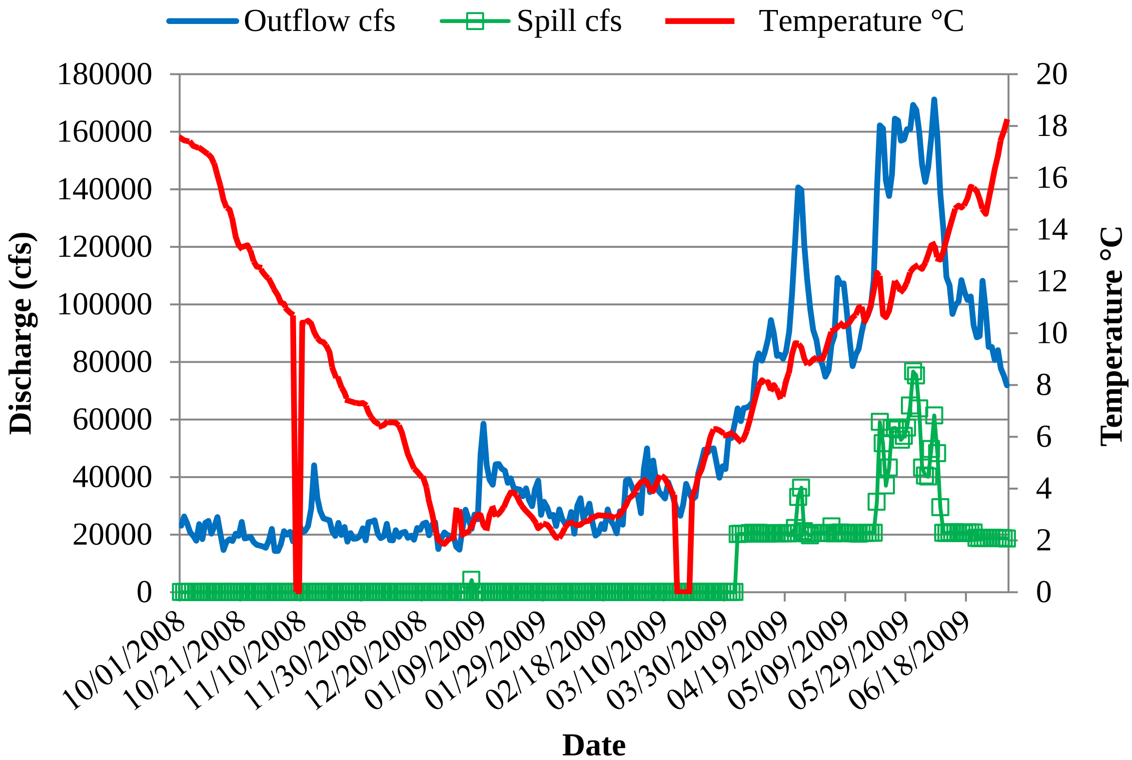
Appendix L. The average monthly discharge in cubic feet per second (cfs) for the months of October 2008 through June 2009 at the Imnaha River USGS gauge 13292000. Bars indicate the minimum and maximum average monthly discharge values observed from 1959 to 2009.



Appendix M. The average daily discharge in cubic feet per second (cfs) and temperature in Celsius (°C) at the Snake River gauge 13334300 from September 22, 2008 through July 9, 2009.



Appendix N. The average monthly discharge in cubic feet per second (cfs) for the months of October 2008 through June 2009 at the Snake River USGS gauge 13334300. Bars indicate the minimum and maximum average monthly discharge values observed from 1959 to 2009.



Appendix O. Measurements of outflow, spill, and mean temperature at Lower Granite Dam from October 1, 2008 to July 1, 2009. Data obtained online at [http://www.cbr.washington.edu/dart/.](http://www.cbr.washington.edu/dart/) cfs – cubic feet per second, ^{o}C – degrees Celsius.