Emigration of Juvenile Natural and Hatchery Chinook salmon (Nacó'x in Nez Perce) and Steelhead (Héeyey in Nez Perce) from the Imnaha River, Oregon

2010 (1 October 2009 to 31 August 2010) Annual Report for the Imnaha River Smolt Monitoring Project
and Lower Snake River Compensation Plan Hatchery Evaluation

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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 for migration year 2010 conducted from October 1, 2009, through the summer of 2010, ending August 31. The studies have been ongoing for the past 19 years and have contributed information to the Fish Passage Center's Smolt Monitoring Program (SMP) for the past 17 years. The project evaluated the survival, biological characteristics, and migration performance of natural and hatchery origin spring/summer Chinook salmon and steelhead emigrating from the Imnaha River. The study collected emigrating smolts in the Imnaha River and used passive integrated transponder (PIT) tags to estimate survival and travel time through the Snake and Columbia River dams. Survival was analyzed from the point of release for hatchery fish to the Imnaha River trap, and from the trap to Lower Granite Dam (LGR) and McNary Dam (MCN) for all release groups of natural and hatchery origin migrants. Migration timing was analyzed from release to LGR. This report represents a compilation of 17 of the past 19 years of SMP operations in addition to the migration year 2010 (MY2010) results.

The project's main goals are to; 1) provide real-time data from juvenile Chinook salmon and steelhead tagged with 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 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 natural Chinook salmon and natural and hatchery 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 from October 1 through the duration of the spring/summer migration period, capturing emigrating natural and hatchery Chinook salmon and steelhead juveniles.

We estimated a minimum of 145,179 (95% C.I. 132,673 to 159,930; C.V. 4.68%) natural Chinook salmon juveniles emigrated past the trap, with approximately 52.6% of the juveniles emigrating during the fall trapping period and 47.5% migrating during the spring and summer trapping period. MY2010 demonstrated a 23% increase in the proportion of the run emigrating as presmolts from MY2009. An estimated minimum of 57,051 (95% C.I. 47,627 to 71,530) natural steelhead smolts emigrated past the trap, mainly in the spring. Survival of hatchery Chinook salmon and steelhead juveniles from the release site to the Imnaha trap was 96% (± 3.7%) and 85% (± 3.1%), respectively, indicating that fish were released in good condition and the rate of residualization was low.

Significant differences in emigration timing were observed for natural compared to hatchery Chinook salmon smolts (spring/summer captures) as determined by the cumulative proportion of juveniles captured at the screw trap. Acclimated volitionally released hatchery steelhead migration timing was similar to natural steelhead, while directly released hatchery steelhead demonstrated a significantly earlier and contracted migration pattern than their natural counterparts.

Arrival timing at Lower Granite Dam (LGR) was significantly earlier for fall tagged natural Chinook salmon presmolts compared to spring-tagged smolts. The significant delay in hatchery Chinook salmon arrival timing at LGR that was observed in MY2009 was not observed in MY2010, with median arrival timing at the dam being similar between the origin types for spring-emigrating smolts. While first and 10^{th} percentile arrival timing at LGR occurred significantly earlier for natural Chinook salmon than for hatchery, the more contracted arrival timing period observed for hatchery Chinook salmon minimized the differences later in the return period. Median arrival timing at LGR for hatchery Chinook salmon occurred four days after that of natural Chinook, with the 90^{th} percentile date occurring three days earlier for hatchery fish. Arrival timing of hatchery steelhead at LGR was significantly earlier for directly released hatchery steelhead than acclimated or natural steelhead early in the migration season, but similar to Chinook salmon, the later portion of the run was more similar between the origin types and different release methods.

All release groups, with the exception of natural Chinook salmon fall-tagged presmolts, arrived in significant numbers after the initiation of full collections for transportation at LGR and subsequent juvenile transport dams. However, the majority of migrants of both species and origin types apparently passed through the hydrosystem via spill. In spite of the fact that 99% of the smolts that were collected were transported during MY2010 due to low flows early in the season (FPC, 2011), our results indicated that only 17% and 22% of hatchery and natural Imnaha River Chinook salmon migrants were transported during the MY2010 season, respectively. Similar to Chinook salmon, the proportions of Imnaha River natural and hatchery steelhead transported ranged from 15% to 20%. With very low collection efficiencies and a very high proportion of removals of collected fish for transportation, minimal PIT tags were available for subsequent detections at dams downstream of LGR, the survival estimate through the hydrosystem had low precision.

Travel time to LGR was negatively correlated to Snake River flow for both natural Chinook salmon smolts (spring-tagged) and natural steelhead smolts, although the relationship was not statistically significant. Hatchery Chinook salmon and steelhead and fall-tagged natural Chinook presmolts all demonstrated positive relationships between travel time to LGR and Snake River flows; though again, the relationship was not statistically significant. These results suggested that natural Chinook salmon and steelhead respond to environmental cues during emigration, but hatchery juveniles were more dependent on release timing and migrated rapidly to LGR in variable environmental conditions. Natural Chinook salmon presmolts 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. The use of court-ordered spill, reservoir drawdown, and removable spillway weirs likely had positive effects on reducing travel time and increasing spillway passage for natural origin smolts, while the implications are not as evident for hatchery fish.

We estimated survival from the Imnaha River screw trap to LGR for natural presmolts (fall-tagged), smolts (spring-tagged) and hatchery Chinook salmon. Results demonstrated that survival of presmolts was 22% (± 3.6%), compared to 77% (± 4.3%) and 70% (± 11.9%) for natural and hatchery smolts, respectively. This was the third lowest estimate of survival since the project's inception for natural Chinook salmon presmolts, which represented 41% of the entire migration year cohort of natural Chinook migrants. Survival from the trap to LGR was estimated to be 85% (± 5.4%) and 99% (± 14.7%) for natural and hatchery steelhead, respectively. Survival estimates were very near the long-term average for natural steelhead, but were extremely high for hatchery steelhead. However, results for hatchery steelhead should be considered with caution. The low detection probabilities and high rates of removals of collected PIT-tagged migrants at the LGR juvenile bypass facilities resulted in high standard errors and wide confidence intervals around the estimates.

Juvenile survival from the Imnaha River trap to McNary Dam (MCN) was estimated to compare species- and origin-specific differences in survival in the reach above LGR (screw trap to LGR) and below LGR (LGR to MCN). Natural and hatchery spring-emigrating Chinook salmon survival rates from the trap to LGR were 77% (± 4.3%) and 70% (± 11.9%) respectively, which were similar to the survival rates estimated from LGR to MCN of 72% (± 8.4%) for natural and 77% (± 23.3%) for hatchery Chinook. Survival of natural steelhead juveniles was significantly lower from LGR to MCN, with a 13% decrease in the survival rate within the Snake River hydrosystem compared to the screw trap to LGR reach. In contrast, hatchery steelhead smolts maintained a high percent of survival within the hydrosystem, albeit with very wide confidence intervals around the estimate (over 50%).

An analysis of the relationship between Snake River flow and survival from 1998 – 2010 revealed a significant correlation between flow and survival to LGR for natural, but not for hatchery steelhead juveniles. No significant relationship was found between Snake River flow and natural or hatchery Chinook salmon survival to LGR. In addition, a significant positive relationship was found between survival to MCN and natural Chinook salmon and steelhead juveniles, but not for hatchery juveniles of either species. Again these results suggested that natural origin juveniles respond to environmental conditions that maximize survival.

Adult returns in 2010 allowed for analyses of smolt to adult return (SAR) index rates through brood year 2005 for Imnaha River natural Chinook salmon, and through migration year 2008 for natural steelhead. SAR index rates measured here were estimated using only fish marked with a passive integrated transponder (PIT) tag that either remained in river or were bypassed back to the river when interrogated at juvenile collection facilities. Although these results did not represent the general Imnaha River run at large (as it excludes transported fish), these analyses provided important evaluations of annual survival trends and comparisons of in-river survival between fall- and spring-tagged natural Chinook salmon and hatchery and natural steelhead. Results demonstrated that natural Chinook SARs have continued to decline for fall-tagged presmolts compared to previous years, but increased for spring-tagged smolts. Spring-tagged natural 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 0.35%, respectively) and LGR to LGR (0.90% and 0.49%, respectively). Overwinter mortality between the Imnaha River screw trap and LGR appears to be a major factor influencing SARs for fall-emigrating

Chinook salmon presmolts. Generally, SAR index rates were higher for hatchery compared to natural steelhead for migration years 2000 to 2007. Average (geometric mean) SAR index rates were 0.61% for hatchery and 0.56% for natural steelhead from the Imnaha River trap to LGR, and 0.71% (hatchery) and 0.67% (natural) from LGR to LGR. Migration year 2008 natural steelhead demonstrated significantly higher SAR index rates for both Imnaha trap to LGR and LGR to LGR than in any other year analyzed (3.71% and 4.05%, respectively).

We evaluated and compared natural and hatchery Chinook salmon and steelhead fork lengths, weights and condition factors. Generally hatchery fish were significantly larger than natural origin juveniles as measured by fork length and weight. The mean condition factor of naturally produced Chinook smolts was also significantly lower than that of hatchery produced Chinook smolts, while the average condition factors of natural and hatchery steelhead smolts were nearly identical. The larger size of hatchery smolts may confer survival benefits by reducing predation during the migration period and early ocean residency, and this may explain the higher SAR index rates for hatchery compared to natural fish. However, differences in the size and condition factors of natural and hatchery smolts should be further evaluated in terms of residualization and the age of returning adults.

Completion of the project objectives resulted in meeting the goals indicated above. A large number of natural and hatchery 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 2010 provided long-term monitoring and evaluation trends for the LSRCP Imnaha River hatchery program.

ACKNOWLEDGMENTS

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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 2010 smolt migration year (MY2010) 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 Endangered Species Act (ESA) listed Chinook salmon and steelhead for the Federal Columbia River Power System (FCRPS) Biological Opinion (NMFS 2000). Within the framework of the Northwest Power and Conservation Council's (NPCC) Sub basin Plans, co-managers in the Imnaha River sub basin 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 2009 through summer of 2010 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 sub basin 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 sub basin 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 ESU that was listed as threatened under the United States Endangered Species Act in 1992. The Nez Perce Tribe DFRM maintains objectives in conjunction with the NPCC Imnaha Sub basin Plan of returning 5,740 adult Chinook (3,800 natural adults) to the Imnaha Basin annually, with a harvest goal of over 700 adults (NPT-DFRM 2013). The estimated adult abundance in 2010 was 937 natural and 5,021 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. Estimates of annual adult steelhead returns to the Imnaha River may have exceeded 4,000 steelhead in the 1960's. The Nez Perce Tribe DFRM maintains objectives in conjunction with the NPCC Imnaha Sub basin Plan of returning 4,315 adult summer steelhead (2,100 natural adults) to the basin annually with a harvest goal of 2,000 adults (NPT-DFRM 2013). 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 Lightning, 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 produce 490,000 Chinook salmon smolts; however, limited rearing space allows for production of only 360,000 Chinook salmon smolts. Another goal is to produce between 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 (FPC-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. The scope of the project was further expanded in spring of 2010 with additional funding provided by the BPA to operate the trap on a year-round basis in order to better assess emigration timing and provide precise population estimates.

One of the aspects of the LSRCP M&E studies in the Imnaha River is to quantify and compare natural and hatchery origin Chinook salmon and steelhead smolt performance, emigration characteristics, survival, and return rates (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 natural and hatchery origin smolt performance, and collect smolt to adult return information. The completion of trapping in August 2010 marked NPT's 19th year of emigration studies on the Imnaha River, and the 17th year of participating in the FPC's Smolt Monitoring Program making this an invaluable set of time series data and analyses.

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 natural and hatchery origin Chinook salmon and steelhead under a framework of M&E objectives listed below. Additionally, these studies 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 natural origin juvenile Chinook salmon and steelhead.

> Objective 1a: Quantify juvenile emigrant abundance for natural origin Chinook salmon emigrating past the Imnaha River trap during the presmolt and smolt emigration seasons as well as a total emigrant abundance estimate for Migration Year (MY) 2010.
>
> Objective 1b: Quantify juvenile emigrant abundance for natural origin steelhead smolts emigrating past the Imnaha River trap.

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

> Objective 2a: Quantify and compare the arrival timing of natural and hatchery origin Chinook salmon at the Imnaha River trap (represents emigration timing from the Imnaha River basin) and describe the environmental parameters of discharge and temperature during peak Chinook salmon emigration periods.
>
> Objective 2b: Quantify and compare the arrival timing of natural and hatchery origin steelhead smolts at the Imnaha River trap (represents emigration timing 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 natural origin Chinook salmon pre-smolts and smolts, hatchery origin Chinook salmon and steelhead smolts, and natural origin steelhead smolts from the Imnaha River trap to Lower Granite Dam (LGR).
>
> Objective 2d: Quantify and compare the travel time of natural and hatchery origin 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 hatchery origin Chinook salmon and steelhead smolts from release to the Imnaha River trap.

Objective 3b: Quantify and compare the survival of natural origin Chinook salmon presmolts and smolts, natural origin steelhead smolts, and hatchery origin 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 natural-origin Chinook salmon and steelhead.

Objective 4a: Quantify and compare annual SAR index rates for natural-origin Chinook salmon presmolts and smolts PIT tagged at the Imnaha River trap for run-of-river release groups.

Objective 4b: Quantify and compare annual SAR index rates for natural-origin steelhead smolts PIT 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 the biological characteristics of fork length (mm), weight (g), and condition factor of natural origin Chinook salmon presmolts, and natural and hatchery origin Chinook salmon and steelhead smolts.

Description of Project Area

The Imnaha River sub basin 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.

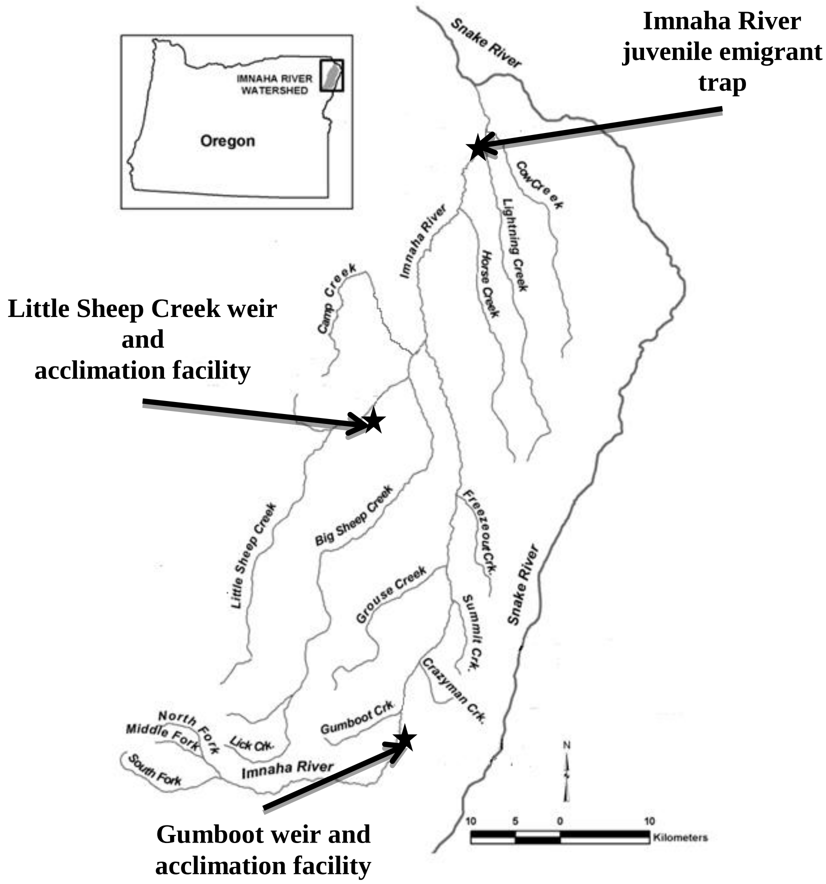

Figure 1. Map of the Imnaha River study area showing the location of the Imnaha River juvenile emigrant trap, the Gumboot Chinook salmon acclimation facility and the Little Sheep Creek steelhead acclimation facility.

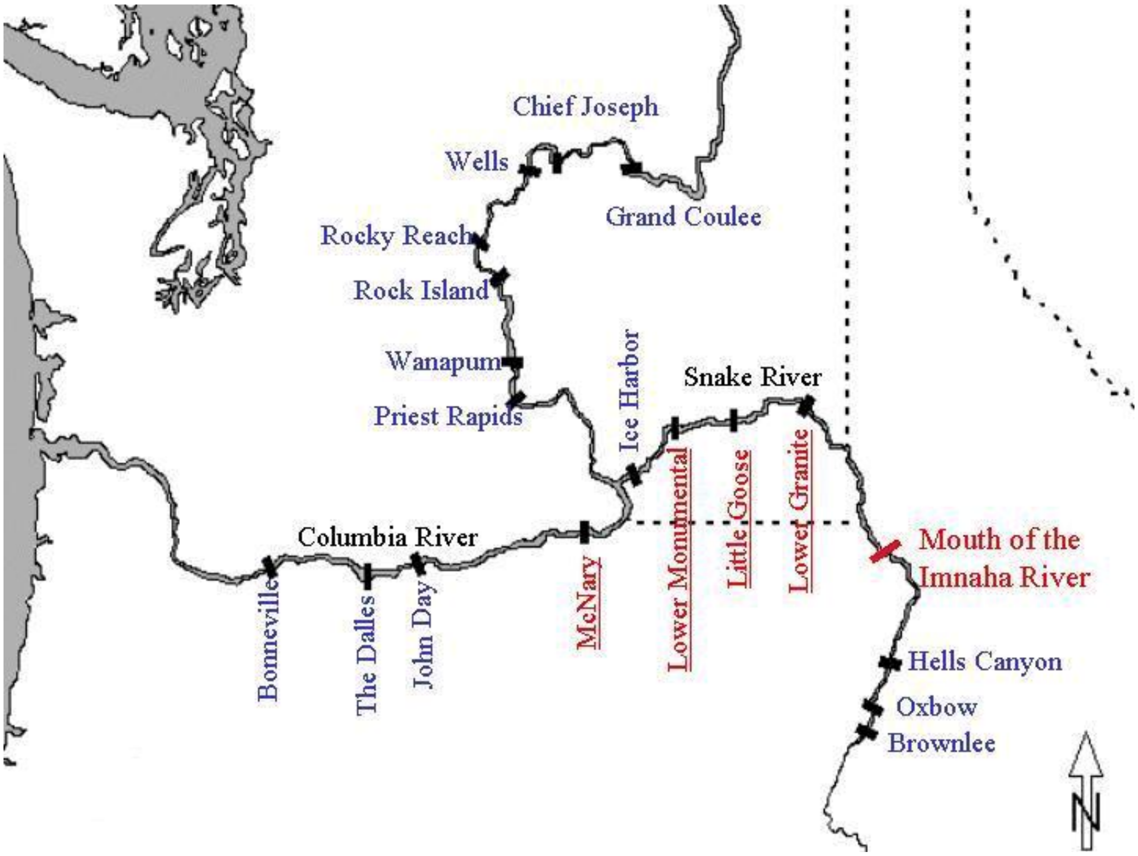

Figure 2. Map of the Columbia River Basin. Dams underlined indicate monitoring points for the Nez Perce Tribe Imnaha River Smolt Monitoring Project.

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

Generally, the spring trapping season spans from February through the middle of June; however, additional funding was obtained in spring of 2010 to fish the trap on a year-round basis in order to gain a better understanding of juvenile salmonid migration patterns and population size in the Imnaha River. 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 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 natural origin Chinook salmon and 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, handling, 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 sub sampling procedures were used to ensure a representative sample of juvenile fish trapped during both sampling and sub sampling procedures. The first sub sampling 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 sub sampling. 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 sub sampling procedure was estimated by expanding the number of processed fish by an appropriate time ratio determined by the duration of the sub sampling 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 species, origin, and numerical composition of the handled fish would be expanded to the total abundance estimate for each species. The second sub sampling 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 sub sampling 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 sub sampling 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 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 actual fish counts or PIT tags, not expanded numbers of fish handled.

PIT tagging and PIT tag recaptures of juvenile natural and hatchery origin Chinook salmon and steelhead

Natural origin Chinook salmon and steelhead juveniles selected for PIT tagging were examined for existing PIT tags, percent of descaling and general condition. 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, and at 20°C handling was reduced to netting, tallying by species, and returning fish to the river, no biological data was recorded. PIT-tagged fish were held in perforated recovery containers in the river and released after dark during the fall through spring trapping seasons. 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. From July through September, the trap was not staffed continuously throughout the day, but rather checked as early as possible in the morning and fish trapped since the previous morning were processed and released either upstream of the trap for efficiency trials or downstream of the trap after recovering from the anesthetic, a period of approximately 30 minutes. To reduce costs, the trap was fished on a five-day-per week basis. No trap efficiency fish were released on the last day of trapping for the week.

PERFORMANCE MEASURE EVALUATIONS

Life-stage specific estimates of natural origin juvenile emigrant abundance

Emigrant abundance for natural origin Chinook salmon presmolts and smolts and natural origin steelhead smolts were estimated for the tributary using the weekly catch numbers 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 natural-origin Chinook salmon and steelhead smolts. The daily goal was to randomly PIT tag 50 Chinook salmon and 50 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, with the exception of the summer trapping period, when fish are released immediately after recovering from the anesthetic. 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 2010, hatchery-origin Chinook salmon and steelhead were released by LSRCP facilities managed by the Oregon Department of Fish and Wildlife (LSRCP, 2010). In 2010 two hatchery steelhead groups were released. First a volitional release from the Little Sheep Acclimation Facility began March 30 after three weeks of acclimation, with remaining smolts forced out of the pond on April 27, 2010. Second, a direct release into Big Sheep Creek occurred on April 6, 2010 (Appendix H, Warren et al. 2012). Hatchery Chinook salmon were volitionally released after three weeks of acclimation from the Gumboot Acclimation Facility starting April 1, with all remaining smolts forced out of the acclimation pond on April 14, 2010, (Feldhaus et al. 2012).

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 natural- and hatchery-origin Chinook salmon and steelhead juveniles. Capture timing of natural-origin Chinook salmon was compared to the timing of recaptures of hatchery-origin 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 natural-origin 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 Kolmogorov-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). During periods of peak emigration, Imnaha River flows were averaged by week. For this report, data on Imnaha River discharge was obtained from USGS gauge 13292000 at Imnaha, Oregon at http://waterdata.usgs.gov/usa/nwis/uv?site_no=13292000. Imnaha River water temperatures were recorded using a thermograph placed 150 meters upstream from the screw trap.

Arrival timing of Imnaha River juvenile emigrants at Lower Granite Dam

Arrival timing at Lower Granite Dam (LGR) was quantified for natural and hatchery origin Chinook salmon and steelhead using PIT tag interrogation data queried from PTAGIS and the proportion of emigrant passage over time. Detections and arrival timing for this report period were based on first-time observations of individual tag codes at the dam. The cumulative distribution of arrival times were compared using a Kolmogorov-Smirnov test (Steel et al. 1997 and STATGRAPHICS 1995) for five different release groups: fall-tagged natural origin Chinook salmon presmolts, natural and hatchery origin Chinook salmon smolts tagged or recaptured during the spring and early summer, and natural and hatchery origin steelhead smolts. The cumulative proportion that arrived before the April 26, 2010 initiation date of full collections for juvenile transportation at LGR (FPC, 2011) 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. The proportion of each release group that was destined for transportation was estimated by multiplying the proportion of the release group passing LGR during the transportation window by the collection efficiency of the juvenile bypass facility and the proportions of collections that were transported.

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 natural and hatchery origin Chinook salmon and steelhead smolts. In addition, we determined the relationship between weekly mean travel time and Snake River flow using a regression analysis. For this report, 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

In-river survival (post release survival in the tributary) was calculated for hatchery origin Chinook and steelhead smolts from their point of release to the Imnaha River juvenile emigrant trap at rkm 7. Hatchery release groups were evaluated independently 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 and a direct release into Big Sheep Creek (steelhead). Survival probabilities were estimated by the Cormack, Jolly and Seber methodology (1964, and 1965, respectively, as cited in Smith et al. 1994) and analyzed using the program PITPRO version 4.10 (Westhagen and Skalski, 2007). The program SURPH (Survival Under Proportional Hazards, version 3; Smith et. al. 1994) was used to test for significant differences in survival or detection probability between origins and hatchery release methods using the Burnham tests and the likelihood ratio test. Data for PITPRO and SURPH was obtained directly from PTAGIS.

Survival estimates from the Imnaha River to LGR and MCN were calculated for natural and hatchery origin Chinook salmon and steelhead smolts (PIT tagged at the trap between January 1 and August 31) and natural origin Chinook salmon presmolts (tagged September 1 – December 31.) Natural origin Chinook salmon release groups were evaluated independently by life-stage (presmolt and smolt) and also as a combined release group by migration year (cohort). Natural origin steelhead smolts trapped during the fall are excluded from analysis due to insufficient numbers for conducting PIT-tag based survival and mark/recapture analyses. The assumptions for the methodology can be found in Smith et al. (1994) and Burnham et al. (1987).

The estimated survival rates of all release groups to LGR are applied to the population estimates at the Imnaha River trap, providing an estimated number of smolts at LGR by origin and life-history type. The variance and standard deviation used to estimate 95% confidence intervals for the smolt estimates are calculated using the formula where X equals the population estimate at the Imnaha River trap and Y equals the estimated survival rate to LGR:

$$Var(X*Y) = E(X)^2 * SE(Y)^2 + E(Y)^2 * SE(X)^2 + SE(X)^2 * SE(Y)^2$$

$$SD(X*Y) = \sqrt{Var(X*y)}$$

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.

Smolt to adult return (SAR) index rates

The smolt to adult return (SAR)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 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.

When PIT-tagged fish are interrogated in the hydrosystem at the four juvenile collection facilities (Lower Granite, Little Goose, Lower Monumental, and McNary dams) they are, by default, segregated from the non-tagged population and diverted back to the river. The PIT tag Separation by Code (SbyC) process is used to override the default action and allow targeted PIT-tagged fish to be treated the same as the non-tagged population, or the run-at-large. In coordination with the Fish Passage Center's Smolt Monitoring Program (FPC-SMP), PIT-tagged juvenile Chinook salmon and steelhead from the Imnaha River are segregated into "monitor-only" mode and "survival" mode release groups. The "survival" mode tags will automatically be shunted back to the river when encountered at the juvenile bypass facilities and can be used to evaluate in-river survival of emigrating juveniles. Juveniles with "monitor-only" mode tags will be treated the same as the non-tagged population and either transported or bypassed depending on the management actions at any given time at each juvenile collection facility. While "monitor-only" mode tags can be used to provide a more comprehensive evaluation of juvenile survival and SAR rates, the calculations are complex and beyond the scope of this report. The Comparative Survival Study (CSS) provides a comprehensive analysis of survival by passage route through the hydrosystem. Annual reports for the CSS are available at http://fpc.org/documents/CSS.html. For this report, SAR rates are calculated for "survival" mode, or run-of-river release groups only. Additional information about the SbyC process is provided on the PTAGIS website at www.ptagis.org/learn/separation-by-code.

SARs were quantified for two groups of PIT-tagged natural origin Chinook salmon from the Imnaha River, the fall-tagged "survival" mode presmolts and spring-tagged "survival" mode smolts for brood years 1996 through 2005. Steelhead SAR index rates were calculated for natural origin steelhead for "survival" mode PIT-tagged release groups by migration year from 2000 through 2008, as the release groups from the Imnaha River trap include juveniles of unknown brood years, making analysis by brood year impossible for natural origin steelhead. Hatchery origin steelhead SAR index rates were evaluated by brood and migration year from hatchery steelhead captured and PIT tagged at the Imnaha River juvenile emigrant trap for migration years 2000 through 2007 (brood years 1999 – 2006.) After brood year 2007, PIT tagging of hatchery steelhead was discontinued at the Imnaha River trap and tagging took place at the hatchery prior to release. Upon recapture, it was unknown which SbyC mode the hatchery smolts were designated, and the resulting sample size from using "survival" mode only PIT-tagged recaptures would be too small to produce valid estimates. Therefore, no SAR index rate was quantified for brood year 2007 (MY2008) hatchery steelhead for this report.

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). Natural origin *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. A student t-test was used to test for significant differences in mean fork length, weight and condition factor between various groups of fish. Differences were considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

Trap operations

The emigrant trap was operated for a total of 142 days during migration year 2010 (MY2010). Fall trapping spanned from October 1 until ice-up on November 18 (49 days), with no inoperable periods due to icy conditions. Spring trapping commenced on February 25 and operated until August 31, 2010, beyond the end of MY2010. Based on length distributions and PIT tag detections of fish trapped and tagged during August-September, a cut-off date of August 31 was used as the end of MY2010. Given that 2010 was the first year that the trap was operated throughout the summer, the appropriate date separating trapping seasons, corresponding to the initial captures of fish from the next brood year, is unknown at this time. We will evaluate the size and migration characteristics of fish captured during the summer trapping period and determine the most appropriate date. During the spring and summer trapping period in 2010, the trap fished for 142 days with a total of 46 inoperable days. Days of in-operation resulted from high flows and debris (20) and scheduled days of in-operation or staffing/equipment problems (26). Sub sampling procedures were used to estimate juvenile abundance for five of the 142 days during the spring trapping period. Please refer to Appendix A for a summary of total hours fished and daily catch.

Target catch

The catch of MY2010 natural origin Chinook salmon totaled 25,457 fish including 14,509 presmolts trapped in the fall of 2009, and 10,948 smolts trapped during spring and summer 2010 (Appendix A.) A total of 17,318 natural origin Chinook salmon were PIT tagged at the Imnaha trap for MY2010, of which 4,908 were marked and released above the trap for trap efficiency trials (Table 1, Appendix B). A total of 23 of the 1,000 natural origin Chinook salmon that were previously PIT tagged by Oregon Department of Fish and Wildlife's (ODFW) Early Life History Program during August and September of 2009 were recaptured at the Imnaha River trap. Please refer to Appendix C for trap date, travel time, and biological data for these fish.

The catch of MY2010 natural origin steelhead totaled 7,515 fish including 254 trapped in fall and 7,261 trapped in spring (Appendix A.) A total of 6,160 natural origin steelhead were PIT tagged, of which 1,766 were marked and released above the trap for trap efficiency trials (Table 2, Appendix B). Natural origin 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 69,208 hatchery origin Chinook smolts representing brood year 2008 were captured at the Imnaha River trap during the MY2010 spring/summer trapping period (Appendix A). Hatchery origin Chinook smolt captures were from an acclimated volitional release group totaling approximately 390,064 smolts released from the Imnaha River Gumboot acclimation facility at rkm 74 beginning April 1, 2010 until April 14 when all remaining smolts were forced out. Of the 390,064 smolts released, a total of 20,605 were PIT tagged (Appendix D). A total of

3,294 previously PIT-tagged hatchery Chinook salmon were recaptured at the Imnaha juvenile emigrant trap.

A total of 20,579 hatchery origin steelhead smolts representing brood year 2008 were captured at the Imnaha River trap during the MY2010 spring/summer trapping period (Appendix A). Hatchery origin steelhead captures were from two release sites in the Imnaha River sub basin totaling 215,467 smolts (Appendix H). A volitional release of 166,842 hatchery origin steelhead from the LSRCP Little Sheep Creek acclimation facility began March 30 and ended April 27 when all remaining fish were forced out. The second was a direct release group of 48,625 hatchery origin steelhead into Big Sheep Creek that occurred April 6, 2010 (Warren et al. 2012). A total of 1,796 previously PIT-tagged hatchery origin steelhead released from the Little Sheep Creek and Big Sheep Creek acclimation facilities were recaptured at the Imnaha River trap. Please refer to Appendix D for additional information on these two release groups of hatchery origin 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 2010 (MY2010; fall 2009 and spring/summer 2010). Table includes the date range of the trap efficiency trial (Date Strata), 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. Estimate), lower 95% confidence interval (Lower C.I.), upper 95% confidence interval (Upper C.I.) and standard error (S.E.).

Date Strata	Caught	Mark	Recap	T.E. (%)	Pop. Estimate	Lower C.I.	Upper C.I.	S.E.
10/1 - 10/10	589	253	64	0.25	2302	1866	2916	275.7
10/11 - 10/17	8488	433	76	0.18	47842	37369	63814	6718
10/18 - 10/24	1516	333	82	0.25	6101	4936	7719	708.7
10/25 - 10/31	1669	298	51	0.17	9597	7472	12468	1324.3
11/1 - 11/7	796	318	104	0.33	2418	2010	2915	230
11/8 - 11/14	1070	389	91	0.23	4536	3636	5625	534.3
11/15 - 11/18	381	155	16	0.1	3496	2434	5439	738.3
Fall totals	14,509	2179	484	0.22	76,292	66,824	88,233	5,437.6
2/25 - 3/20	1239	288	47	0.16	7460	5775	9914	1067.1
3/21 - 3/27	729	321	91	0.28	2552	2112	3101	259.5
3/28 - 4/3	3670	266	47	0.18	20414	16121	26102	2651.3
4/4 - 4/10	1095	328	54	0.16	6550	5008	8513	877.7
4/11 - 4/17	828	197	24	0.12	6558	4863	9352	1143.7
4/18 - 4/24	317	124	9	0.07	3963	2541	6225	950.6
4/25 - 5/1	722	272	26	0.1	7300	5286	10514	1359.6
5/2 - 5/8	926	330	59	0.18	5108	3947	6654	683
5/9 - 5/15	770	341	55	0.16	4703	3589	6011	628.1
5/16 - 5/22	221	79	8	0.1	1964	1371	2789	369.2
5/23 - 5/29	198	99	21	0.21	900	696	1144	115.1
5/30 - 8/31	233	84	13	0.15	1415	1052	1960	228.6
Spring totals	10,948	2,729	454	0.16	68,887	61,951	77,766	4,045.1
MY 2010 Totals	25,457	4,908	938	0.18	145,179	132,673	159,930	6,789.6

Table 2. Gauss population estimates by release group and totals for natural origin steelhead captured in the Imnaha River juvenile emigrant trap during spring/summer 2010. Table includes the date range of the trap efficiency trial (Date Strata), 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. Estimate), lower 95% confidence interval (Lower C.I.), upper 95% confidence interval (Upper C.I.) and standard error (S.E.).

Date Strata	Caught	Mark	Recap	T.E. (%)	Pop. Estimate	Lower C.I.	Upper C.I.	S.E.
2/27 - 4/3	207	94	14	0.15	1311	830	2209	372.9
4/4 - 4/17	192	73	12	0.16	1093	682	1771	287.3
4/18 - 4/24	559	168	8	0.05	10497	4807	24273	4399.6
4/25 - 5/1	589	248	13	0.05	10476	4864	24463	4348.8
5/2 - 5/8	1240	370	70	0.19	6479	4388	10015	1442.6
5/9 - 5/15	2559	320	67	0.21	12080	8396	17439	2368.3
5/16 - 5/22	1236	178	20	0.11	10535	6201	18620	3374.8
5/23 - 5/29	430	208	30	0.14	2899	1753	4833	784
5/30 - 8/31	249	107	15	0.14	1681	1041	2898	464.7
MY2010 Totals	7,261	1,766	249	0.13	57,051	47,627	71,530	6,134.0

Incidental catch

The incidental catch during the fall, spring, and summer of MY2010 was estimated to total 3,027 fish comprising of six families of fishes: Salmonidae, Centrarchidae, Catostomidae, Cyprinidae, Cottidae, and Petromyzotidae (Appendix E.) The catch of Salmonidae consisted of 178 adult steelhead, 3 adult Chinook salmon, 1,316 rainbow trout, 49 mountain whitefish (*Prosopium williamsoni*), and 107 bull trout (*Salvelinus confluentus*). Bull trout were divided into adults 300 mm and greater (n=13), and juveniles less than 300 mm (n=94). The juvenile rainbow trout were determined to be resident fish based on morphological characteristics and were not enumerated as natural origin steelhead juveniles in this report. The catch of Centrarchidae consisted of 116 smallmouth bass (*Micropterus dolomieui*), and one unidentified bluegill or pumpkinseed (*Lepomis macrochirus* or *Lepomis gibbosus*). The catch of the Catostomidae family consisted of 12 bridgelip suckers (*Catostomus columbianus*), 18 largescale suckers (*Catostomus macrocheilus*), and 642 suckers of unidentified species. The catch of Cyprinidae included 20 chislemouth (*Acrocheilus alutaceus*), 303 longnose dace (*Rhinichthys cataractae*), 86 Northern pikeminnow (*Ptychocheilus oregonensis*), and 14 redside shiner (*Richardsonius balteatus*). The catch of the Cottidae family consisted of 132 sculpins of unidentified species. There was a catch of one additional fish of unknown genus and species; listed as “Other” in Appendix E. A total of 29 juvenile Pacific Lamprey (*Lampetra tridentata*) of the family Petromyzotidae were caught in the spring of 2010. Lamprey were categorized by their developmental stage as either ammocoetes (larvae), and macropthalmia (juveniles). Please refer to Appendix E for a summary table of the MY2010 Incidental Catch data and Appendix F for detailed Pacific Lamprey catch and biological data.

Trapping and tagging mortality

Mortalities handled at the Imnaha River trap during the MY2010 trapping season included 126 natural origin and 29 hatchery origin Chinook salmon, and 11 natural origin and 11 hatchery origin steelhead. Twenty-six of the natural origin Chinook salmon mortalities occurred during the fall of 2009, accounting for 0.27 % of the Chinook salmon fall catch (Appendix G). Of these 26 mortalities, 14 were from trapping, 3 from handling, 5 from tagging, and 4 that were dead on arrival. One hundred natural origin Chinook salmon mortalities occurred during the spring: 26 due to trapping, 52 from handling, 20 from PIT tagging and 2 that were dead on arrival at the Imnaha trap (Appendix H). The 100 mortalities accounted for 0.91 % of the natural origin Chinook salmon catch during the spring of 2010. Twenty-nine hatchery origin Chinook salmon mortalities were recorded in the spring of 2010. Of these, 22 were attributed to trapping, two to handling, and 5 were dead on arrival. These 29 mortalities accounted for 0.04% of the total catch of hatchery Chinook salmon in MY2010. There were 11 natural origin steelhead mortalities during the spring of 2010 (Appendix H), and none during the fall of 2009. Nine of these were from trapping, and two from handling. There were no tagging mortalities of natural origin steelhead. Mortality accounted for 0.15% of the total natural steelhead catch in the spring of 2010. A total of 11 hatchery steelhead mortalities were recorded during the spring of MY2010. Nine of these were attributed to trapping, one to handling, and one that was dead on arrival, accounting for 0.05% of the total hatchery origin steelhead catch.

Thirty-seven incidental catch mortalities occurred during the MY2010 trapping season. Thirty-three of these occurred during spring trapping and four during the fall. Trapping caused the mortality of one adult hatchery Chinook salmon, one longnose dace, two rainbow trout, 18 suclpin, one smallmouth bass, and one unidentified sucker. There were a total of 13 mortalities handled that were presumably dead on arrival, including one adult hatchery steelhead kelt, one longnose dace, 10 sculpin, and one smallmouth bass.

PERFORMANCE MEASURE EVALUATIONS

Life-stage specific estimates of natural origin juvenile emigrant abundance

The Gauss population estimate of spring juvenile emigrant abundance for natural Chinook salmon was 68,887 smolts, (95% C.I. 61,951 to 77,766; Table 1), with a C.V. of 5.87%. Spring 2010 trap efficiencies for natural Chinook salmon smolts averaged 16% and ranged from 7% to 28% through the season (Table 1). The fall juvenile emigrant abundance estimate for natural Chinook salmon presmolts was 76,292 (95% C.I. 66,824 to 88,233; Table 1) with a C.V. of 7.13%. Trap efficiencies averaged 22% and ranged from 10% to 33% through the 2009 fall season (Table 1). The MY2010 combined juvenile emigrant abundance estimate (fall and spring total) for natural origin Chinook salmon was 145,179 (95% C.I. 132,673 to 159,930) with a C.V. of 4.68%. Our results indicate that 52.6% of Chinook salmon juveniles emigrated past the trap during the fall 2009 trapping period, and 47.5% during spring of 2010.

The 2010 spring juvenile emigration abundance estimate for natural steelhead smolts was 57,051 (95% C.I. 47,627 to 71,530; Table 2) with a C.V. of 10.75%. Trap efficiencies for natural steelhead averaged 13% and ranged from 5% to 21% (Table 2).

These juvenile emigration abundance estimates should be considered minimum estimates, as the trap was not operated during the winter of MY2010 (late November 2009 through early February 2010) and was not operated during periods of high flows and cold, icy conditions (Appendix A, Table 1). However, extended trapping efforts through the summer and fall of 2010 allowed us to more precisely evaluate total spring/summer emigrant abundance, and to identify the transition into the next migration year (MY2011). After MY2010, the trap will be fished as continuously as possible to evaluate emigrant passage timing and abundance throughout the year. In addition, trap efficiency trials were limited by low marking and recapture rates during periods with fewer emigrating juveniles, such as the summer months of June through September. The number of juveniles that emigrated when the trap was not operational was not determined for migration year 2010, but will be estimated in future reports.

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 natural and hatchery Chinook salmon and steelhead smolts as well as between natural fall-tagged Chinook presmolts and spring-tagged smolts using the cumulative proportion of juveniles captured over time and a Kolmogorov-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.

Hatchery Chinook salmon from the volitional release group migrated rapidly from their release site to the screw trap. The first fish were observed at the trap within two days of the start of the volitional release on April 1 and over 90% of the group migrated past the trap by April 17. Spring-emigrating natural Chinook salmon smolts demonstrated significantly different arrival timing than hatchery smolts, with the median arrival timing occurring by April 3, ten days earlier and prior to the 10^{th} percentile arrival timing of the hatchery group (Table 3). Results of the K-S test indicated that the maximum difference between natural and hatchery Chinook salmon emigration timing occurred on April 4, 2010, when hatchery volitional releases were just beginning while over 50% of the natural population had already migrated past the trap (MaxD = 0.5167, $p < 0.0001$; Figure 4). While it is important to consider emigration at various life stages demonstrated by naturally reared salmon compared to hatchery releases of predominantly smolting juveniles, the analyses in this report serve only to compare the performance of hatchery reared juveniles to that of their natural counterparts emigrating during the spring trapping period.

Arrival timing was compared between natural steelhead and two release groups of hatchery steelhead. The cumulative proportion of emigrants arriving at the Imnaha trap was evaluated and significant differences were found between both the acclimated volitional and direct-stream release groups of hatchery fish and their natural counterparts. However, the acclimated volitional release group very closely mimicked natural emigration timing until the tail end of the run when significant differences occurred, while the direct-stream release group demonstrated significantly different emigration timing throughout the run (Table 3 and Figure 5). Results of the K-S test demonstrated that the maximum difference in emigration timing occurred on April 20 for directly released fish and May 16 for acclimated volitionally released fish (MaxD-Direct release = 0.341, $p < 0.0001$; MaxD-Acclimated release = 0.1384, $p < 0.0001$; Figure 5). The

10th percentile, median, and 90th percentile arrival timing was very similar for natural origin and acclimated volitionally released hatchery fish, indicating that emigration timing was very similar for these groups and the highly significant MaxD value is more likely a result of large sample sizes (N = 7,261 for natural and N = 1,333 for hatchery steelhead) rather than a biologically meaningful difference in emigration timing. In contrast, arrival timing of the direct release group differed significantly (Table 3). Differences between the two hatchery release groups were also evident, with an earlier overall arrival timing observed in the direct-release group based on earlier 10th, median and 90th percentile arrival timing dates. These results demonstrate that overall, the acclimated volitional release group most closely mimicked natural steelhead emigration timing, while the direct-stream release group demonstrated significantly different migration patterns, similar to previous years.

Table 3. First, 10th percentile, median, 90th percentile, and last arrival dates for natural and hatchery origin Chinook salmon and steelhead smolt release groups captured at the Imnaha River trap during the 2010 spring and summer trapping period, 25 February to 31 August. *Fall-emigrating presmolts excluded from analysis.

Origin and Species	First Arrival	10th Percentile	Median	90th Percentile	Last Arrival
Natural Chinook salmon	27-Feb	20-Mar	3-Apr	11-May	11-Aug
Hatchery Chinook salmon	3-Apr	7-Apr	13-Apr	17-Apr	15-Jul
Natural Steelhead	26-Feb	20-Apr	12-May	22-May	30-Aug
Hatchery Steelhead-Acclimated	1-Apr	19-Apr	13-May	22-May	29-Jun
Hatchery Steelhead-Direct	8-Apr	8-Apr	4-May	18-May	20-Jun

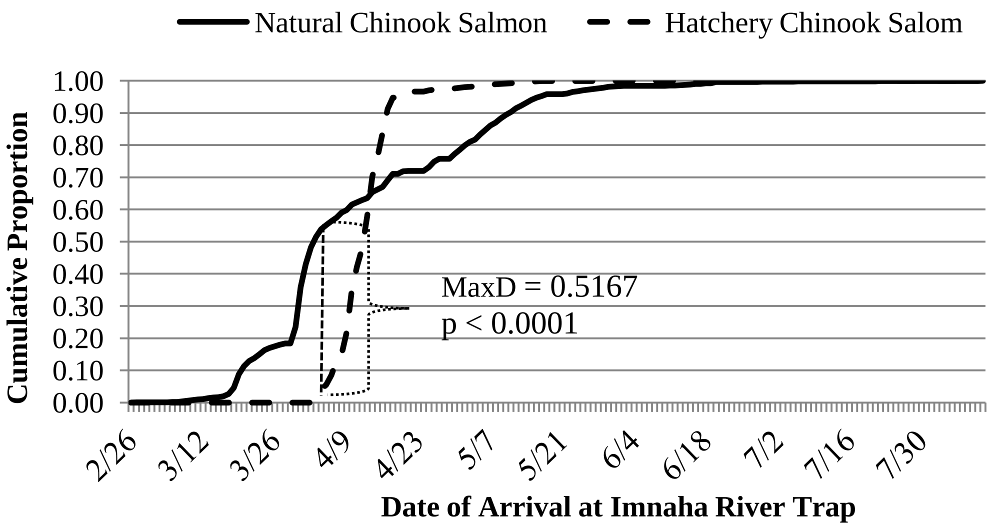

Figure 4. Comparison of emigration timing of natural and hatchery Chinook salmon smolts from the Imnaha River presented as the cumulative capture proportion of each origin type at the Imnaha River trap during the spring 2010 trapping season, 25 February to 31 August. Maximum difference in emigration timing (MaxD, represented as the dashed vertical line and bracket) between the origin types occurred on April 4, 2010.

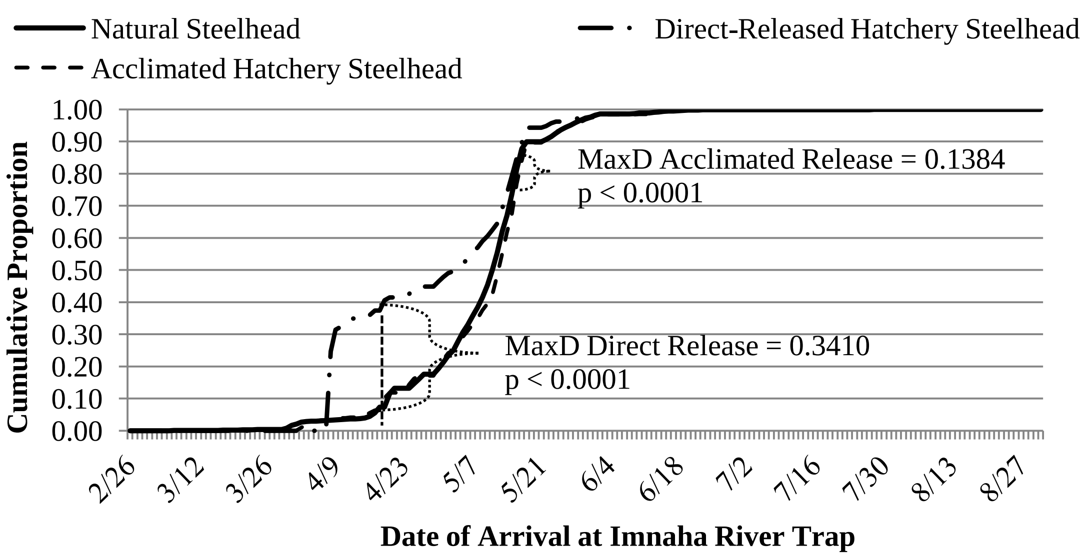

Figure 5. Comparison of emigration timing of natural and hatchery steelhead from the Imnaha River presented as the cumulative capture proportion of each origin type at the Imnaha River trap during the 2010 spring and summer trapping season, 25 February to 31 August. Maximum difference in emigration timing (MaxD, represented as the dashed vertical lines and brackets) between the origin types occurred on April 20, 2010 for the direct-stream release group and May 16 for the acclimated volitional release group.

Peak emigration timing in relation to Imnaha River discharge and temperature

Imnaha River discharge was averaged by week throughout the fall and spring emigration seasons in cubic feet per second (cfs). Natural Chinook salmon smolt emigration from the Imnaha River peaked between March 21, and April 10, 2010 with the largest number of migrants arriving at the trap during the week of March 28 through April 3, 2010. Imnaha River flows ranged from 272 cfs from March 21 – 27, to 418 cfs during the week of March 28 – April 3. Imnaha River flows peaked at 2,424 cfs during the week of June 6 – 12, when the number of natural Chinook salmon migrants passing the trap was very low. For the fall-tagged presmolt group, peak arrival timing at the trap coincided with peak flows during the week of October 11 – 17, when Imnaha River flows averaged 192 cfs. Natural steelhead arrival at the trap peaked during the week of May 9 – May 15 when flows averaged 969 cfs. Flows during the steelhead migration season ranged from 272 cfs during the week of March 21 – 27, to 2,424 cfs during the week of June 6 – 12. Temperature data for the Imnaha River was not available for the 2010 migration year due to the loss of the temperature logger.

Arrival timing of Imnaha River juvenile emigrants at Lower Granite Dam

Arrival timing at Lower Granite Dam (LGR) was calculated for natural and hatchery juvenile emigrants. Analyses of median, 10^{th} and 90^{th} percentile, and first and last arrival dates to LGR were used to evaluate differences between natural and hatchery Chinook salmon and steelhead arrival timing as well as between natural Chinook salmon presmolts and smolts. In addition, differences in cumulative arrival timing were tested for significance using a K-S test. We also calculated the proportion of Imnaha River emigrants from each release group that had passed LGR prior to the date initiation of collections for transportation through the hydrosystem. Collections for transportation (barging/trucking) at juvenile collection facilities at LGR, Little Goose Dam (LGS) Lower Monumental Dam (LMN), and MCN began on April 26, 2010 and it was assumed that fish arriving at LGR prior to April 26 were not transported, while those arriving on that date or later would be transported if collected at any of the transport dams (FPC, 2011). Analyses of collection efficiencies and proportions destined for transport referenced in this report were performed by the Fish passage Center, and are available in their annual reports (http://fpc.org/documents/FPC_Annual_Reports.html).

Chinook salmon arrival timing at LGR

Results indicated that fall-tagged natural Chinook salmon (presmolts) arrived at LGR earlier than spring-tagged Chinook salmon smolts as demonstrated by the earlier median and cumulative arrival timing at LGR (Table 4; Figure 6). The first fall-tagged Chinook presmolt was detected at LGR on October 29, 2009, indicating passage of age-0 Spring/Summer Chinook salmon juveniles began outmigration during the fall in 2009-10. This also suggested that outmigration may have occurred throughout the winter months when the juvenile by-pass facilities were not operational. The cumulative arrival timing curves were significantly different (Figure 6) with maximum difference in the proportion of arrivals between fall-tagged and spring-tagged smolts occurring on April 27, 2010 ($MaxD = 0.6264$, $p < 0.0001$; Figure 6). On April 26, 2010 when collections for smolt transportation through the hydrosystem began, 64.18% of fall-tagged Chinook salmon had already passed LGR, as opposed to only 14.55% of spring-tagged Chinook salmon (Table 5). With collection efficiencies averaging 26% for natural Chinook during the transportation season at LGR (FPC, 2011) an estimated 9.3% of Chinook salmon tagged as presmolts in the fall were likely transported compared to 22.2% of spring-tagged Chinook 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.

Table 4. Arrival timing for natural Chinook salmon presmolts (fall-tagged), natural Chinook salmon smolts (spring-tagged), hatchery Chinook salmon smolts, and natural and hatchery steelhead smolts determined by Passive Integrated Transponder (PIT) tag detections at Lower Granite Dam in migration year 2010.

Origin and Species	First Arrival	10th Percentile	Median	90th Percentile	Last Arrival
Natural Chinook salmon smolts	12-Apr	25-Apr	6-May	23-May	16-Jul
Natural Chinook salmon presmolts	29-Oct	22-Apr	24-Apr	1-May	20-May
Hatchery Chinook salmon smolts	23-Apr	29-Apr	10-May	20-May	30-May
Natural Steelhead	14-Apr	27-Apr	18-May	1-Jun	26-Jun
Hatchery Steelhead-Acclimated	20-Apr	30-Apr	20-May	4-Jun	1-Jul
Hatchery Steelhead-Direct	17-Apr	23-Apr	18-May	25-May	17-Jun

Table 5. Cumulative proportion of Imnaha River juvenile emigrants that passed Lower Granite Dam (LGR) by April 26, 2010, the date of initiation of full collections for transportation around the hydrosystem, and the estimated proportion of emigrants destined for transportation. Proportions are based on the percentage of the total detections of Passive Integrated Transponder (PIT) tagged juveniles at LGR and the collection efficiencies at the juvenile bypass facility at LGR during the 2010 migration year.

Origin and species	Proportion Passed LGR by April 26 (%)	Proportion Destined for Transportation (%)
Natural Chinook salmon smolts	14.6	22.2
Natural Chinook salmon presmolts	64.2	9.3
Hatchery Chinook salmon smolts	2.5	16.6
Natural Steelhead	9.4	19.9
Hatchery Steelhead-Acclimated	7.8	17.5
Hatchery Steelhead-Direct	23.4	14.5

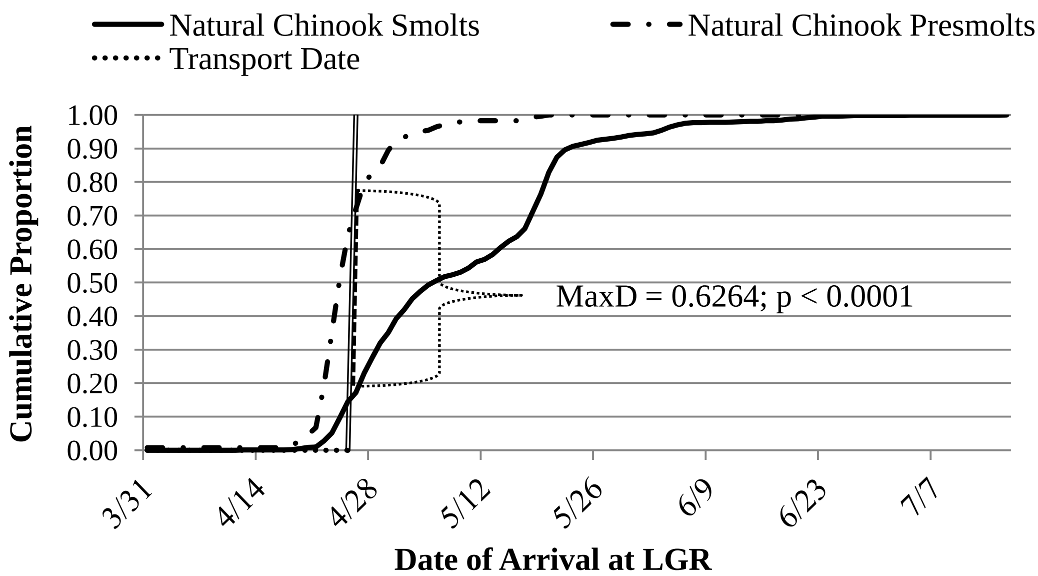

Figure 6. Arrival timing of natural origin fall-tagged Chinook presmolts and spring-tagged smolts at Lower Granite Dam (LGR) during the 2010 migration year. Maximum difference (MaxD) in arrival timing between the two release groups occurred on April 27, 2010 and is represented by the dashed vertical line with a bracket. The double vertical line indicates the initiation date of full collections for juvenile transportation at LGR, April 26, 2010.

Natural Chinook salmon smolts demonstrated earlier arrival timing at LGR compared to hatchery smolts during the beginning of the run, but arrival timing converged shortly after the median. The 90th percentile arrival date for natural Chinook was later than that of hatchery Chinook (Table 4). Maximum difference in arrival timing at LGR between hatchery and natural juveniles occurred on May 1, 2010 (MaxD = 0.2313, $p < 0.0001$; Figure 7). Both groups demonstrated very low proportions passed LGR when collections began on April 26 (14.55% for natural origin, 2.51% for hatchery origin; Table 5). Although a high proportion of juveniles arrived after collections started in 2010, collection efficiencies at LGR were low, averaging 17% for hatchery Chinook salmon and 22% for natural smolts. While collection efficiencies were low at LGR and subsequent dams, over 99% of smolts that entered the juvenile bypass system were collected and transported (FPC 2011) resulting in the transportation of an estimated 16.6% and 22.2% of the hatchery and natural Chinook salmon smolt release groups, respectively (Table 5). High rates of removals of PIT-tagged fish entering the collection facilities resulted in very low numbers of tags available for subsequent detection in the hydrosystem. The implications of high rates of removal will be explained further in the sections on juvenile survival to LGR and MCN below.

Natural Chinook salmon were detected at LGR over a month later than the last hatchery juveniles (Table 4). These juveniles were PIT-tagged later in the migration season at the Imnaha River trap and based on their size and emigration timing may have been early emigrating fall Chinook salmon. Fall Chinook salmon have been observed spawning above the juvenile trap in the lower Imnaha River (Adult Technical Team, 2010) and the detection timing at LGR corresponds with that of juvenile fall Chinook salmon (Fish Passage Center, 2011). Although the low numbers of late arriving Chinook salmon had little effect on the median arrival timing, extended trapping efforts after migration year 2010 will hopefully shed light on the mixed runs of Chinook salmon that spawn and rear in the Imnaha River.

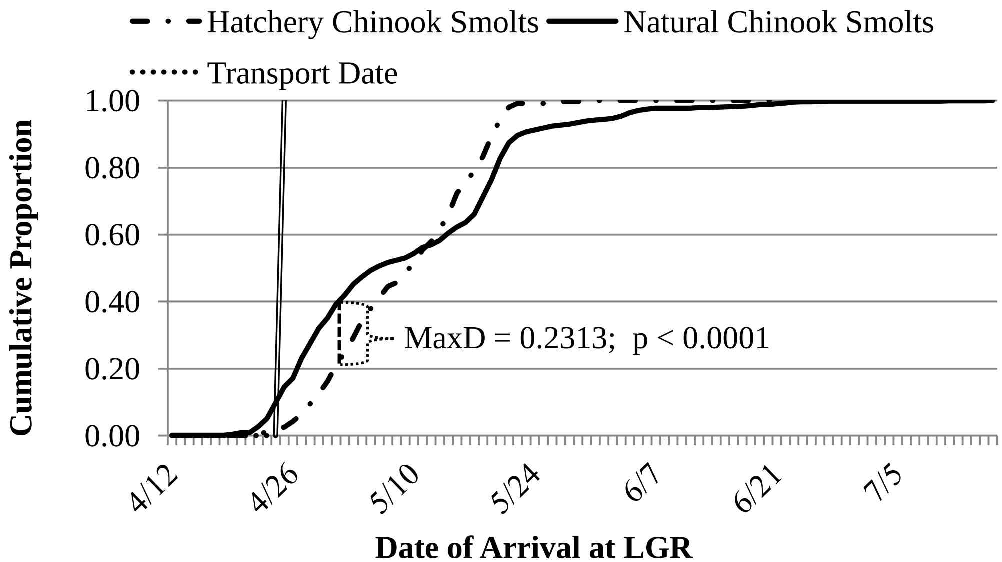

Figure 7. Arrival timing at Lower Granite Dam (LGR) of natural and hatchery origin Chinook salmon smolts emigrating during the spring and summer of 2010. Maximum difference in arrival timing between the origin types occurred on May 1, 2010 (MaxD, represented by the dashed vertical line with a bracket). The double vertical line indicates the initiation date of full collections for juvenile transportation at LGR, April 26, 2010.

In spite of the significant differences in arrival timing signified by the MaxD value, migration behaviors were similar for natural and hatchery Chinook salmon juveniles based on arrival timing patterns at the Imnaha River trap and LGR. The differences in emigration timing between these two groups actually decreased as they traveled to LGR, as indicated by their median and 90th percentile arrival timing dates at the Imnaha River trap (Table 3) and at LGR (Table 4). In contrast, the migration behavior observed during the spring of 2009 demonstrated similar median arrival timing at the Imnaha River trap and a two week difference in arrival timing at LGR (Hatch et al. 2013).

Steelhead arrival timing at LGR

Median arrival timing at LGR did not differ significantly between the hatchery groups and natural steelhead (Table 4). However, when analyzing the cumulative proportion of arrivals, significant differences became apparent. Large differences early in the run distinguished arrival timing between direct-release hatchery fish and natural fish (MaxD = 0.1834, p =0.00547 on May 1) and later in the run for acclimated hatchery fish and natural origin fish (MaxD = 0.3239, $p < 0.0001$ on May 20; Figure 8). Arrival at LGR for all three release groups followed the same pattern of emigration timing as was observed at the Imnaha River trap, indicating that these fish maintained a similar rate of emigration from the Imnaha River to LGR. There was no significant delay observed in their migration timing that affected one group uniquely.

Transportation around the hydrosystem was initiated at LGR on April 26, 2010. At that time, an estimated 7.75%, 23.4%, 9.37% of the acclimated hatchery, direct-released hatchery and natural steelhead migrated passed the dam, respectively (Table 5). Collection efficiencies averaged 19% for hatchery steelhead and 22% for natural steelhead during the transportation season at LGR

(FPC, 2011) and over 99% of collected smolts were transported. These results indicated that approximately 19.9% of the natural steelhead release group, 17.5% of the acclimated hatchery release group, and 14.5% of the direct-released hatchery group were transported, leaving the majority of all release groups migrating in-river past LGR (Table 5).

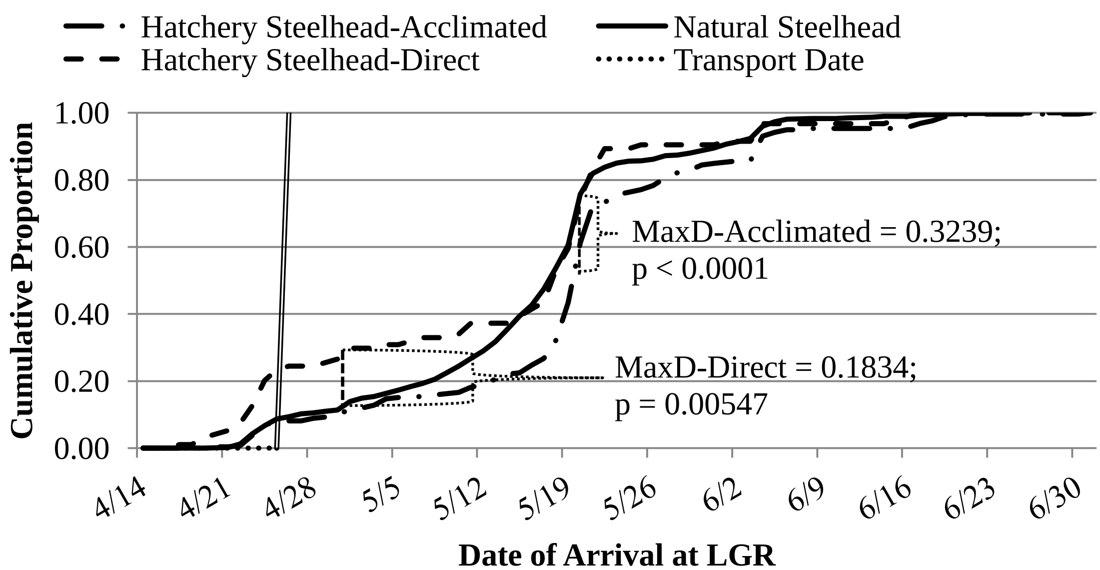

Figure 8. Arrival timing at Lower Granite Dam (LGR) of natural origin steelhead and two release groups of hatchery origin steelhead smolts emigrating during the spring and summer of 2010. Maximum difference in arrival timing between the origin and release types occurred on May 1 for directly released hatchery steelhead and May 20 for acclimated volitionally released hatchery steelhead (MaxD, represented by the dashed vertical lines with brackets). The double vertical line indicates the initiation date of full collections for juvenile transportation at LGR, April 26, 2010.

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

<u>*Chinook salmon juvenile emigrant travel time*</u>

Juvenile Chinook salmon exhibited a wide range in travel times from the Imnaha River trap to LGR. Individual fish travel times varied from 3 – 40 days for spring-tagged hatchery and natural smolts and from 154 – 256 days for fall-tagged presmolts. Mean weekly travel times varied greatly depending on the group and time of year. Generally, travel times were slightly longer for hatchery smolts compared to natural smolts and decreased as the season progressed. Mean travel times of 20 to 30 days early in the season diminished to 10 – 15 days later in the season (Table 6). Evidence suggested that decreased travel time was correlated with increasing flows (Figure 9). High numbers of natural Chinook smolts (spring-tagged) were detected at LGR from mid-April through mid-June, allowing for an investigation of the relationship between travel time and flow. In contrast, an early, contracted migration period limited the range of flows experienced by the fall-tagged natural and hatchery juveniles, limiting our ability to assess the relationship between travel time and flow or spill (Table 6) for these groups. Results demonstrated a negative, non-significant, relationship between natural Chinook salmon smolt travel time and Snake River flow ($r^2 = 0.26$, P = 0.08). In contrast, natural Chinook presmolts and hatchery Chinook smolts both trended toward a positive relationship between travel time to LGR and

Snake River flows (r^2 = 0.25, P = 0.31 for natural presmolts and r^2 = 0.20, P = 0.38 for hatchery smolts). Results from hatchery smolts and natural presmolts suggested that travel time was more heavily influenced by release date (hatchery) and delayed migration early in the migration period before the effects of flow influenced travel time later in the season. LGR passage timing results demonstrated that Chinook salmon presmolts overwinter in the Snake River above LGR, and continue migration in early spring, with the first pulse of spring-tagged migrants. Average weekly travel times for this group generally increased by approximately 7 days (1 week) throughout the migration period (Table 6), which would be expected from a common pool of presmolts aggregated in the Snake River with different tag dates but a similar migration timing behavior. Although the distribution of detections at LGR appear to be bimodal for the spring-tagged natural smolt group and the hatchery smolt group, this is likely a result of high flows in the Imnaha River that limited trap operations and the administration of PIT tags, or the recapture of PIT-tagged hatchery fish at the trap. However, an adequate number of PIT tagged juveniles were available during these high flow periods (April 19 – 29; Appendix A) to assess the relationship between travel time and flow at LGR. Overall there was a decreasing trend in interrogations at LGR as flows increased in late May, then a rapid drop in detections around peak flows. However, given the trend in detections during a period of gradually increasing flows up until about May 25 (Figure 10), it was likely that a majority of the smolts had passed LGR prior to the spike in flows. Travel time remained relatively constant at 14 – 15 days up through the week of peak flows (May 3; Table 6) suggesting that travel times were not greatly affected by flow. The reduced travel times after peak flows may have been a behavioral response to an environmental cue to minimize travel times to the ocean that late in the outmigration season.

Overall, flows throughout the smolt migration season in 2010 were below average (FPC, 2011). The positive relationship between Snake River flow and travel time likely had a positive effect on survival through the hydrosystem. Although early arrival timing at LGR when flows were lower did not appear to benefit hatchery Chinook salmon smolts or natural Chinook salmon presmolts over-wintering in Lower Granite Reservoir, results suggested that a significant proportion of spring-tagged Chinook salmon smolts were still above LGR after May 1 (n = 722 in MY2010, data not shown) and would have benefited by increased flows and greatly reduced mean travel times. Increasing flows and spill, as well as the operation of surface passage structures like removable spillway weirs, appear to reduce travel time and likely have a positive impact on passage and survival for natural origin Chinook smolts (FPC, 2011).

Table 6. Weekly mean travel time from the Imnaha River trap to Lower Granite Dam (LGR) for hatchery Chinook salmon smolts, natural Chinook salmon spring-tagged smolts and natural Chinook salmon fall-tagged presmolts in 2010. The table includes LGR detection week, number of Chinook salmon detected (count), mean travel time in days, the range of travel times (10% and 90% bounds) for all three release groups and mean Snake River flow in cubic feet per second (cfs). *Single detections, no 10% to 90% range was available.

LGR Detection Week	Hatchery Smolt Count	Hatchery Smolt Mean Travel Time (Days)	Hatchery Smolt Range of Travel Times (10% - 90%)	Natural Smolt Count	Natural Smolt Mean Travel Time (Days)	Natural Smolt Range of Travel Times (10% - 90%)	Natural Presmolt Count	Natural Presmolt Mean Travel Time (Days)	Natural Presmolt Range of Travel Times (10% - 90%)	Snake River Flow (cfs)
3/25/10	--	--	--	--	--	--	1*	137	--	23,479
4/1/10	--	--	--	--	--	--	--	--	--	24,393
4/8/10	--	--	--	1*	16	--	--	--	--	21,618
4/15/10	--	--	--	12	27	(19 - 38)	17	159	(154 - 190)	29,021
4/22/10	26	17	(7 - 25)	379	27	(7 - 38)	214	164	(156 - 195)	43,230
4/29/10	73	22	(12 - 28)	309	25	(7 - 40)	36	171	(164 - 201)	42,007
5/6/10	44	28	(17 - 33)	109	26	(7 - 39)	8	181	(187 - 205)	36,205
5/13/10	77	30	(7 - 36)	277	15	(4 - 31)	4	180	(199 - 246)	43,258
5/20/10	31	27	(7 - 35)	228	14	(4 - 24)	1*	--	--	57,570
5/27/10	1*	43	--	32	15	(6 - 30)	--	--	--	53,474
6/3/10	--	--	--	44	14	(4 - 27)	--	--	--	135,153
6/10/10	--	--	--	7	12	(3 - 29)	--	--	--	106,152
6/17/10	--	--	--	19	10	(4 - 24)	--	--	--	74,886
6/24/10	--	--	--	3	6	(6 - 7)	--	--	--	62,007
7/1/10	--	--	--	1*	14	--	--	--	--	45,146
7/8/10	--	--	--	1*	21	--	--	--	--	34,827
7/15/10	--	--	--	1*	30	--	--	--	--	29,976
7/22/10	--	--	--	--	--	--	--	--	--	23,436

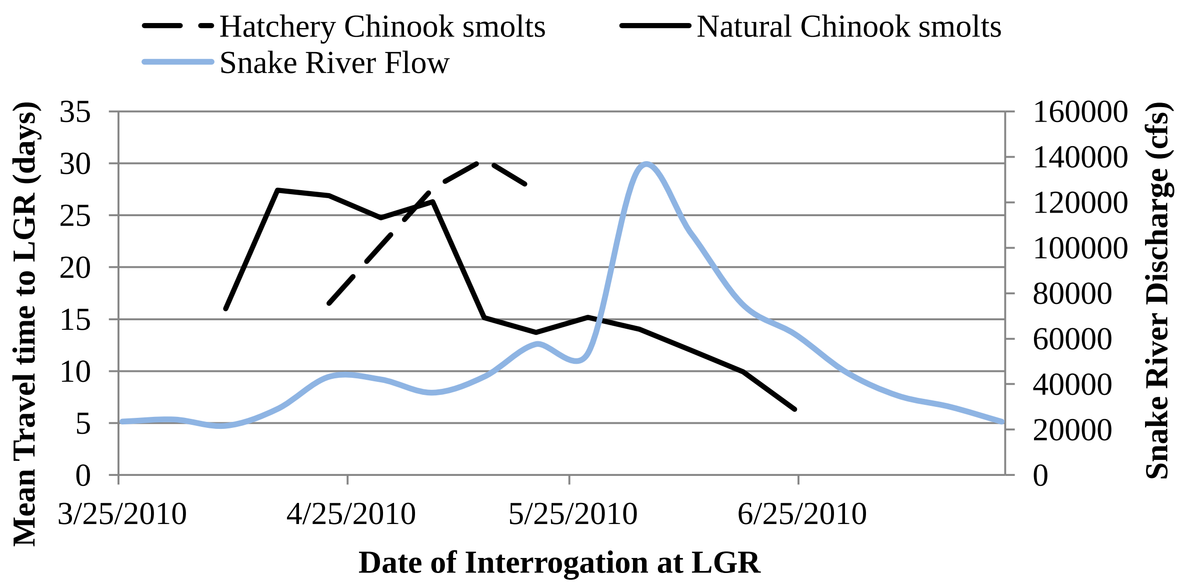

Figure 9. Mean weekly travel time from the Imnaha River trap to Lower Granite Dam (LGR) for migration year 2010 hatchery Chinook salmon smolts, natural Chinook salmon smolts tagged during the spring trapping period, and Snake River flow in thousands of cubic feet per second (cfs).

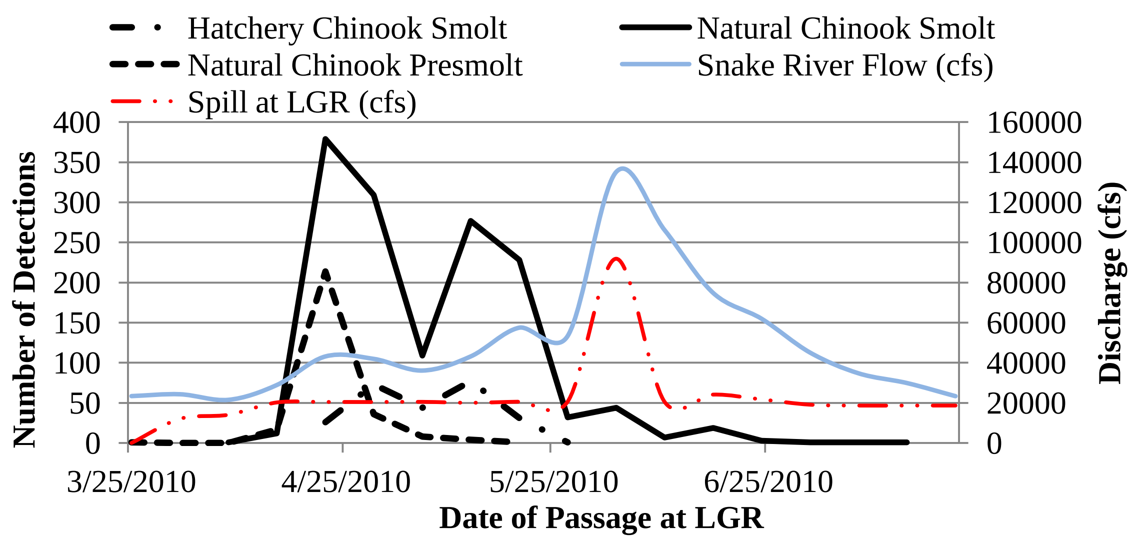

Figure 10. Peak passage timing at Lower Granite Dam (LGR) presented as the number of Passive Integrated Transponder (PIT) tagged Chinook salmon detections at LGR during the spring and summer of 2010 and Snake River flow and spill at LGR presented in cubic feet per second (cfs). Figure includes the date of passage of PIT-tagged fish at LGR by release group for hatchery Chinook salmon smolts, natural Chinook salmon smolts, and natural Chinook salmon presmolts.

Steelhead juvenile emigrant travel time

Juvenile steelhead travel times from the Imnaha River trap to LGR varied from 6 – 26 days and mean weekly travel times ranged from 3 – 16 days, depending the group and time of year.

Generally travel times were slightly longer for hatchery smolts compared to natural smolts and decreased as the season progressed. Mean travel times of 8 to 10 days early in the season diminished to 3 – 8 days later in the season (Table 7). Natural steelhead travel times from the Imnaha River trap to LGR generally decreased as the trapping period progressed and flows increased (Figure 11), although the relationship between travel time and Snake River flow was not statistically significant ($r^2 = 0.22$, P = 0.12). And similar to hatchery Chinook salmon, travel time for hatchery steelhead juveniles trended toward a positive relationship with Snake River flows (Figure 11), although the relationship was not statistically significantly ($r^2 = 0.01$; P = 0.81).

Steelhead passage at LGR was later than that observed for Chinook salmon and appeared to trend upward in May, coinciding with increasing flows and spill, and peaked prior to high flows in early June (Figure 12). Travel times decreased gradually as flows increased in May, and then decreased significantly during the second and third weeks of June, coinciding with maximum Snake River flows. Although peak flows and coinciding spill made it difficult to quantify the number of smolts passing LGR during this time period, tagging data at the Imnaha River trap (Table 2, Appendix A) indicated that emigration from the Imnaha River peaked in mid-May and, based on mean travel times of 7 – 10 days to LGR (Table 7), the majority of steelhead smolts passed LGR prior to peak flows in June.

Table 7. Weekly mean travel time from the Imnaha River trap to Lower Granite Dam (LGR) for hatchery and natural origin steelhead smolts in spring and summer of 2010. The table includes LGR detection week, number of hatchery and natural steelhead smolts detected (count), mean travel time in days, the range of travel times (10% and 90% bounds), and mean Snake River flow in cubic feet per second (cfs).

LGD Detection Week	Hatchery Smolt Count	Hatchery Smolt Mean Travel Time (Days)	Hatchery Smolt Range of Travel Times (10% - 90%)	Natural Smolt Count	Natural Smolt Mean Travel Time (Days)	Natural Smolt Range of Travel Times (10% - 90%)	Snake River Flow (cfs)
3/25/10	--	--	--	--	--	--	23,479
4/1/10	--	--	--	--	--	--	24,393
4/8/10	--	--	--	1*	15	--	21,618
4/15/10	6	10	(6 - 13)	2	20	(19 - 20)	29,021
4/22/10	40	9	(3 - 17)	134	8	(3 - 22)	43,230
4/29/10	22	11	(3 - 23)	89	8	(4 - 14)	42,007
5/6/10	16	10	(3 - 26)	151	6	(4 - 9)	36,205
5/13/10	85	8	(2 - 18)	412	6	(3 - 10)	43,258
5/20/10	119	7	(2 - 12)	333	5	(2 - 9)	57,570
5/27/10	20	9	(2 - 14)	68	7	(3 - 9)	53,474
6/3/10	30	16	(2 - 41)	90	8	(2 - 14)	135,153
6/10/10	3	2	(2 - 3)	9	3	(2 - 4)	106,152
6/17/10	11	3	(2 - 4)	11	3	(2 - 4)	74,886
6/24/10	--	--	--	2	5	(4 - 6)	62,007
7/1/10	1*	2	--	--	--	--	45,146
7/8/10	--		--	--	--	--	34,827
7/15/10	--		--	--	--	--	29,976
7/22/10	--		--	--	--	--	23,436

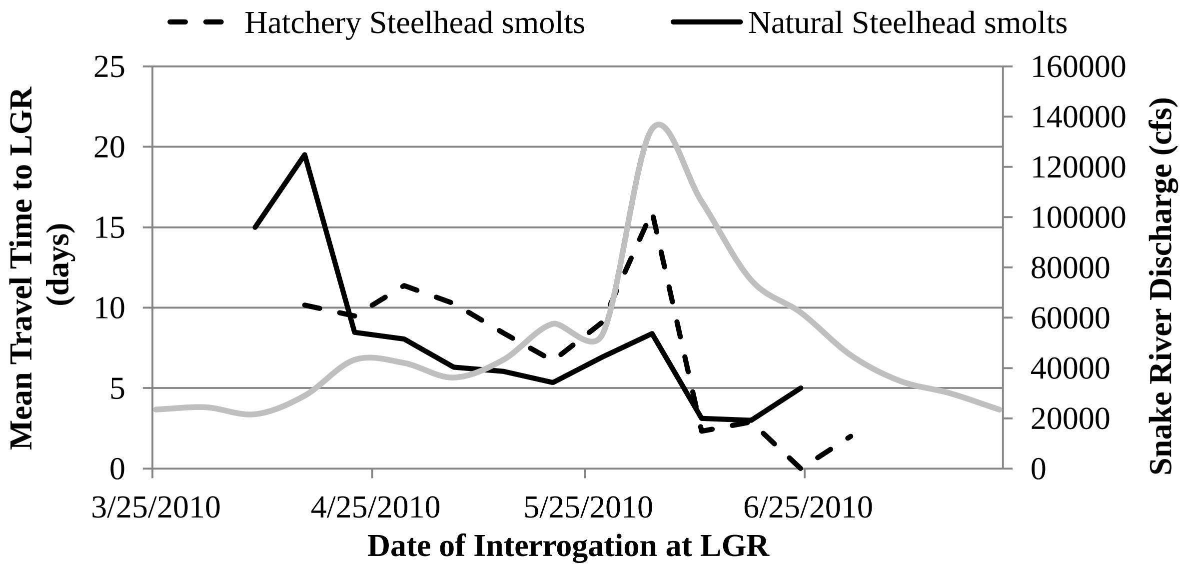

Figure 11. Mean weekly travel time from the Imnaha River trap to Lower Granite Dam (LGR) for migration year 2010 hatchery and natural origin steelhead smolts and Snake River flow in thousands of cubic feet per second (cfs).

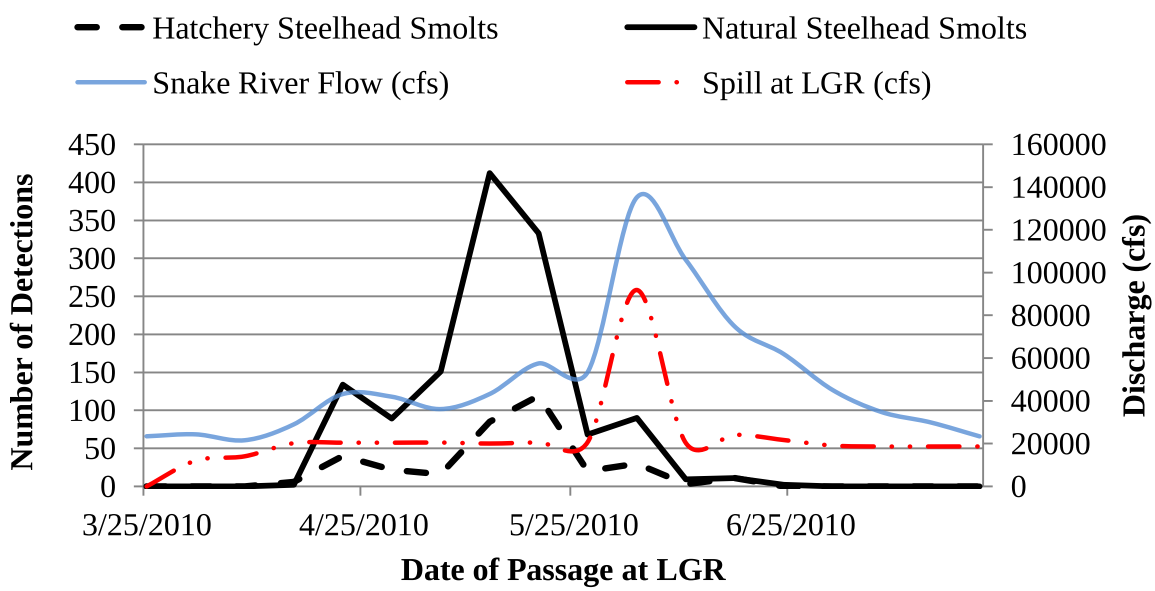

Figure 12. Passage timing at Lower Granite Dam (LGR) presented as the number of Passive Integrated Transponder (PIT) tagged steelhead detections at LGR during the spring and summer of 2010 and Snake River flow and spill at LGR presented in cubic feet per second (cfs). Figure includes the date of passage of PIT-tagged fish at LGR by release group for hatchery and natural steelhead smolts.

Life-stage specific estimates of juvenile emigrant survival

Post release survival of hatchery Chinook salmon smolts

Post release survival from release to the trap of acclimated hatchery Chinook salmon was 96% (± 3.7%) resulting in an estimated 373,681 (± 14,237) hatchery Chinook salmon emigrating past the Imnaha River juvenile emigrant trap during the spring of 2010. Survival was similar to previous estimates that have ranged from 63% (± 2.1%) in 2006 to 100% (± 14.3%) in 1994 (Figure 13). The relatively low mortality and high estimate of smolts passing the trap suggested that migration year 2010 (brood year 2008) hatchery Chinook were released in good condition and very few fish residualized as precocial parr within the Imnaha River.

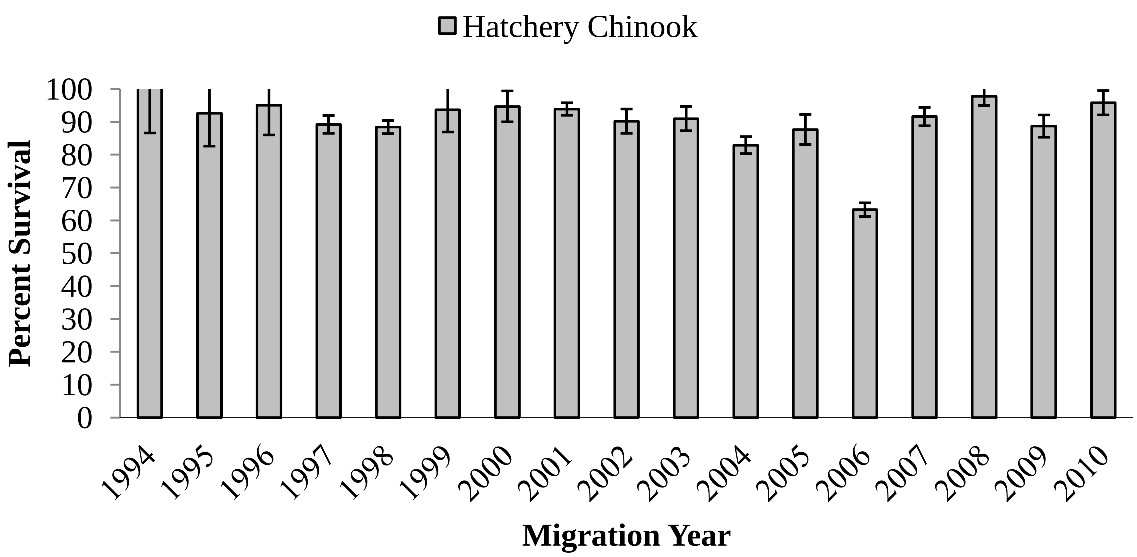

Figure 13. Estimated post release survival of hatchery Chinook salmon smolts from release at the Imnaha River Gumboot acclimation facility to the Imnaha River juvenile emigrant trap during the spring from 1994 to 2010. The error bars indicate 95% confidence intervals.

Post release survival of hatchery steelhead smolts

Survival from release to the trap of the combined hatchery steelhead release groups (directly-released and acclimated) was 85% (± 3.1%) resulting in an estimated 184,008 (± 6,679) hatchery steelhead emigrating past the Imnaha River juvenile emigrant trap during the spring of 2010. Survival was similar to previous estimates that have ranged from 56% (± 8.0%) in 1994 to 100% (± 9.2%) in 2003 (Figure 14). Analyzing the release methods independently, survival for the acclimated group was 86% (± 3.7%), resulting in approximately 143,484 (± 6,090) hatchery smolts emigrating past the Imnaha trap, and directly-released hatchery steelhead had an estimated 84% (± 6.1%) survival rate to the trap, resulting in approximately 40,602 (± 3,161) hatchery smolts surviving and migrating from that release group. No significant difference was found in survival to the Imnaha River trap ($P = 0.57$) or the probability of being detected after release ($P = 0.7780$) between the two release methods.

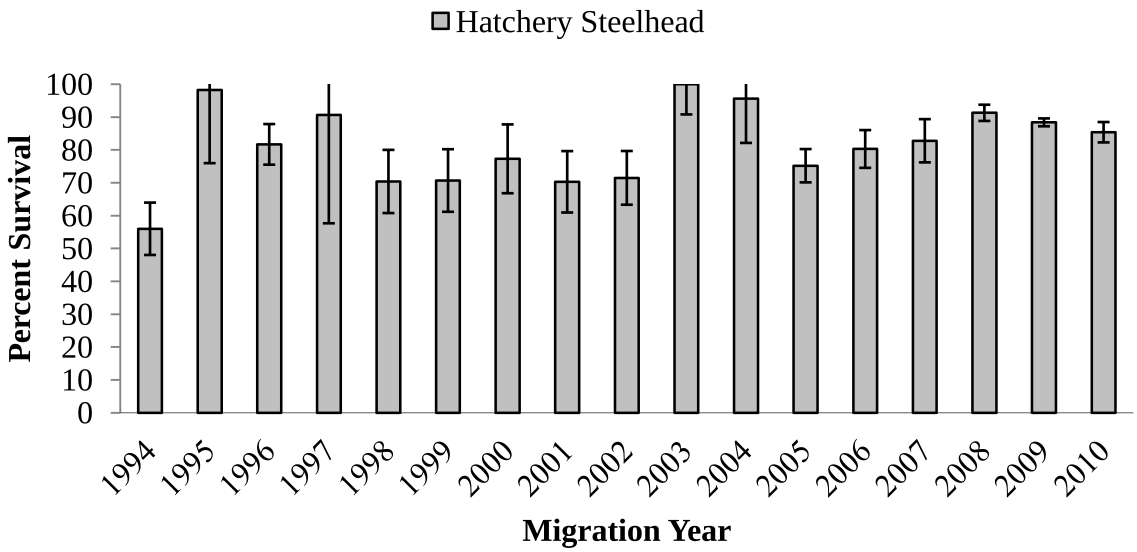

Figure 14. Estimated post release survival of hatchery steelhead from release to the Imnaha River juvenile emigrant trap during the spring from 1994 to 2010. The error bars indicate 95% confidence intervals.

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

Survival from the trap to LGR was estimated for both fall-tagged natural Chinook salmon presmolts and spring-tagged smolts independently, as well as for a combined release group of all natural Chinook PIT-tagged during MY2010 (brood year 2008). The survival estimate of fall-tagged natural Chinook salmon presmolts from the trap to LGR was 22% (± 3.6%), compared to 77% (± 4.3%, Table 8 and Figure 15) for spring-tagged natural Chinook salmon smolts. Comparison of the two release groups using SURPH information revealed that there was a significantly higher proportion of spring-tagged smolts detected after release than fall-tagged presmolts (x^2 = 3,360.99, df = 15, $p < 0.001$). For the fall-tagged presmolt group, survival to LGR in 2010 was the third lowest estimate since monitoring began in 1994, behind migration years 2005 and 2006 (Figure 15). While the spring-tagged smolt survival rate was within the range historically seen for Imnaha natural Chinook smolts, it was below the average of 81.7% (Table 8). The combined 2008 brood year total survival estimate to LGR for natural Chinook salmon was 47% (± 2.6%). The presmolt life history type represented 52.6% of the MY2010 cohort, and the poor survival rate of this group had a huge impact on the overall survival of this cohort.

Hatchery Chinook salmon smolt survival from the Imnaha River trap to LGR was 70% (± 11.9%) in MY2010, which was very near the annual average for hatchery Chinook salmon (Table 8). From 1994 through 2010 the survival rate from the trap to LGR for spring-tagged natural Chinook smolts was consistently higher than that observed for hatchery Chinook salmon smolts that were recaptured and released from the trap.

Survival from the trap to LGR in 2010 was estimated to be 85% (± 5.4%) for natural origin steelhead, and 99% (± 14.7) for hatchery steelhead (Table 8, Figure 16). Survival for hatchery steelhead was calculated using only PIT tag recaptures from the Imnaha River trap, or hatchery fish tagged at the trap as a tagging release group. Average survival rates from 1995 through

2010 were similar between natural and hatchery steelhead, but with more annual variation within the hatchery release group, as indicated by the higher coefficient of variation (Table 8).

Detection efficiencies at LGR were very low in 2010, with the hatchery release groups having the lowest detection rates ever observed from 1994 through 2010 (15.6% for hatchery Chinook compared to 23.2% for natural Chinook salmon smolts). There were a high number of first observations at dams downstream of LGR, even as far as Bonneville Dam, for all release groups in 2010, indicating that a large proportion of the juvenile migrants passed LGR, and possibly through the entire hydrosystem, undetected. Of those that were collected/detected, over 99% were transported; hence, there were minimal tags left in the hydrosystem to provide enough subsequent detections necessary to estimate survival with low standard error using the Cormack-Jolly-Seber model. These lower rates of collection and detection efficiency compounded by a high rate of removal, resulted in higher than average levels of standard error and wide confidence intervals around survival estimates for this migration year.

Table 8. Estimates of survival from the Imnaha River juvenile emigrant trap to Lower Granite Dam for natural and hatchery Chinook salmon and steelhead smolts tagged or recaptured (hatchery) at the Imnaha trap during the spring from 1993 to 2010. Ninety-five percent confidence intervals are shown in parentheses and average, standard deviation (S.D.) and coefficient of variation (C.V.) across years are presented at the bottom of the table.

Migration Year	Natural Chinook (%)		Hatchery Chinook (%)		Natural Steelhead (%)		Hatchery 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	(8.0)	90.1	(3.9)	81.4	(2.0)
1998	85.2	(2.0)	75.7	(3.1)	86.0	(2.2)	82.9	(2.4)
1999	88.5	(2.0)	71.6	(4.7)	87.7	(3.1)	85.4	(2.0)
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	(8.8)
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)
2010	77.0	(4.3)	70.2	(11.9)	85.2	(5.4)	99.9	(14.7)
Average	81.7		71.9		84.9		84.8	
S.D.	5.5		5.7		3.8		7.9	
C.V.	0.07		0.08		0.05		0.09	

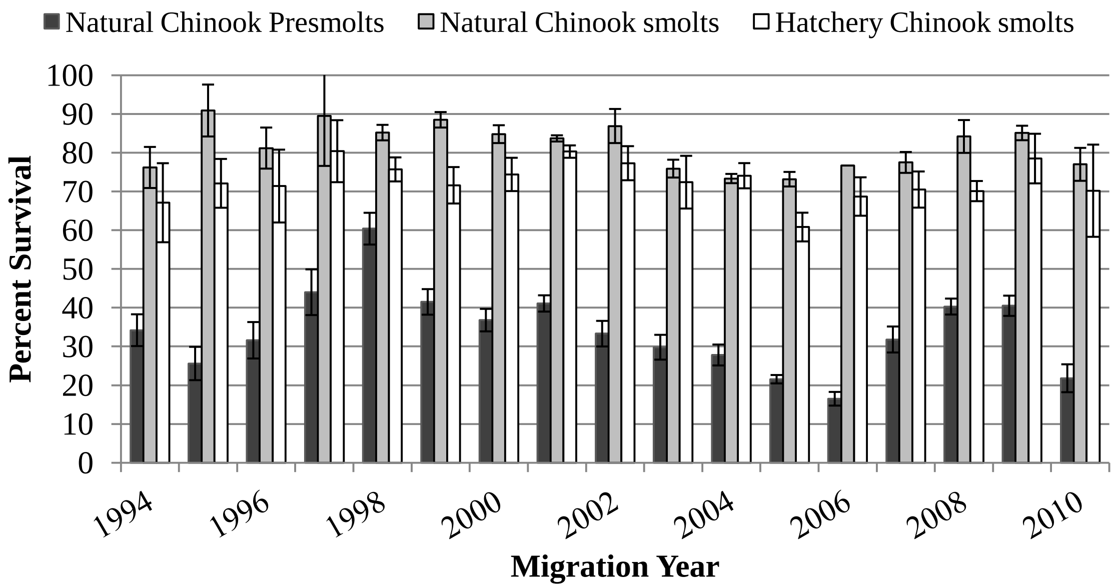

Figure 15. Estimated survival of natural Chinook salmon presmolts and smolts, and hatchery Chinook salmon smolts from the Imnaha River juvenile emigrant trap to Lower Granite Dam (LGR) from 1994 to 2010. The error bars indicate 95% confidence intervals.

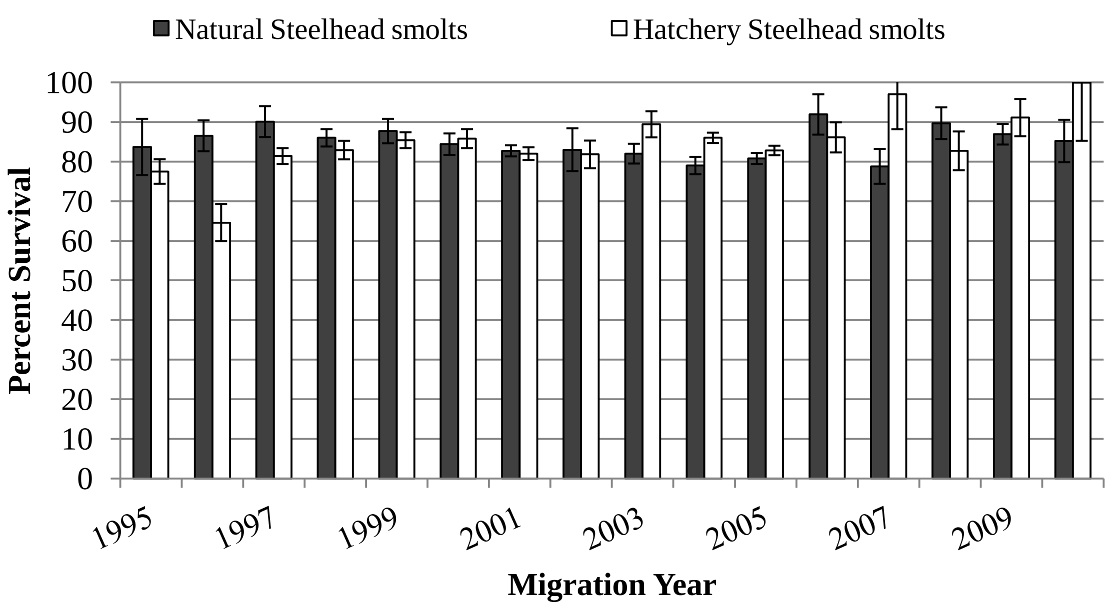

Figure 16. Estimated survival of natural and hatchery steelhead smolts from the Imnaha River juvenile emigrant trap to Lower Granite Dam (LGR) during the spring from 1995 to 2010. The error bars indicate 95% confidence intervals.

Smolts at Lower Granite Dam (LGR)

The overall survival rate of 47% for natural Chinook salmon to LGR produced an estimated 67,799 (± 7,220) smolts at LGR. This estimate included 16,632 (± 3,516) fall-tagged Chinook salmon smolts and 53,043 (± 6,768) spring-tagged Chinook salmon smolts. Hatchery Chinook survival to LGR of 70% yielded an estimated 262,324 (± 43,139) smolts surviving to LGR. The much wider confidence interval for hatchery smolts was a result of large standard error around the survival estimate to LGR resulting from low detection efficiencies, as discussed above. Natural steelhead survival to LGR of 85% yielded an estimated 48,607 (± 10,694) smolts surviving to LGR. Hatchery steelhead survival near 100% from the Imnaha River trap to LGR yielded an estimated 183,824 (± 26,364) smolts at LGR.

Estimated survival from the Imnaha River to MCN for MY2010 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 and 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 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, 2011) 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 64% of fall-tagged natural Chinook salmon arrived at LGR prior to the start of transportation compared to only 15% of spring-tagged natural Chinook. Once transportation started the average capture probability was 26% for natural Chinook salmon yearlings (FPC, 2011) 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 three lower Snake River dams (LGR, LGO, LMN) and MCN on the Columbia River would have resulted in a higher number of the later emigrating juvenile groups (hatchery Chinook, acclimated hatchery steelhead, and natural steelhead) being captured and transported, while a significantly smaller proportion of the earlier emigrating groups (natural Chinook and directly-released hatchery steelhead) would have been transported. Consequently, it was likely that these release 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. 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 natural Chinook salmon presmolts, smolts, the two groups combined as the natural Chinook salmon 2008 brood year cohort, hatchery Chinook salmon smolts, and natural and hatchery steelhead smolts to allow for comparisons among the groups.

Overall survival from LGR to MCN was relatively high for all groups of Chinook salmon in MY2010, with similar survival rates observed for hatchery Chinook salmon smolts, spring-tagged natural Chinook smolts and fall-tagged presmolts (Table 9). Mandated spill seemed to have a positive effect on survival by reducing travel times for Snake River Basin salmon stocks through the hydrosystem (FPC, 2011). Similar survival from LGR to MCN for the fall-tagged presmolt group compared to the natural smolt group indicated that the lower survival rates observed for this group resulted from increased overwinter mortality in the section between the Imnaha River trap and LGR. With the cumulative loss between the trap and MCN, this release group had an estimated survival rate of only 18% to MCN, reducing the MY2010 natural Chinook cohort total survival to only 38% (Table 9).

Hatchery steelhead maintained the high survival rate observed from their release at the acclimation facility to the Imnaha River trap, to LGR, and through the Snake River hydrosystem. Survival to MCN for the combined release groups of hatchery steelhead was estimated near 87% in MY2010 (Table 9). Reach survival from LGR to MCN for this group was almost 97%, though standard error was extremely high and 95% confidence intervals were over 50% so these results should be considered with caution. Natural steelhead smolts tagged at the Imnaha River trap survived at an estimated rate of nearly 62% to MCN. Survival from LGR to MCN for this group was similar to that of the Chinook salmon release groups and was estimated to be 72% (± 14.2%).

Table 9. Estimated survival of passive integrated transponder tagged release groups of natural and hatchery Chinook salmon and steelhead juveniles from the Imnaha River trap from October 1, 2009 to August 31, 2010. Estimates are from release at the trap to Lower Granite Dam (LGR), from LGR to McNary Dam (MCN) and from the trap to MCN. Natural Chinook salmon presmolts were fall-tagged juvenile Chinook salmon, natural Chinook smolts were spring-tagged juvenile Chinook salmon and natural Chinook cohort total were a combination of fall- and spring-tagged Chinook salmon. Ninety-five percent confidence intervals (95% C.I.) are shown in parentheses.

	Number Released	Trap to LGR (95% C.I.)	LGR to MCN (95% C.I.)	Trap to MCN (95% C.I.)
Natural Chinook presmolts	9,214	21.8 (3.6)	76.9 (20.8)	18.0 (2.8)
Natural Chinook smolts	7,959	77.0 (4.3)	71.5 (8.4)	60.0 (2.9)
Natural Chinook cohort total	17,173	46.7 (2.6)	73.4 (7.9)	37.5 (2.0)
Hatchery Chinook smolts	3,271	70.2 (11.9)	76.7 (23.3)	62.7 (7.5)
Natural Steelhead smolts	6,159	85.2 (5.4)	71.9 (14.2)	61.7 (8.9)
Hatchery Steelhead smolts	1,771	99.9 (14.7)	96.9 (50.5)	86.6 (26.5)

We investigated the pattern of annual survival from the Imnaha trap to MCN for each species by origin. Average annual survival was slightly higher for hatchery and natural Chinook salmon compared to steelhead and C.V. estimates were lower, suggesting higher annual variation in survival for steelhead (Table 10). Comparisons among origin types revealed that survival was significantly higher for spring-tagged natural Chinook smolts compared to hatchery Chinook smolts (t = 2.06, P = 0.026; Table 10). In contrast, there was no significant difference in average annual survival to MCN for natural and hatchery steelhead (t = 2.06, P = 0.68; Table 10).

Table 10. Annual survival estimates of natural and hatchery Chinook salmon and steelhead from the Imnaha River trap to McNary Dam from 1998 to 2010; 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	Natural Chinook (%)		Hatchery Chinook (%)		Natural Steelhead (%)		Hatchery 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)
2010	60.0	(2.9)	62.7	(7.5)	61.7	(8.9)	86.6	(26.5)
Average	63.8		56.1		52.2		55.1	
S.D.	9.4		7.1		14.7		19.8	
C.V.	0.15		0.13		0.28		0.36	

Additional differences in annual survival to MCN patterns were indicated by analyzing the relationship between natural and hatchery survival for each species. Regression analysis demonstrated no relationship in annual survival estimates to MCN for natural and hatchery Chinook salmon smolts (r^2 = 0.02, P = 0.66; Figure 17). Although average annual survival to MCN was consistently greater for natural compared to hatchery juvenile Chinook salmon (Table 10), a lack of relationship of annual survival from 1998 – 2010 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 natural and hatchery steelhead (r^2 = 0.53, P = 0.005; Figure 17), suggesting that the effects of annual environmental variation were similar between the two groups. The significance of the relationship was heavily influenced by data from 2001. Although regression analysis using all data points except 2001 was not significant (r^2 = 0.27, P = 0.085), the environmental conditions experienced by juvenile steelhead in 2001 were exceptional, characterized by extremely low flows, and this resulted in a similar magnitude of decreased survival for hatchery and natural steelhead.

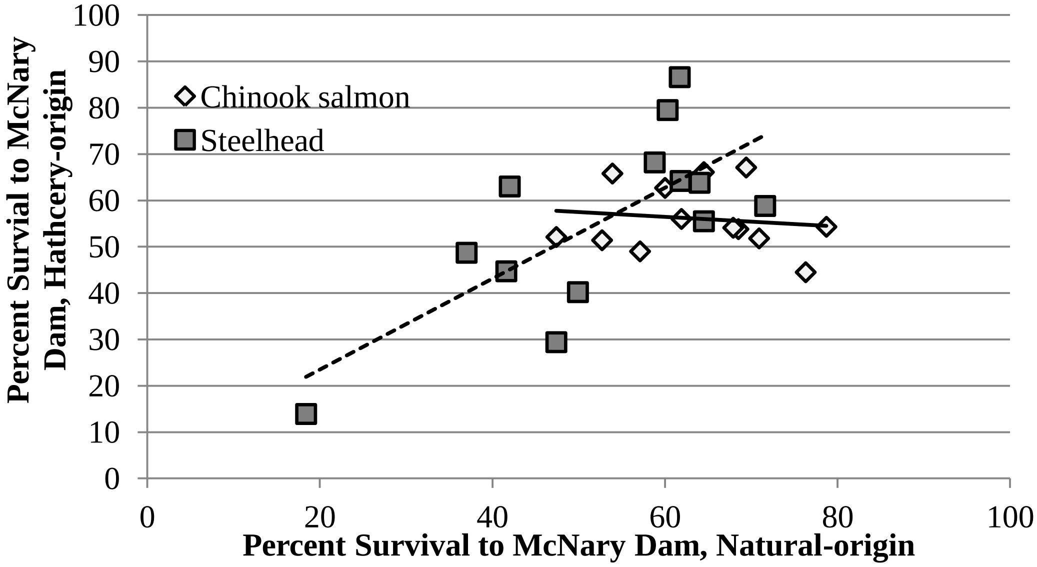

Figure 17. Relationship between estimated percent survival of natural and hatchery Chinook salmon (solid line) and steelhead (dashed line) smolts from the Imnaha River juvenile emigrant trap to McNary Dam (MCN) from 1998 to 2010.

Juvenile emigrant survival in relation to Imnaha and Snake River flow

Possible environmental factors influencing juvenile survival include flow, spill and temperature. We were not able to analyze the relationship between survival and temperature as the temperature data from fall 2009 through spring 2010 from the trap was not available due to loss of the temperature logger.

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 (r^2 = 0.74, P < 0.01) 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 natural (r^2 = 0.11, P = 0.19) or hatchery (r^2 = 0.07, P = 0.30) Chinook salmon (Figure 18). Analyzing steelhead survival to LGR revealed a significant positive relationship between average daily flow in May and survival for natural steelhead (r^2 = 0.58, P < 0.001), but not hatchery steelhead (r^2 = 0.12, P = 0.19; Figure 19).

A significant positive relationship between survival to MCN and flow was found for natural Chinook salmon (r^2 = 0.49, P = 0.01), and steelhead (r^2 = 0.39, P = 0.04) but not hatchery Chinook salmon (r^2 = 0.19, P = 0.14) or steelhead (r^2 = 0.10, P = 0.06). Scatter plots showing the relationship between survival to MCN and flow are presented in Figure 20 and Figure 21. These results suggest that natural 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.

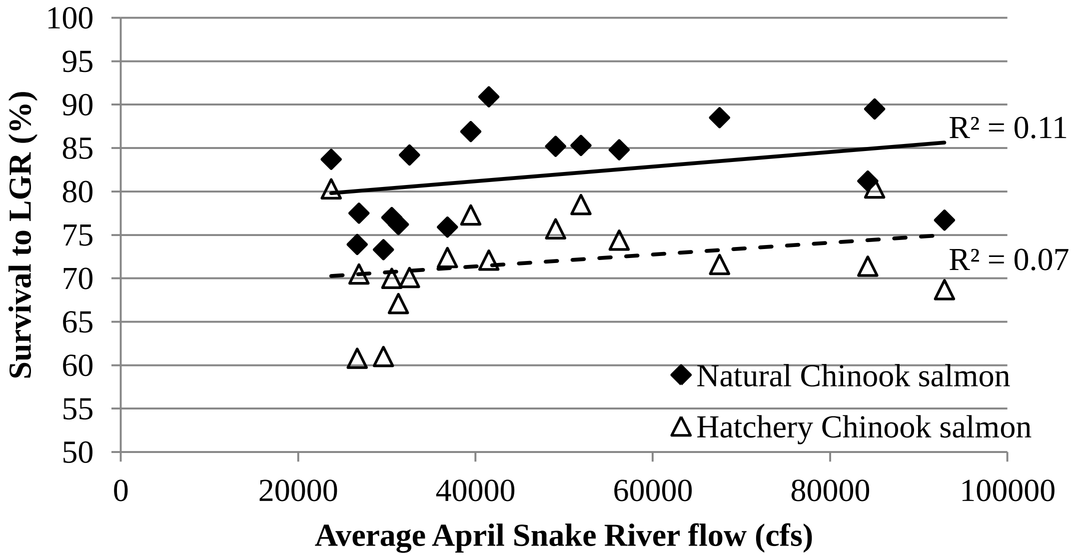

Figure 18. Relationship between annual percent survival of natural (solid line) and hatchery (dashed line) Chinook salmon to Lower Granite Dam (LGR) and average Snake River flow in April measured at the stream flow gage in Anatone, Washington. cfs – cubic feet per second.

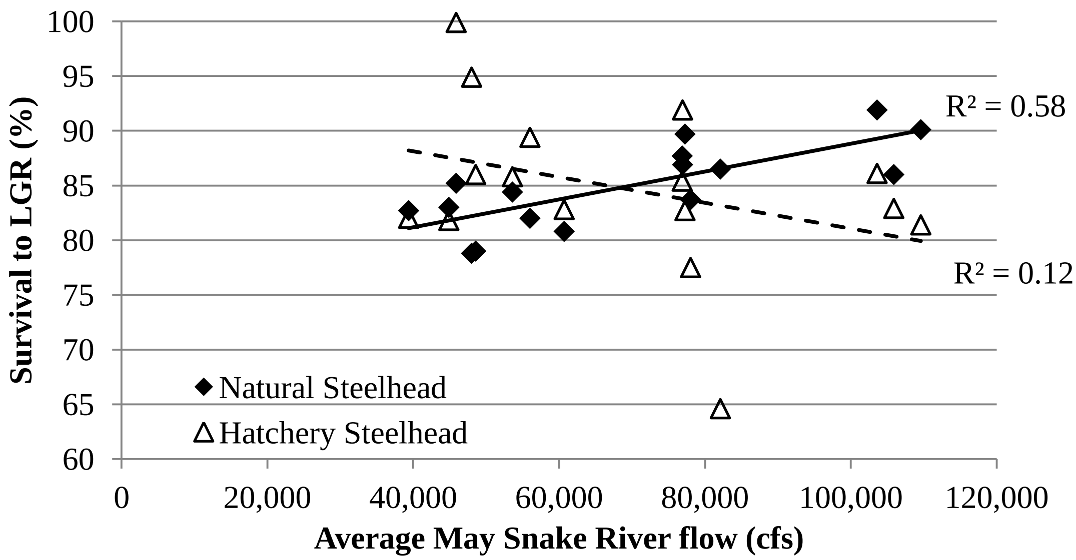

Figure 19. Relationship between annual percent survival of natural (solid line) and hatchery (dashed line) steelhead to Lower Granite Dam (LGR) and average Snake River flow in May measured at the stream flow gage in Anatone, Washington. cfs – cubic feet per second.

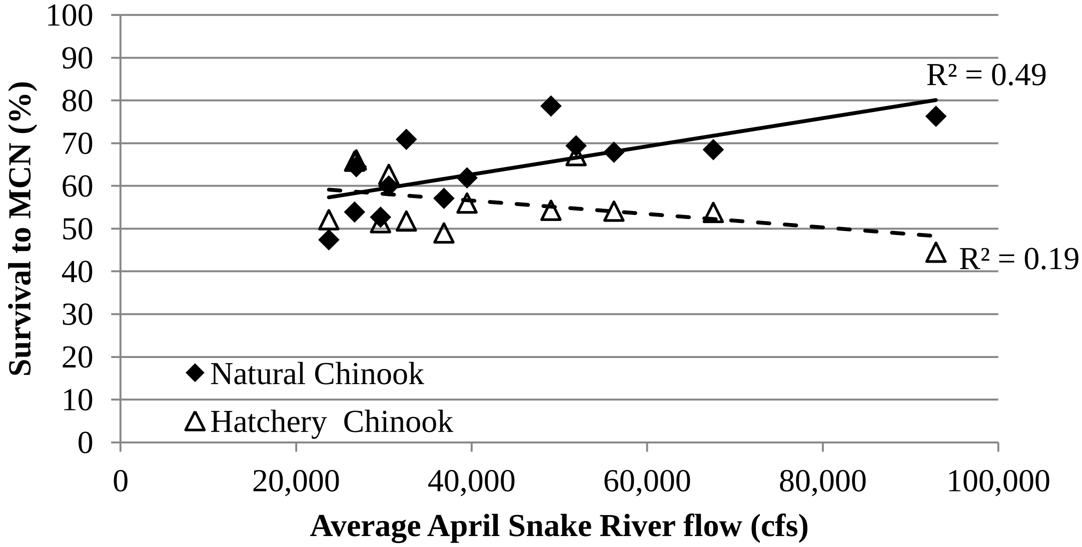

Figure 20. Relationship between annual percent survival of natural (solid line) and hatchery (dashed line) Chinook salmon to McNary Dam (MCN) and average Snake River flow in April measured at the stream flow gage in Anatone, Washington. cfs – cubic feet per second.

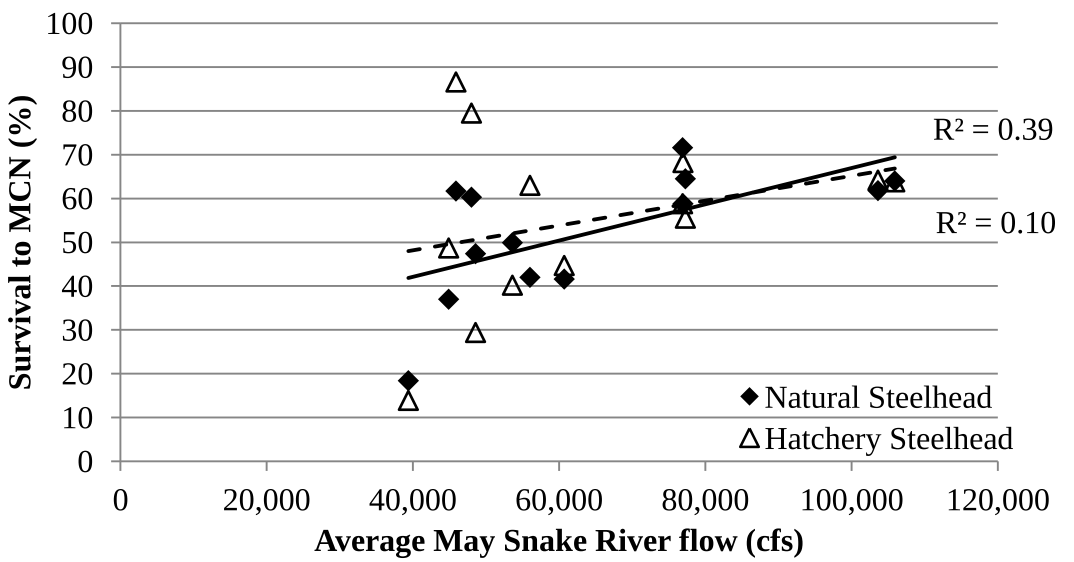

Figure 21. Relationship between annual percent survival of natural (solid line) and hatchery (dashed line) steelhead to McNary Dam (MCN) and average Snake River flow in May measured at the stream flow gage in Anatone, Washington. cfs – cubic feet per second.

Smolt to adult return index rates

Smolt to adult return index rates for Chinook salmon

Adult returns in 2010 allowed for the estimation of smolt to adult return (SAR) index rates for brood years 1996 through 2005 for Chinook salmon and migration years 2000 through 2008 for steelhead. SAR index rates were calculated from the Imnaha River trap to LGR and from LGR to LGR. These should be considered SAR index rates because they were not representative of the entire brood year population or even the total PIT-tagged population as a true SAR would. However, they were useful as a means to analyze and compare annual variation and the origin effects on survival to the adult life stage.

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 the estimated numbers of smolts and total adult returns at LGR. With the installation of in-river PIT tag arrays in the Imnaha River it may be possible to calculate SAR rates from the Imnaha trap back to the Imnaha River for future return years. This will enable us to estimate SAR rates using juvenile emigrant abundance estimates at the Imnaha River trap and smolts at LGR combined with total adults back to LGR and the Imnaha River (using the in-stream PIT tag arrays).

Adult detections in 2010 completed the estimation of SAR index rates for brood year 2005 Chinook salmon (Table 11). The small number of survival mode tags available combined with low returns of PIT-tagged adults limited the ability to draw conclusions regarding SAR index rates for BY2005. Fall-tagged Chinook demonstrated a 0.00% return of adults from the group of tags interrogated at LGR as juveniles (SAR index LGR—LGR; Table 11) continuing the downward trend in SARs observed over the last five brood years for that group. However, data from brood years 2004 and 2005 suggest an increase in the SAR index rate for the spring-tagged smolt group, with the LGR—LGR SAR index rate approaching 1.0%.

When the 0.00% SAR index rate from brood year 2005 was removed, a comparison of SAR index rates for fall- and spring-tagged natural 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 11). The LGR to LGR SAR was not affected by the higher mortality rate for fall-tagged juveniles between the Imnaha River trap and LGR compared to the spring-tagged juveniles and in effect only estimated survival from LGR to LGR. However, given the low number of adult tags detected, especially for fall-tagged juveniles (Table 11), conclusively demonstrating survival differences between the groups was not possible.

Smolt to adult return index rates for natural and hatchery steelhead

Juvenile natural steelhead emigrate at variable ages 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” or run-of-river mode and “monitor-only” mode groups for survival analysis through the hydrosystem. Analyses were performed on run-of-river groups only. PIT tagging of hatchery steelhead smolts at the Imnaha River trap was discontinued in 2008, and all PIT tagging of hatchery fish took place at the hatchery before release. Therefore, after brood year 2007, no SARs for hatchery steelhead will be quantified for this project using the current methodology, as it was not possible to determine passage designation (survival or monitor mode) after recapturing them at the trap, and this confounds our ability to compare to our natural origin release group.

Adult returns in 2010 completed the migration year 2008 SAR index rate analyses for natural steelhead. Migration year 2008 natural steelhead demonstrated a significant increase in SAR index rates compared to previous years for both Imnaha—LGR and LGR—LGR (Table 12.) The increased SAR rate observed here was similar to that observed for the Snake River aggregate steelhead in MY2008 (Comparative Survival Study, 2012), indicating that Imnaha River steelhead survival was similar to that of the entire Snake River basin. Average (geometric mean) SAR index rates for survival mode natural and hatchery steelhead from migration years 2000 – 2007 demonstrated that hatchery steelhead had higher SAR index rates (Table 12).

Table 11. Smolt to adult return (SAR) index rates for passive integrated transponder (PIT) tagged, survival mode (in-river migration) Imnaha River natural Chinook salmon to Lower Granite Dam (LGR) and LGR to LGR for brood years 1996 to 2005. 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). Geomean— geometric mean.

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
2005	987	68[2]	3[1]	1	2	0	0.30	0.00
Geomean							0.35	0.49
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
2005	3852	950	22[3]	1	18	3	0.57	0.95
Geomean							0.61	0.90

[1]These three adults were not detected at LGR as smolts and therefore can only be used for Imnaha to LGR SAR Index rate calculations.
[2]Of these 68 PIT-tagged smolts detected at LGR, there were no subsequent adult detections of these tags at LGR.
[3]Only 9 of these 22 PIT-tagged adults were detected at LGR as smolts and can be used for LGR to LGR SAR Index rate calculations.

Table 12. Smolt to adult return (SAR) index rates for passive integrated transponder (PIT) tagged, survival mode (in-river juvenile migration) Imnaha River natural and hatchery steelhead tagged at the Imnaha River trap to Lower Granite Dam (LGR) and from LGR to LGR for migration years 2000 to 2008. Geomean— geometric mean.

Brood Year	Migration Year	Number PIT-tagged	PIT-tagged Smolts at LGR	Number of Adult detections at LGR	Ocean Age at Return			SAR Index Imnaha to LGR %	SAR Index LGR to LGR (%)
Hatchery Steelhead tagged at Imnaha River Trap					I	II	III		
1999	2000	5,846	5,016	65	49	16	0	1.11	1.3
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	1.4
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
2007	2008	--	--	--	--	--	--	--	--
	Geomean							0.61	0.71
Natural 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
	2008	1,241	370	46	31	14	1	3.71	4.05
	Geomean							0.56	0.67

Life-stage specific evaluation of biological characteristics

The biological characteristics of length, weight, and condition factor at emigration were evaluated for natural and hatchery origin juveniles for MY2010. 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. Hatchery populations of Chinook salmon and steelhead exhibited significantly greater mean fork lengths and weights at emigration compared to naturally produced smolts ($p < 0.00001$; Table 13 and Figures 22 and 23). The condition factor of naturally produced Chinook salmon smolts was significantly less than that of hatchery reared smolts ($p < 0.0001$), while steelhead condition factors were very similar. Fall-tagged natural Chinook salmon presmolts averaged 75 mm in fork length, 4.9 g in weight, and had an average condition factor of 1.09 (Table 13). Although hatchery and natural length distributions overlapped for both Chinook salmon (Figure 22) and steelhead (Figure 23), larger proportions of hatchery fish were significantly larger than the largest natural fish. Any survival benefits attributable to size differences would be expected given the differences observed here. Refer to appendices I. and J. for mean smolt size of hatchery and natural Chinook salmon and steelhead at the Imnaha River trap throughout the project's history and survival estimates by migration year.

Table 13. Sample sizes, means, ranges, and standard deviations of fork lengths (mm), weights (g), and condition factors (K) for natural and hatchery Chinook salmon and steelhead captured during the 2010 migration year, 1 October 2009 to 31 August 2010, at the Imnaha River juvenile emigrant trap.

		Fall 2009	Spring 2010			
Attribute	Statistic	Natural Chinook Presmolts	Natural Chinook Smolts	Hatchery Chinook Smolts	Natural Steelhead Smolts	Hatchery Steelhead Smolts
Fork Length (mm)	Sample Size (n)	9517	8020	2442	6159	2124
	Mean	75	99	128	167	214
	Minimum	43	31	99	89	114
	Maximum	124	176	158	297	320
	Standard Deviation	10	10	8	19	25
Weight (g)	Sample Size (n)	9487	7967	2432	6156	2124
	Mean	4.9	10.7	24.0	46.8	100.2
	Minimum	1.1	1.3	8.1	7.2	19.2
	Maximum	18.7	51.8	43.5	255.4	378.9
	Standard Deviation	2.0	3.2	4.9	16.7	39.1
Condition Factor (K)	Sample Size (n)	9487	7967	2432	6156	2124
	Mean	1.09	1.07	1.13	0.98	0.97
	Minimum	0.64	0.52	0.74	0.64	0.53
	Maximum	1.99	1.73	1.66	1.65	1.95
	Standard Deviation	0.16	0.10	0.11	0.08	0.08

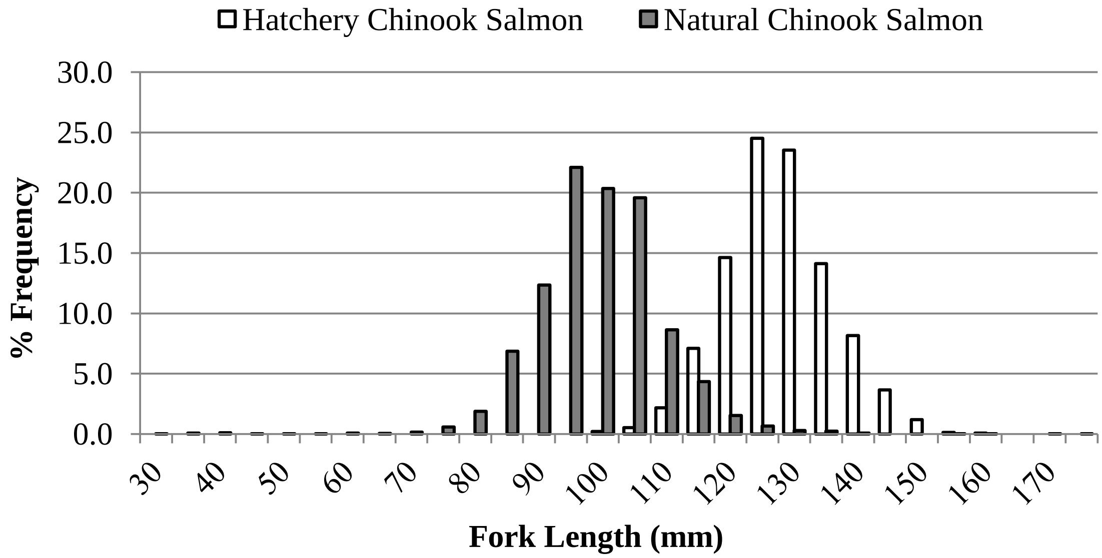

Figure 22. Length frequency distribution of natural and hatchery Chinook salmon smolts trapped in the Imnaha River juvenile emigrant trap from February 25 to August 31, 2010.

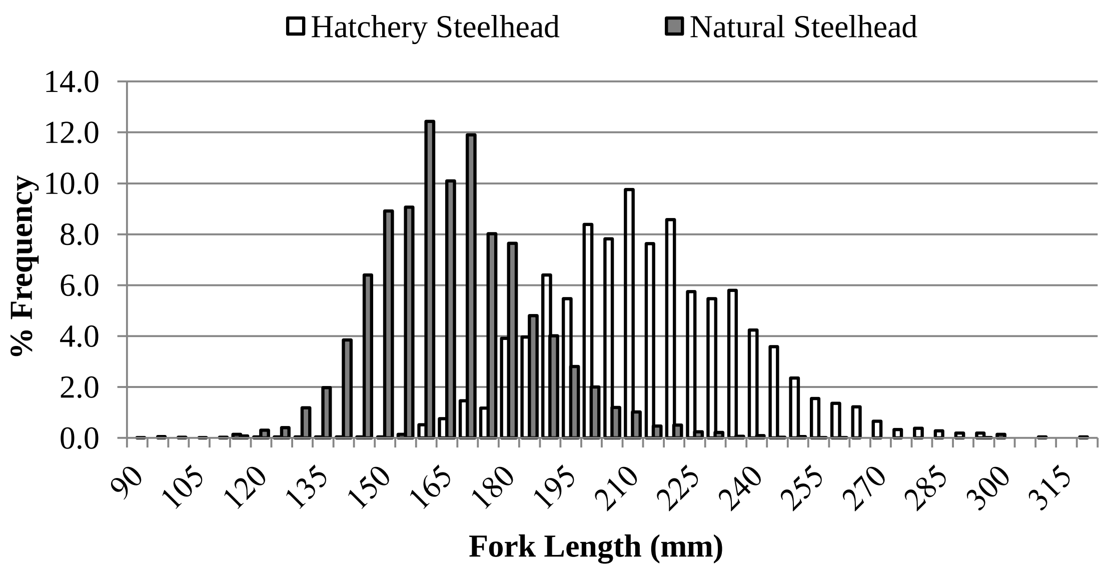

Figure 23. Length frequency distribution of natural and hatchery steelhead smolts trapped in the Imnaha River juvenile emigrant trap, February 25 to August 31, 2010.

Relationship between juvenile survival and size

Data collected from 1994 – 2010 indicated that Imnaha River LSRCP hatchery programs produced significantly larger smolts than those produced by natural spawning and rearing. The differences in size between hatchery and natural 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. Hatchery and natural Chinook averaged 128 mm and 99 mm fork length, respectively, when interrogated at the Imnaha River trap. At this size, both were at higher risk of predation. By the initiation date of full collections for transportation at LGR (April 26, 2010) only about 2.5% of the hatchery Chinook group had passed the dam and only14.6% of the natural Chinook salmon smolt group had passed. While collection efficiencies were lower than in recent years, averaging 17% and 26% for hatchery and natural Chinook respectively, the proportion of collected individuals destined to be transported was 99.9% in 2010. In other words, approximately 16.5% of the total hatchery Chinook smolt population was likely transported, and 31.5% of the combined natural Chinook cohort (fall-tagged and spring-tagged) was likely transported. Of the natural Chinook cohort, fish tagged as presmolts were transported at a much lower rate (9.3%) than spring-tagged smolts (22.2%) due to their earlier passage timing through the Snake River hydrosystem. It is also likely that the fall-tagged release group had a larger body size than the spring-tagged group when they arrived at LGR, as these fish reared in warmer water over the winter than those that spent the winter in the Imnaha River. Larger body size may have contributed to a higher survival rate from LGR to the ocean, as seen by the higher survival rate for the fall-tagged group within the Snake River, and a higher LGR-LGR SAR for this release group. Of all of the Imnaha River Chinook salmon release groups that were evaluated, the natural Chinook salmon smolt cohort that was transported, may have experienced reduced growth opportunity and were at the highest risk of predation in the estuary (Muir et al. 2006). In 2010 this represented 22.2% and 9.3% of the spring-tagged smolts and fall-tagged presmolts, respectively. Generally, both natural and hatchery steelhead smolts were greater 150 mm total length when captured at the Imnaha River trap (Table 13) making it likely that the 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 hatchery Chinook salmon and steelhead by assessing the survival from release at the acclimation facilities to the Imnaha River trap. Results demonstrated a very high post-release survival rate from release to the trap for hatchery Chinook salmon (96%; Figure 11) indicating that very few fish residualized and had the opportunity to mature as precocial parr. Survival/migration rates were also relatively high for hatchery steelhead (85%, Figure 14) with the direct-stream release group surviving/migrating at a slightly lower rate than the acclimated group (84% and 86% respectively). Consequently, LSRCP hatchery programs for both Chinook salmon and steelhead appear to be successful in limiting the level of residualism in the Imnaha River.

Our results suggested that size at release for both hatchery Chinook salmon and steelhead was likely 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 (Claiborne et al. 2011; Ewing and Ewing 2002; Nielson and Geen 1986; Scheuerell, 2005) for Imnaha River natural 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. Maintain extended trapping seasons in 2011 to better assess the emigration timing of Imnaha River juvenile Chinook salmon and steelhead. Utilize year-round trapping efforts until the presmolt 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 hatchery and natural Chinook salmon and steelhead.
4. Evaluate arrival and passage timing at LGR of Imnaha River stocks compared to other Snake River basin stocks to determine if there is a difference in emigration timing between sub basins, and potential differences in transportation rates/migration route, and consequently, smolt to adult returns.
5. Evaluate the environmental conditions as they relate to emigration patterns and survival of hatchery and natural Chinook salmon and steelhead emigrating from the Imnaha River, specifically the effects of temperature, flow and spill.
6. Evaluate whether a shift in life history types of Imnaha River natural Chinook salmon from a primarily smolt-dominated life history to one with increasing proportions of presmolt migrants is occurring, and the potential impacts on subsequent survival rates and SAR's.
7. Provide a more comprehensive analysis of SARs for both natural and hatchery 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 PIT tag arrays installed in the Imnaha River in late 2010.
8. Provide analyses on smolt to adult survival (SAS) for Imnaha River natural and hatchery Chinook salmon and steelhead.
9. Further investigate the effects of smolt size differences between natural and hatchery Chinook salmon and steelhead on juvenile survival and adult returns, and make recommendations for the Imnaha River LSRCP hatchery programs.

10. Evaluate the use of the Imnaha River PIT tag arrays to assess residualism of both natural and hatchery Chinook salmon and steelhead, as well as possible delays in smolt emigration of juveniles PIT-tagged at the Imnaha River trap.
11. 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.
12. If possible, evaluate impacts of handling and PIT tagging on the survival of different life history stages of natural origin Chinook, and on smaller length classes of steelhead.

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APPENDICES

Appendix A. The number of hours sampled and the catch, including subsample estimates, of natural origin and hatchery origin Chinook salmon and steelhead at the Imnaha River juvenile emigrant trap from 1 October 2009 to 31 August 2010. 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	Natural Chinook	Hatchery Chinook	Natural Steelhead	Hatchery Steelhead
10/1/2009	17.5	0	0	0	0
10/2/2009	25	0	0	0	0
10/3/2009	24	6	0	8	0
10/4/2009	24	2	0	22	0
10/5/2009	25	97	0	27	0
10/6/2009	24	147	0	19	0
10/7/2009	21.5	58	0	12	0
10/8/2009	26.5	78	0	5	0
10/9/2009	24	23	0	3	0
10/10/2009	22.5	178	0	6	0
10/11/2009	29.5	477	0	8	0
10/12/2009	23	402	0	14	0
10/13/2009	25.5	594	0	11	0
10/14/2009	24.5	862	0	18	0
10/15/2009	29.5	4255	0	2	0
10/16/2009	14	1386	0	1	0
10/17/2009	25.5	512	0	2	0
10/18/2009	21	154	0	0	0
10/19/2009	26.5	257	0	1	0
10/20/2009	21.5	213	0	1	0
10/21/2009	25	337	0	1	0
10/22/2009	21.5	149	0	0	0
10/23/2009	25	314	0	0	0
10/24/2009	24.5	92	0	0	0
10/25/2009	23.5	257	0	0	0
10/26/2009	24	225	0	0	0
10/27/2009	24.5	318	0	5	0
10/28/2009	24	359	0	3	0
10/29/2009	24.5	207	0	4	0
10/30/2009	26.5	94	0	1	0
10/31/2009	22	209	0	0	0
11/1/2009	23	77	0	4	0
11/2/2009	24.5	57	0	1	0

Sample End Date	Hours Fished	Natural Chinook	Hatchery Chinook	Natural Steelhead	Hatchery Steelhead
11/3/2009	24	163	0	0	0
11/4/2009	23.5	109	0	0	0
11/5/2009	23	118	0	1	0
11/6/2009	25	62	0	1	0
11/7/2009	23.5	210	0	0	0
11/8/2009	23.5	111	0	0	0
11/9/2009	24	144	0	0	0
11/10/2009	24	160	0	0	0
11/11/2009	24	196	0	0	0
11/12/2009	27	230	0	3	0
11/13/2009	23.5	127	0	61	0
11/14/2009	23	102	0	0	0
11/15/2009	24	80	0	4	0
11/16/2009	23.5	49	0	2	0
11/17/2009	23.5	96	0	1	0
11/18/2009	23.5	156	0	2	0
2/25/2010	15.5	0	0	0	0
2/26/2010	23	0	0	1	0
2/27/2010	23	1	0	0	0
2/28/2010	24	0	0	0	0
3/1/2010	24.5	2	0	0	0
3/2/2010	24	0	0	0	0
3/3/2010	23.5	2	0	0	0
3/4/2010	27	2	0	0	0
3/5/2010	22	1	0	0	0
3/6/2010	23.5	4	0	0	0
3/7/2010	23.5	10	0	1	0
3/8/2010	24.5	13	0	2	0
3/9/2010	24	25	0	1	0
3/10/2010	24	27	0	0	0
3/11/2010	24	12	0	0	0
3/12/2010	24	20	0	0	0
3/13/2010	23.25	29	0	1	0
3/14/2010	25.25	16	0	0	0
3/15/2010	24	15	0	1	0
3/16/2010	24.5	38	0	1	0
3/17/2010	23	73	0	1	0
3/18/2010	26.5	202	0	3	0

Sample End Date	Hours Fished	Natural Chinook	Hatchery Chinook	Natural Steelhead	Hatchery Steelhead
3/19/2010	26	470	0	2	0
3/20/2010	20.5	277	0	1	0
3/21/2010	22.5	169	0	2	0
3/22/2010	24	104	0	1	0
3/23/2010	24	124	0	1	0
3/24/2010	24.5	150	0	4	0
3/25/2010	25.5	71	0	1	0
3/26/2010	23	50	0	2	0
3/27/2010	24.5	61	0	2	0
3/28/2010	24	44	0	1	0
3/29/2010	23.5	3	0	1	0
3/30/2010	22.5	551	0	24	1
3/31/2010	23.5	1364	0	66	1
4/1/2010	28	779	0	29	29
4/2/2010	21.5	574	0	41	296
4/3/2010	25.5	355	1496	17	181
4/4/2010	21.5	256	1294	6	176
4/5/2010	24	146	1031	3	88
4/6/2010	25	126	2095	4	59
4/7/2010	23	122	3009	9	46
4/8/2010	26	172	1467	9	562
4/9/2010	24.5	87	4769	7	699
4/10/2010	21.5	186	9094	4	246
4/11/2010	24	83	4954	12	229
4/12/2010	24	75	3957	7	68
4/13/2010	24	69	6966	0	50
4/14/2010	23.5	197	8488	5	37
4/15/2010	27.5	87	4147	15	46
4/16/2010	22.5	91	5256	34	57
4/17/2010	24.5	226	5184	77	161
4/18/2010	21.5	218	2351	135	172
4/19/2010	N/A	N/A	N/A	N/A	N/A
4/20/2010	7.5	90	1147	301	746
4/21/2010	6.5	9	225	123	312
4/22/2010	N/A	N/A	N/A	N/A	N/A
4/23/2010	N/A	N/A	N/A	N/A	N/A
4/24/2010	N/A	N/A	N/A	N/A	N/A
4/25/2010	10	133	213	104	462
4/26/2010	24	183	197	102	302

Sample End Date	Hours Fished	Natural Chinook	Hatchery Chinook	Natural Steelhead	Hatchery Steelhead
4/27/2010	24	106	69	112	162
4/28/2010	N/A	N/A	N/A	N/A	N/A
4/29/2010	N/A	N/A	N/A	N/A	N/A
4/30/2010	13	159	172	132	396
5/1/2010	24	141	174	139	475
5/2/2010	26	147	81	147	377
5/3/2010	23.5	120	96	117	242
5/4/2010	24.5	79	93	210	363
5/5/2010	22.5	175	143	202	391
5/6/2010	12	151	113	166	330
5/7/2010	24.5	159	99	206	389
5/8/2010	23.5	95	75	192	360
5/9/2010	24	146	81	224	467
5/10/2010	24	112	73	279	402
5/11/2010	24.5	104	92	340	487
5/12/2010	23.5	129	98	381	808
5/13/2010	24.5	89	73	494	1173
5/14/2010	23	92	102	361	1116
5/15/2010	23.5	98	74	480	1156
5/16/2010	26	82	75	556	1681
5/17/2010	8.5	56	26	464	1428
5/18/2010	22	59	28	160	1170
5/19/2010	N/A	N/A	N/A	N/A	N/A
5/20/2010	N/A	N/A	N/A	N/A	N/A
5/21/2010	N/A	N/A	N/A	N/A	N/A
5/22/2010	9	24	4	56	292
5/23/2010	25	49	5	63	280
5/24/2010	26.5	27	4	75	134
5/25/2010	24	28	6	73	122
5/26/2010	23	31	2	61	79
5/27/2010	24	14	2	51	159
5/28/2010	24	20	2	55	172
5/29/2010	24	29	1	52	111
5/30/2010	24	32	0	51	135
5/31/2010	24	7	0	21	99
6/1/2010	24	11	0	43	130
6/2/2010	24	9	1	31	149
6/3/2010	N/A	N/A	N/A	N/A	N/A
6/4/2010	N/A	N/A	N/A	N/A	N/A

Sample End Date	Hours Fished	Natural Chinook	Hatchery Chinook	Natural Steelhead	Hatchery Steelhead
6/5/2010	N/A	N/A	N/A	N/A	N/A
6/6/2010	N/A	N/A	N/A	N/A	N/A
6/7/2010	N/A	N/A	N/A	N/A	N/A
6/8/2010	N/A	N/A	N/A	N/A	N/A
6/9/2010	8	0	0	8	26
6/10/2010	9.5	2	0	9	12
6/11/2010	12.5	10	0	4	1
6/12/2010	N/A	N/A	N/A	N/A	N/A
6/13/2010	17.25	14	0	11	46
6/14/2010	11.5	13	0	10	47
6/15/2010	24	14	1	15	67
6/16/2010	11	15	0	4	55
6/17/2010	N/A	N/A	N/A	N/A	N/A
6/18/2010	22.5	23	0	10	15
6/19/2010	24	5	0	4	11
6/20/2010	24	38	0	13	29
6/21/2010	N/A	N/A	N/A	N/A	N/A
6/22/2010	N/A	N/A	N/A	N/A	N/A
6/23/2010	9	0	0	2	1
6/24/2010	N/A	N/A	N/A	N/A	N/A
6/25/2010	N/A	N/A	N/A	N/A	N/A
6/26/2010	N/A	N/A	N/A	N/A	N/A
6/27/2010	N/A	N/A	N/A	N/A	N/A
6/28/2010	11	5	0	1	0
6/29/2010	13	3	0	0	2
6/30/2010	26	6	0	0	0
7/1/2010	12.5	0	0	1	0
7/2/2010	23	2	1	0	3
7/3/2010	N/A	N/A	N/A	N/A	N/A
7/4/2010	N/A	N/A	N/A	N/A	N/A
7/5/2010	19.5	1	0	1	0
7/6/2010	21.5	1	0	0	2
7/7/2010	24	0	0	0	1
7/8/2010	24	2	0	0	0
7/9/2010	24	2	0	1	0
7/10/2010	N/A	N/A	N/A	N/A	N/A
7/11/2010	N/A	N/A	N/A	N/A	N/A
7/12/2010	10	0	0	0	0
7/13/2010	24	1	0	0	0

Sample End Date	Hours Fished	Natural Chinook	Hatchery Chinook	Natural Steelhead	Hatchery Steelhead
7/14/2010	N/A	N/A	N/A	N/A	N/A
7/15/2010	22	1	1	0	0
7/16/2010	24	1	0	0	0
7/17/2010	N/A	N/A	N/A	N/A	N/A
7/18/2010	N/A	N/A	N/A	N/A	N/A
7/19/2010	14.5	0	0	0	0
7/20/2010	24.5	1	0	0	0
7/21/2010	24	1	0	0	0
7/22/2010	23.5	4	0	1	0
7/23/2010	24	3	0	0	0
7/24/2010	N/A	N/A	N/A	N/A	N/A
7/25/2010	N/A	N/A	N/A	N/A	N/A
7/26/2010	11	0	0	0	0
7/27/2010	22	1	0	0	0
7/28/2010	24	0	0	2	0
7/29/2010	24	1	0	0	0
7/30/2010	25	3	0	0	0
7/31/2010	N/A	N/A	N/A	N/A	N/A
8/1/2010	N/A	N/A	N/A	N/A	N/A
8/2/2010	13	0	0	0	0
8/3/2010	21	0	0	0	0
8/4/2010	N/A	N/A	N/A	N/A	N/A
8/5/2010	N/A	N/A	N/A	N/A	N/A
8/6/2010	N/A	N/A	N/A	N/A	N/A
8/7/2010	N/A	N/A	N/A	N/A	N/A
8/8/2010	N/A	N/A	N/A	N/A	N/A
8/9/2010	23	0	0	0	0
8/10/2010	24	0	0	0	0
8/11/2010	23	1	0	0	0
8/12/2010	26	0	0	1	0
8/13/2010	N/A	N/A	N/A	N/A	N/A
8/14/2010	N/A	N/A	N/A	N/A	N/A
8/15/2010	N/A	N/A	N/A	N/A	N/A
8/16/2010	14	0	0	0	0
8/17/2010	24	0	0	0	0
8/18/2010	24	0	0	0	0
8/19/2010	24	0	0	0	0
8/20/2010	24	0	0	0	0
8/21/2010	N/A	N/A	N/A	N/A	N/A

Sample End Date	Hours Fished	Natural Chinook	Hatchery Chinook	Natural Steelhead	Hatchery Steelhead
8/22/2010	N/A	N/A	N/A	N/A	N/A
8/23/2010	13.5	0	0	0	0
8/24/2010	24	0	0	0	0
8/25/2010	24	0	0	0	0
8/26/2010	24	0	0	0	0
8/27/2010	24	0	0	0	0
8/28/2010	N/A	N/A	N/A	N/A	N/A
8/29/2010	N/A	N/A	N/A	N/A	N/A
8/30/2010	13.5	0	0	4	0
8/31/2010	24	0	0	0	0
Fall Total	1,169.50	14,509	0	254	0
Spring Total	3,080.25	10,948	69,208	7,261	20,579
MY Total	4,249.75	25,457	69,208	7,515	20,579

Appendix B. The number of natural origin Chinook salmon and steelhead administered passive integrated transponder tags (PIT) weekly at the Imnaha River juvenile emigrant trap from 1 October to 31 August 2010.

Week	Chinook Salmon PIT-tagged	Steelhead PIT-tagged
10/1/2009	278	0
10/8/2009	2462	0
10/15/2009	2323	1
10/22/2009	1506	1
10/29/2009	894	0
11/5/2009	971	0
11/12/2009	785	0
2/25/2010	5	1
3/4/2010	81	4
3/11/2010	202	4
3/18/2010	1395	14
3/25/2010	829	97
4/1/2010	1513	109
4/8/2010	415	27
4/15/2010	706	680
4/22/2010	403	318
4/29/2010	815	918
5/6/2010	889	1663
5/13/2010	413	1607
5/20/2010	157	326
5/27/2010	121	301
6/3/2010	0	8
6/10/2010	66	51
6/17/2010	56	29
6/24/2010	14	0
7/1/2010	4	2
7/8/2010	5	0
7/15/2010	3	0
7/22/2010	7	1
7/29/2010	0	0
8/5/2010	0	0
8/12/2010	0	0
8/19/2010	0	0
8/26/2010	0	0
Fall Totals	**9,219**	**2**
Spring Totals	**8,099**	**6,160**
Season Totals	**17,318**	**6,162**

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 2009 and spring 2010. Fork lengths are reported in millimeters (mm) and weights to the nearest 0.1 gram (g).

Migration Year	Tagging Agency	Recapture File	PIT Tag ID	Date Tagged	Date Recaptured	Travel Time (Days)	Recapture Fork Length (mm)	Recapture Weight (g)	Recapture Condition Factor (K)
2010	ODFW	BDM09284.NT1	3D9.1C2CBCC967	9/1/09	10/11/09	40	72	3.8	1.02
2010	ODFW	BDM09285.NT1	3D9.1C2D08D84B	8/31/09	10/12/09	42	80	5.7	1.11
2010	ODFW	BDM09285.NT1	3D9.1C2D0BF193	8/31/09	10/12/09	42	67	3.3	1.10
2010	ODFW	BDM09286.NT1	3D9.1C2D0A3B9E	8/31/09	10/13/09	43	64	3.3	1.26
2010	ODFW	BDM09288.NT1	3D9.1C2D08C493	9/2/09	10/15/09	43			
2010	ODFW	BDM09288.NT1	3D9.1C2D0A1516	9/1/09	10/15/09	44			
2010	ODFW	BDM09288.NT1	3D9.1C2D0AEE41	8/31/09	10/15/09	45			
2010	ODFW	BDM09288.NT1	3D9.1C2D0B92A2	9/2/09	10/15/09	43	74	4.8	1.18
2010	ODFW	BDM09289.NT1	3D9.1C2CBCB60F	8/31/09	10/16/09	46			
2010	ODFW	BDM09289.NT1	3D9.1C2D08B837	8/31/09	10/16/09	46	79	6.2	1.26
2010	ODFW	BDM09289.NT1	3D9.1C2D09961C	8/31/09	10/16/09	46			
2010	ODFW	BDM09289.NT1	3D9.1C2D0C1954	9/1/09	10/16/09	45	70	4.2	1.22
2010	ODFW	BDM09290.NT1	3D9.1C2D0A396D	9/1/09	10/17/09	46	62	3.2	1.34
2010	ODFW	BDM09290.NT1	3D9.1C2D0A45E9	8/31/09	10/17/09	47	65	3.2	1.17
2010	ODFW	BDM09292.NT1	3D9.1C2D0A3935	8/31/09	10/19/09	49	65	3.1	1.13
2010	ODFW	BDM09306.NT1	3D9.1C2D0B6392	9/1/09	11/2/09	62	64	2.8	1.07
2010	ODFW	BDM10068.NT1	3D9.1C2CFC0A48	9/2/09	3/9/10	188	96	8.7	0.98
2010	ODFW	BDM10083.NT1	3D9.1C2D0B9D62	9/2/09	3/24/10	203	92	7.9	1.01
2010	ODFW	BDM10090.NT1	3D9.1C2D0AEE85	8/31/09	3/31/10	212	101	11.6	1.13
2010	ODFW	BDM10094.NT1	3D9.1C2D090765	9/2/09	4/4/10	214	95	9	1.05
2010	ODFW	BDM10110.NT1	3D9.1C2D0A414A	8/31/09	4/20/10	232	124	19.6	1.03
2010	ODFW	BDM10110.NT1	3D9.1C2D0A5A43	9/1/09	4/20/10	231	100	10.7	1.07
2010	ODFW	BDM10123.NT1	3D9.1C2D08D3BF	8/31/09	5/3/10	245	100	11.2	1.12

Appendix D. Releases of hatchery-origin Chinook salmon and steelhead smolts to the Imnaha River sub basin and the number of smolts released with a passive integrated transponder (PIT) tag during migration year 2010 (Chinook data Feldhaus et al. 2012; steelhead data from Warren et al. 2012).

Release Year	Species	Arrival at Acclimation Site	Number Released	Release Dates	Total PIT Tags Released	Release Site
2010	Chinook salmon	March 10 - 11	390,064	April 1 – April 14	20,605	Imnaha River (Gumboot)
2010	Steelhead	March 3 - 5	166,842	March 30 – April 27	16,915	Little Sheep Creek
2010	Steelhead	Direct Stream	48,625	April 6	4,783	Big Sheep Creek

Appendix E. The catch of incidental fish during the fall, 1 October to 18 November 2010, and the spring and summer from 25 February to 31 August 2010, at the Imnaha River juvenile emigrant trap for the 2010 migration year. Catch totals include sub sampling estimates.

Family	Common Name	Fall 2009	Spring 2010
Salmonidae	Adult Steelhead	1	177
	Adult Chinook	2	1
	Rainbow Trout / Steelhead	527	789
	Mountain Whitefish	47	2
	Bull Trout	89	5
	Adult Bull Trout	12	1
Centrarchidae	Smallmouth Bass	103	13
	Bluegill & Pumpkinseed	0	1
Catostomidae	Bridgelip Sucker	3	9
	Largescale Sucker	0	18
	Sucker (unidentified species)	232	410
Cyprinidae	Chislemouth	10	10
	Longnose Dace	13	290
	Northern Pikeminnow	38	48
	Redside Shiner	8	6
Cottidae	Sculpin (unidentified species)	26	106
Petromyzotidae	Pacific Lamprey macropthalmia	0	7
	Pacific Lamprey ammocoetes	0	22
Other	Other species not listed	0	1
	Total Catch	**1111**	**1916**

Appendix F. Pacific Lamprey, *Lampetra tridentate*, caught during the migration year 2010 trapping season, 1 October 2009 to 31 August 2010. 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)	Count
4/20/2010	Ammocoete	146	5.1	1
4/20/2010	Ammocoete	140	4.9	1
4/20/2010	Ammocoete	153	7.9	1
4/20/2010	Macropthalmia	162	8.5	1
4/20/2010	Ammocoete	155	6.3	1
4/21/2010	Ammocoete	145	6.9	1
4/21/2010	Macropthalmia	160	6.5	1
5/12/2010	Ammocoete	132	12.1	1
5/17/2010	Ammocoete	126	6	1
5/17/2010	Ammocoete	156	7.3	1
5/17/2010	Ammocoete	156	7.3	1
5/17/2010	Ammocoete	147	5.1	1
5/18/2010	Ammocoete	-	-	11
5/22/2010	Ammocoete	150	6.9	1
6/20/2010	Macropthalmia	-	-	5

Appendix G. Mortality of Chinook salmon and steelhead smolts due to trapping, handling, PIT tagging and those that were dead on arrival (DOA) at the Imnaha River juvenile emigrant trap from 1 October to 18 November, 2009.

	Chinook				Steelhead			
	Natural		Hatchery		Natural		Hatchery	
Source of Mortality	N	Percent of Total Trapped	N	Percent of Total Trapped	N	Percent of Total Trapped	N	Percent of Total Trapped
Trapping	14	0.15	0	0.00	0	0.00	0	0.00
Handling	3	0.03	0	0.00	0	0.00	0	0.00
Tagging	5	0.05	0	0.00	0	0.00	0	0.00
DOA	4	0.04	0	0.00	0	0.00	0	0.00
Number Captured	9,587		0	0	254		0	
Total Mortality	26	0.27	0	0.00	0	0.00	0	0.00

Appendix H. Mortality of Chinook salmon and steelhead smolts due to trapping, handling, PIT tagging and those that were dead on arrival (DOA) at the Imnaha River juvenile emigrant trap from 25 February to 31 August, 2010.

	Chinook				Steelhead			
	Natural		Hatchery		Natural		Hatchery	
Source of Mortality	N	Percent of Total Trapped	N	Percent of Total Trapped	N	Percent of Total Trapped	N	Percent of Total Trapped
Trapping	26	0.24	22	0.03	9	0.12	9	0.04
Handling	52	0.47	2	0.00	2	0.03	1	0.00
Tagging	20	0.18	0	0.00	0	0	0	0.00
DOA	2	0.02	5	0.01	0	0	1	0.00
Number Captured	10,948		69,208		7,261		20,579	
Total Mortality	100	0.91	29	0.04	11	0.15	11	0.05

Appendix I. Natural and hatchery Chinook salmon smolt size at the Imnaha River juvenile emigrant trap and estimated survival from the trap to Lower Granite Dam (LGR) from migration year 1994 through 2010. mm—millimeters, g—grams, S.D.—standard deviation.

Migration Year	Brood Year	Origin	Mean Fork Length (mm)	S.D. Fork Length	Weight (g)	S.D. Weight	Sample Size at Trap	Fish Per Pound	Survival Trap to LGR	S.D. Survival
1994	1992	Natural	102	9	11.7	3.4	3190	38.77	76.2	5.3
1995	1993	Natural	99	9.8	10.7	3.4	1003	42.39	80.9	6.7
1996	1994	Natural	101	8.4	11.4	3	1797	39.79	81.2	5.3
1997	1995	Natural	108	9.2	13	3.6	270	34.89	89.5	12.9
1998	1996	Natural	106	7.9	12.7	3.2	3969	35.72	85.2	2
1999	1997	Natural	104	9.8	12.4	3.5	5422	36.58	88.5	2
2000	1998	Natural	110	9.5	14.1	3.8	4330	32.17	84.8	2.3
2001	1999	Natural	108	10	13	3.9	9956	34.89	83.7	0.8
2002	2000	Natural	104	11.4	12.3	5.4	2333	36.88	86.9	4.4
2003	2001	Natural	104	9.37	11.8	3.6	4841	38.44	75.9	2.3
2004	2002	Natural	100.3	9.7	11.4	3.2	9847	39.79	73.3	1.2
2005	2003	Natural	97.9	9.8	11.1	3.4	3472	40.86	73.9	1.7
2006	2004	Natural	97.8	9.5	10.6	3.4	1158	42.79	76.7	8.2
2007	2005	Natural	99	11.8	12.6	4.1	7547	36.00	77.5	2.7
2008	2006	Natural	98.6	9.5	11.5	3.3	3269	39.44	84.2	4.2
2009	2007	Natural	99.7	10	11.6	3.5	6115	39.10	85.1	1.9
2010	2008	Natural	99	10	10.7	3.2	8020	42.39	77	4.3
1994	1992	Hatchery	126	13.3	21.6	4.8	9034	21.00	67.1	10.2
1995	1993	Hatchery	127	8.3	21.3	4.5	391	21.30	72.1	6.3
1996	1994	Hatchery	131	8.6	26	6.1	11896	17.45	71.4	9.4
1997	1995	Hatchery	131	10.6	25.4	7.2	10616	17.86	80.4	8
1998	1996	Hatchery	135	11.1	27.2	8.4	3098	16.68	75.7	3.1
1999	1997	Hatchery	134	11.3	26.8	7.56	6838	16.93	71.6	4.7
2000	1998	Hatchery	132	9.6	26.7	6.8	2399	16.99	74.4	4.3

2001	1999	Hatchery	142	12.1	30	7.5	7107	15.12	80.3	1.6
2002	2000	Hatchery	139	16.9	28.5	11.9	3918	15.92	77.3	4.4
2003	2001	Hatchery	139	15.6	29.7	11.4	1743	15.27	72.4	6.8
2004	2002	Hatchery	118	10.3	18.7	5.3	2694	24.26	61	0.9
2005	2003	Hatchery	117.8	8.2	18.9	4.4	2418	24.00	60.8	3.7
2006	2004	Hatchery	121	9.6	20.1	5	1462	22.57	68.7	5
2007	2005	Hatchery	123	11.2	22.2	6.2	1084	20.43	70.5	4.7
2008	2006	Hatchery	124.1	11.4	22.8	6.6	1754	19.89	70.1	2.6
2009	2007	Hatchery	123.2	8.1	22.6	4.5	1957	20.07	78.5	6.4
2010	2008	Hatchery	128	8	24	4.9	2442	18.90	70.2	11.9

Appendix J. Natural and hatchery steelhead smolt size at the Imnaha River juvenile emigrant trap and estimated survival from the trap to Lower Granite Dam (LGR) from migration year 1994 through 2010. mm—millimeters, g—grams, S.D.—standard deviation.

Migration Year	Origin	Mean Fork Length (mm)	S.D. Fork Length	Weight (g)	S.D. Weight	Sample Size at Trap	Fish Per Pound	Survival Trap to LGR	S.D. Survival
1994	Natural	172	19.4	52.4	17.0	2228	8.66	-	-
1995	Natural	173	19.5	52.7	18.2	568	8.61	83.7	7.1
1996	Natural	175	19.0	56.9	17.8	3786	7.97	86.5	3.9
1997	Natural	175	19.7	55.8	18.9	864	8.13	90.1	3.9
1998	Natural	177	20.7	56.8	20.7	2843	7.99	86	2.2
1999	Natural	184	18.7	62.3	19.83	2517	7.28	87.7	3.1
2000	Natural	184	21.0	62	22.16	4668	7.32	84.4	2.7
2001	Natural	178	24.3	55.5	24.3	3733	8.17	82.7	1.4
2002	Natural	172	19.8	51.1	17.3	4738	8.88	83	5.4
2003	Natural	174	23.2	53.9	20.7	5961	8.42	82	2.5
2004	Natural	169.6	21.0	50.5	19.6	5652	8.98	79	2.2
2005	Natural	168.5	18.6	51.4	17.1	4541	8.82	80.8	1.4
2006	Natural	171.4	19.5	53.7	18	2298	8.45	91.9	5.1
2007	Natural	169	19.2	53.5	18.5	7195	8.48	78.8	4.4

2008	Natural	166.3	19.2	50.4	17.4	2524	9.00	89.7	4
2009	Natural	172.9	17.6	54.5	16.9	5163	8.32	86.9	2.6
2010	Natural	167	19.0	46.8	16.7	6159	9.69	85.2	5.4
1994	Hatchery	209	19.3	89	27.8	3229	5.10	-	
1995	Hatchery	208	18.5	86.1	25.6	1537	5.27	77.5	3.1
1996	Hatchery	201	18.3	80.9	24	31,094	5.61	64.6	4.7
1997	Hatchery	210	19.8	88	26.1	7345	5.15	81.4	2
1998	Hatchery	218	20.0	102	30.4	3890	4.45	82.9	2.4
1999	Hatchery	216	18.0	98.3	0.95	6444	4.61	85.4	2
2000	Hatchery	224	18.4	106.8	27.07	5751	4.25	85.8	2.4
2001	Hatchery	217	22.7	98.2	31.6	4365	4.62	82	1.6
2002	Hatchery	216	21.2	102.7	31.4	2428	4.42	81.8	3.5
2003	Hatchery	222	22.9	110.6	34	5397	4.10	89.4	3.3
2004	Hatchery	215.8	21.7	100.5	31.8	4498	4.51	86	1.3
2005	Hatchery	216.9	22.1	107.5	35.5	6596	4.22	82.8	1.2
2006	Hatchery	217.9	22.4	109.9	35	1993	4.13	86.1	3.8
2007	Hatchery	215	23.6	105	37.9	2360	4.32	97	8.8
2008	Hatchery	210.9	20.5	100.1	31	1030	4.53	82.7	4.9
2009	Hatchery	218.4	23.4	110.2	38.6	1923	4.12	91.1	4.7
2010	Hatchery	214	25.0	100.2	39.1	2124	4.53	99.9	14.7