Emigration of Juvenile Chinook Salmon and Steelhead from the Imnaha River

Progress Report for Migration Year 2017

Nez Perce Tribe
Department of Fisheries Resources Management
Research Division

Joseph, Oregon

Emigration of Natural and Hatchery Juvenile Chinook Salmon (Nacó'x in Nez Perce) and Steelhead (Héeyey in Nez Perce) from the Imnaha River, Oregon During Migration Year 2017

Annual Report for the Imnaha River Smolt Monitoring Project
and Lower Snake River Compensation Plan
Hatchery Evaluation Project

Prepared by:
Lora Tennant
Brian Simmons
Tyler Stright

Nez Perce Tribe
Department of Fisheries Resources Management
Lapwai, Idaho 83540

Prepared for:
U.S. Department of Energy
Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

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Boise, Idaho 83709

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EXECUTIVE SUMMARY

This report summarizes the Nez Perce Tribe's Imnaha River Chinook Salmon (Nacó'x in Nez Perce language; *Oncorhynchus tshawytscha*) and steelhead (Héeyey in Nez Perce language; *Oncorhynchus mykiss*) juvenile emigration studies for migration year 2017 (MY2017). These studies have been ongoing for the past 25 years and have contributed information to the Fish Passage Center's (FPC) Smolt Monitoring Program (SMP) for the past 23 years. The project evaluates the survival, biological characteristics, and migration performance of natural and hatchery spring/summer Chinook Salmon and steelhead emigrating from the Imnaha River. This project captures emigrating juveniles in the Imnaha River, implants them with passive integrated transponder (PIT) tags, and uses associated PIT tag technology to estimate survival and travel time through the Snake and Columbia River dams. Survival was estimated from Imnaha River trap and to Lower Granite Dam (LGR) and McNary Dam (MCN) for all natural and hatchery emigrant groups. Additionally, survival was estimated for hatchery emigrants from their point of initial release to the Imnaha River trap. Migration timing was analyzed from release at the Imnaha River trap to LGR. This report represents a compilation of 24 of the 25 years of SMP operations in addition to the MY2017 results.

The main goals of the project are to: 1) provide real-time data to the Fish Passage Center from Chinook Salmon and steelhead emigrants PIT-tagged at the Imnaha River trap and; 2) compare performance metrics between natural and hatchery Chinook Salmon and steelhead as part of the Lower Snake River Compensation Plan (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 Chinook Salmon and steelhead; 2) quantify and compare life-stage specific emigration timing of Imnaha River Chinook Salmon and steelhead; 3) quantify and compare life-stage specific survival of emigrating Imnaha River Chinook Salmon and steelhead from the Imnaha River to Lower Granite Dam on the Snake River and to McNary Dam on the Columbia River; 4) quantify and compare smolt to adult return (SAR) rates for natural and hatchery Imnaha River Chinook Salmon and steelhead and; 5) describe life-stage specific biological characteristics of Imnaha River Chinook Salmon and steelhead emigrants.

Project objectives were completed with the operation of a rotary screw trap in the Imnaha River about 7 river kilometers (rkm) above the confluence with the Snake River. The trap operated from early October 2016 through early July 2017 capturing Chinook Salmon presmolts in the fall and Chinook and steelhead smolts in the spring and summer. Trapping was discontinued in early July because of low flows and warm water conditions which precluded safe tagging and handling of fish.

We estimated the minimum number of natural Chinook Salmon emigrating past the trap during MY2017 to be 97,212 (75,800 – 129,311; 95% confidence interval) with 62,308 (43,808 – 102,857) emigrating as presmolts and 34,904 (28,453 – 43,322) emigrating as smolts. We estimated the minimum number of steelhead passing the trap to be 27,269 (22,803 – 33,111).

Emigration timing varied at the Imnaha River trap and LGR by species, origin type, and life history. Emigration timing at the Imnaha River trap for hatchery fish was largely driven by release timing. Natural Chinook Salmon presmolts not only arrived at the Imnaha River trap earlier than natural Chinook Salmon smolts, but presmolts also arrived at LGR earlier than smolts (median arrival dates at LGR 4/15/17 and 4/21/17, respectively). Hatchery Chinook Salmon arrived the latest of the Chinook Salmon emigrant groups with a median arrival date at LGR of 05/05/17. Emigration timing of natural and hatchery steelhead smolts at LGR was more similar (median arrival dates at LGR 05/06/17 and 05/09/17, respectively) than that of the Chinook Salmon emigrant groups; however, a K-S test of the cumulative distributions of the two steelhead groups arriving at LGR suggests that the arrival timing was significantly different ($p < 0.001$) between natural and hatchery steelhead smolts. The early arrival of Imnaha River emigrants at LGR and lower collection efficiencies at LGR for migration year 2017 resulted in low proportions of Imnaha River emigrants being collected at LGR for transportation. Natural Chinook Salmon and steelhead smolts generally took less time to travel from the Imnaha River trap to LGR than hatchery conspecifics.

We estimated survival from the Imnaha River trap to LGR for all natural and hatchery emigrant groups. Survival of natural Chinook Salmon presmolts to LGR was estimated to be 0.34 (0.31-0.37; 95% CI), natural Chinook Salmon smolts was 0.76 (0.73-0.80), and hatchery Chinook Salmon smolt survival was 0.70 (0.57-0.90). Chinook Salmon emigrant survival from the Imnaha River to LGR has had a negative trend over time; however, this trend does not persist when evaluating survival from the Imnaha River trap to McNary Dam (MCN) for the same emigrant groups. The trend in survival either becomes stable or begins to increase with time. Survival of natural steelhead smolts from the Imnaha River trap to LGR was 0.82 (0.77-0.87) and hatchery steelhead smolt survival was 0.90 (0.81-1.02). Steelhead survival from the Imnaha River trap to LGR and the Imnaha River trap to MCN has been increasing with time. Additionally, analysis relating survival to the lower Snake River discharge and spill at the four lower Snake River dams suggests that increasing spill can have significant positive association with increases in emigrant survival. After the 2006 court ordered increase in spill took effect at the lower Snake River dams, increases in survival have been documented for both Chinook Salmon and steelhead emigrants.

Adult returns in 2017 allowed for estimates of smolt to adult return (SAR) rates from LGR to LGR for Imnaha River Chinook Salmon for brood years through 2012, and for Imnaha River steelhead migration years through 2015. Smolt to adult return rates were estimated using fish marked with both monitor and survival mode separation by code PIT tags. Smolt to adult return rates for Imnaha River Chinook Salmon and steelhead have been poor for the past few years (e.g., often < 2.0%), and 2017 was not an exception to this recent trend. The highest SAR for Chinook Salmon was natural presmolts that were monitor mode PIT-tagged and returned as adults to LGR (1.41%). The highest SAR for steelhead was hatchery smolts that were monitor mode PIT-tagged and returned as adults to LGR (0.57%).

We evaluated and compared natural and hatchery Chinook Salmon and steelhead smolts by fork length, weight, and condition factor. Both hatchery steelhead and Chinook Salmon smolts had significantly higher mean fork length, weight, and condition factor for migration year 2017. However, the statistically significant higher condition factor for hatchery smolts may not confer significant biological difference.

Completion of the project objectives resulted in meeting the goals indicated above. A total of 2,313 natural Chinook Salmon presmolts, 2,775 natural Chinook Salmon smolts, and 2,810 natural steelhead smolts were PIT-tagged and evaluated as part of the Fish Passage Center's Smolt Monitoring Program during MY2017. Data collected also provided long-term monitoring and evaluation trends for the LSRCP Imnaha River hatchery program.

ACKNOWLEDGMENTS

The Nez Perce Tribe appreciates the administrative support necessary to complete these projects and this report. Project funding from the United States Fish and Wildlife Service's Lower Snake River Compensation Plan initiated the Imnaha River emigration project investigations in 1992 and the project continues today. The Bonneville Power Administration (BPA) provides significant project cost share funding for the Imnaha Smolt Monitoring Project. Debbie Docherty, the BPA contracting officer technical representative (COTR) for the project, provided wise budgetary council and oversight throughout the contacting periods.

We wish to thank the following NPT employees for their hard work in the field and their dedication to collecting accurate data for this report: Donald Anderson, David Bright, Anthony Capetillo, Joseph McCormack and Neal Meshell. Ryan Kinzer provided technical support and advice for these studies and the report.

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Acronyms

BiOp: Biological Opinion

BON: Bonneville Dam

BPA: Bonneville Power Administration

BY####: Brood Year ####

cfs: Cubic feet per second

CI: Confidence Interval

COTR: Contracting Officer Technical Representative

CSS: Comparative Survival Study

CV: Coefficient of Variation

DFRM: Department of Fisheries Resources Management

DPS: Distinct Population Segment

ESA: Endangered Species Act

ESU: Evolutionarily Significant Unit

FCRPS: Federal Columbia River Power System

FPC: Fish Passage Center

g: grams

IHD: Ice Harbor Dam

IRSMP: Imnaha River Smolt Monitoring Program

IMNTRP: Imnaha River Screw Trap

JDD: John Day Dam

K: Condition Factor

K-S test: Kolmogorov-Smirnov test

LGR: Lower Granite Dam

LGS: Little Goose Dam

LMN: Lower Monumental Dam

LSRCP: Lower Snake River Compensation Plan

MaxD: Maximum difference in emigration timing

MCN: McNary Dam

mm: millimeter

MPG: Major Population Group

MS-222: Tricaine Methanesulfonate

MY####: Migration Year ####

M&E: Monitoring and Evaluation

NPT: Nez Perce Tribe

ODFW: Oregon Department of Fish and Wildlife

PIT Tag: Passive Integrated Transponder Tag

PTAGIS: PIT Tag Information System Database

PSMFC: Pacific States Marine Fisheries Commission

rkm: river kilometer

SAR: Smolt to Adult Return

SbyC: Separation by Code

SD: Standard Deviation

SMP: Smolt Monitoring Program

SURPH: Survival Under Proportional Hazards

TDD: The Dalles Dam

TE: Trap Efficiency

USFWS: United States Fish and Wildlife Service

Introduction

This report summarizes juvenile emigration and monitoring study by the Nez Perce Tribe (NPT) Department of Fisheries Resources Management (DFRM) for the Imnaha River Smolt Monitoring Project and the Lower Snake River Compensation Plan (LSRCP) during migration year (MY) 2017. This study is closely coordinated with project partners and collects information on biological characteristics, including juvenile emigration timing and survival, and smolt to adult return rates for Imnaha subbasin natural and hatchery spring/summer Chinook Salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*), both populations are listed as threatened under the Endangered Species Act (ESA). This study also provides biological information for the Federal Columbia River Power System (FCRPS) Biological Opinion (NMFS 2008). Along with our co-managers in the Imnaha subbasin, we have identified the need to collect information on life history, migration patterns, juvenile emigrant abundance, and reach specific smolt survival rates for both Chinook Salmon and steelhead (Ecovista 2004). The study conducted during the fall of 2016 through the summer of 2017 provides information to the majority of the high priority data needs.

Population Status

The Grande Ronde-Imnaha Major Population Group (MPG) is an important contributor to the Snake River Basin Chinook Salmon Evolutionarily Significant Unit (ESU) and has major cultural and social significance for tribal and non-tribal people of northeast Oregon (Hesse et al. 2004). Historically, the Imnaha subbasin supported one of the largest runs of spring/summer Chinook Salmon in northeast Oregon (Wallowa County and Nez Perce Tribe 1993). Prior to the construction of the four lower Snake River dams, an estimated 6,700 natural spring/summer Chinook Salmon adults returned to the subbasin annually (USACE 1975). However, returns of Imnaha subbasin natural adults have declined significantly and are often attributed to dam construction and other major anthropogenic influences. As a result, the population was listed as threatened under the Endangered Species Act in 1992. The Imnaha Subbasin Management Plan maintains objectives of returning 5,740 adult Chinook Salmon (3,800 natural adults) to the Imnaha Basin annually (Ecovista 2004). Between 2011 and 2015, the estimated in-river natural adult escapement ranged from 238 in 2013 to 817 in 2011 and hatchery adult escapement ranged from 717 in 2013 to 2,100 in 2015 (Joseph Feldhaus ODFW personal communication).

Imnaha River summer steelhead are one of five MPGs that are part of the Snake River Basin Steelhead Distinct Population Segment (DPS) that was listed as threatened under the ESA in 1997. Their listing status was reaffirmed in January 2006. Listed natural fish from Little Sheep Creek were incorporated into the Little Sheep hatchery broodstock; therefore, hatchery progeny (naturally produced fish and hatchery fish with an intact adipose fin) were considered part of the DPS and were covered by Section 4(d) protective regulations in the 2006 rule (ODFW 2011). Estimates of annual adult steelhead returns to the Imnaha subbasin may have exceeded 4,000 steelhead in the 1960s. The Imnaha Subbasin Management Plan maintains objectives of returning 4,315 adult summer steelhead (2,100 natural adults) to the basin annually (Ecovista 2004). Currently and/or recently, steelhead returns are monitored in small tributaries including Camp, Cow, Lightning, Horse, Dry, Crazyman, Grouse, Gumboot, and Mahogany 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 escapement ranging from 30 to more than 200 individuals for each stream (Young and Hatch 2012). Recent work by the Imnaha Adult Steelhead Monitoring project estimated >1,300 returning natural fish to the upper Imnaha subbasin in 2011, >1,100 in 2012, >500 in 2013, and >650 in 2014 (Harbeck and Espinosa 2012; Harbeck et al. 2014, 2015a, 2015b).

Project History

The vision of the Nez Perce Tribe DFRM is to recover and restore all native species and populations of anadromous and resident fish within the traditional lands of the Nez Perce Tribe (DFRM Strategic Plan Ad Hoc Team 2013). The Nez Perce people have historically 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, the once robust salmon and steelhead runs have declined significantly.

The Lower Snake River Compensation Plan 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 summer steelhead losses in the Snake River basin attributed to the four Lower Snake River hydroelectric facilities. In 1985 the NPT 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 USFWS LSRCP presently supports 11 hatchery programs in Idaho, Oregon, and Washington. This program is one approach to attempt to conserve and recover anadromous fish populations in the Snake River basin. One goal of the LSRCP program is to maintain the hatchery production of 360,000 Chinook Salmon smolts and 215,000 to 330,000 steelhead smolts for annual release in the Imnaha River (United States v. Oregon 2008).

Juvenile Chinook Salmon and steelhead emigrant monitoring in the Imnaha River has been ongoing since 1992. The LSRCP funded the first two years of monitoring and in 1994 direct funding for the NPT Imnaha River Smolt Monitoring Project (IRSMP) to monitor natural and hatchery Chinook Salmon and steelhead was provided by the Bonneville Power Administration (BPA) as part of the larger Smolt Monitoring by Non-Federal Entities Project (No. 198712700) and the Fish Passage Center's (FPC) Smolt Monitoring Program (SMP). These larger projects provide data on smolt emigration from major tributaries to the Snake and Columbia rivers and past the hydroelectric facilities. Smolts tagged with passive integrated transponder (PIT) tags are used 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 FPC by IRSMP for Imnaha River smolts at the Imnaha River trap and Snake and Columbia rivers mainstem dams. Fish condition 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 used in hydroelectric facility operational decisions regarding flow and spill management to improve smolt passage, and continues to contribute to a time series of data for Chinook Salmon and steelhead smolt arrival and survival 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. After evaluating two seasons of year round trapping efforts, data suggested that temperatures were often too high after mid-July to tag or handle fish and only ~2.5% of smolts emigrated from the Imnaha River during late summer (Hatch and Harbeck 2013). As a result, year round trap operations were discontinued in mid-July 2013. The MY2017 trapping season covered in this report began in early October 2016 and ended in early July 2017 when low flows and warm water temperatures prevented safe tagging and handling fish.

The goal of the LSRCP M&E study in the Imnaha River is to quantify and compare natural and hatchery Chinook Salmon and steelhead smolt performance, emigration characteristics, survival, and adult return rates (Kucera and Blenden 1998). Specifically, 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 Lower Granite and McNary dams, compare natural and hatchery smolt performance, and collect smolt to adult return information. In 2003, the study began participation in the Separation by Code (SbyC) system. The SbyC technology at the hydrosystem bypass facilities allows for the accurate representation of non PIT-tagged fish migrating through the hydrosystem using a predetermined group of PIT-tagged fish. The SbyC technology is described further detail in the Methods section of this report under *Smolt to Adult Return Rates.* The completion of trapping in July 2017 marked the NPT's 26th year for the emigration project on the Imnaha River, and the 24th year of participating in the FPC's Smolt Monitoring Program.

Imnaha River Juvenile Emigrant Monitoring & Evaluation Objectives

The IRSMP and Imnaha River LSRCP M&E studies assess the life-stage specific status and performance of natural and hatchery Chinook Salmon and steelhead under a framework of M&E objectives listed below. Additionally, these studies provide near real-time data from fish PIT-tagged at the Imnaha River 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 juvenile Chinook Salmon and steelhead.

Objective 1a: Quantify juvenile emigrant abundance for natural Chinook Salmon emigrating past the Imnaha River trap during the presmolt and smolt emigration seasons as well as a total annual emigrant abundance estimate by migration year.

Objective 1b: Quantify juvenile emigrant abundance for natural 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 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, and periods when little to no movement is observed.

Objective 2b: Quantify and compare the arrival timing of natural and hatchery 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, and periods when little to no movement is observed.

Objective 2c: Quantify and compare the arrival timing of natural Chinook Salmon presmolts and smolts, hatchery Chinook Salmon and steelhead smolts, and natural steelhead smolts from the Imnaha River trap to Lower Granite Dam.

Objective 2d: Quantify and compare the travel time of natural and hatchery juvenile Chinook Salmon and steelhead from the Imnaha River trap to Lower Granite Dam.

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

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 post-release survival of PIT-tagged hatchery Chinook Salmon and steelhead smolts from the release site to the Imnaha River trap.

Objective 3b: Quantify and compare the survival of natural Chinook Salmon presmolts and smolts, natural steelhead smolts, and hatchery Chinook Salmon and steelhead smolts from the Imnaha River trap to Lower Granite Dam and McNary Dam.

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

M&E Objective 4: Quantify and compare smolt to adult return rates for Imnaha River Chinook Salmon and steelhead.

Objective 4a: Quantify and compare annual smolt to adult return rates for natural Chinook Salmon presmolts and smolts PIT-tagged at the Imnaha River trap and hatchery Chinook Salmon recaptured at the trap for by-passed and run-of-river release groups.

Objective 4b: Quantify and compare annual smolt to adult return rates for natural steelhead smolts PIT-tagged at the Imnaha River trap and hatchery steelhead recaptured at the trap for by-passed and 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 for natural Chinook Salmon presmolts, and natural and hatchery Chinook Salmon and steelhead smolts.

Methods

Project Area

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

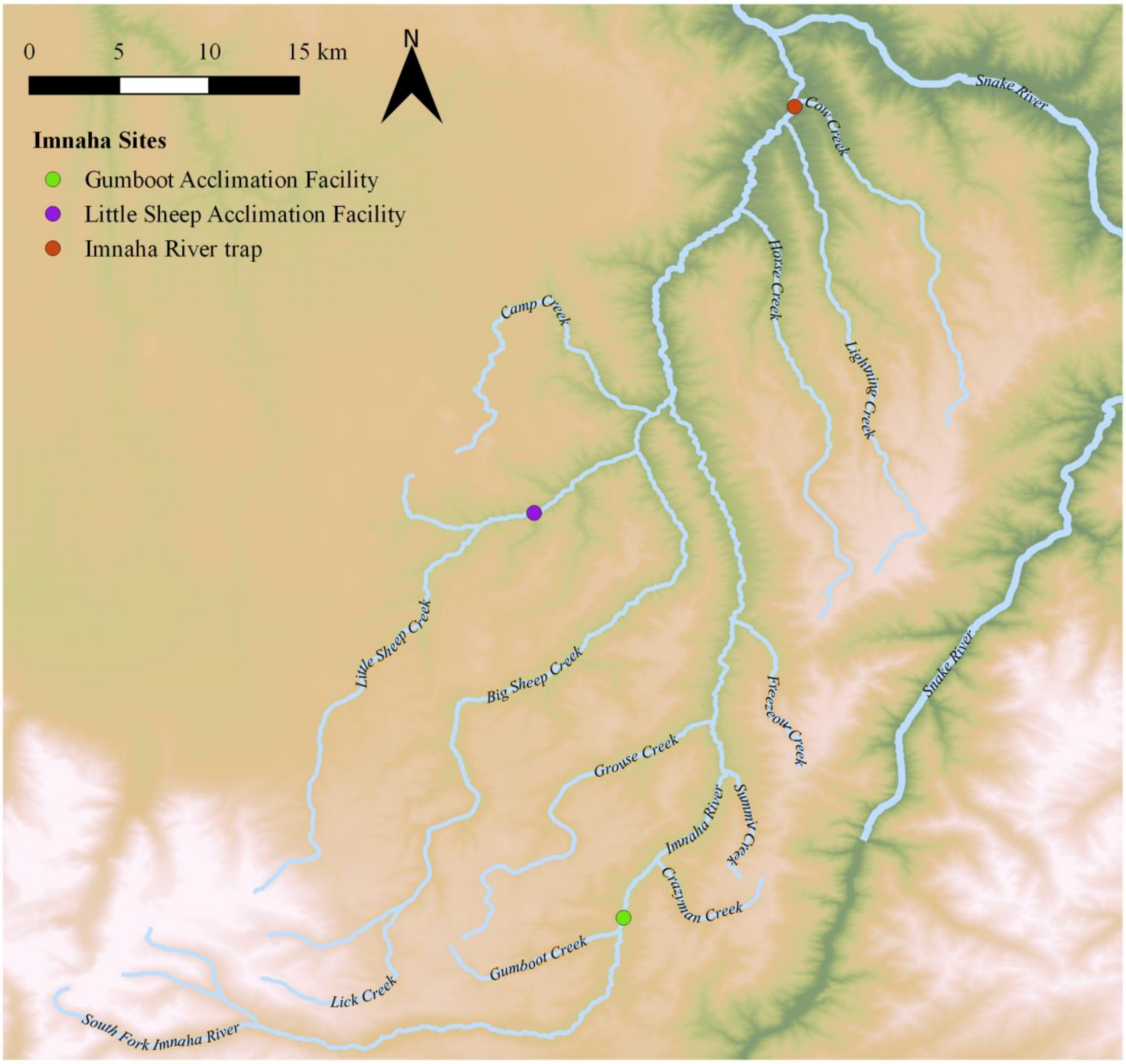

Figure 1. Map of the Imnaha River study area showing the location of the Imnaha River trap, the Gumboot Chinook Salmon acclimation facility, and the Little Sheep Creek steelhead acclimation facility.

Imnaha River Chinook Salmon and steelhead smolts must emigrate through several reservoirs and dam facilities before entering the Pacific Ocean. Snake River dams include: Lower Granite Dam (LGR), Little Goose Dam (LGS), Lower Monumental Dam (LMD) and Ice Harbor Dam (IHD; Figure 2). Columbia River dams include: McNary Dam (MCN), John Day Dam (JDD), The Dalles Dam (TDD), and Bonneville Dam (BON; Figure 2).

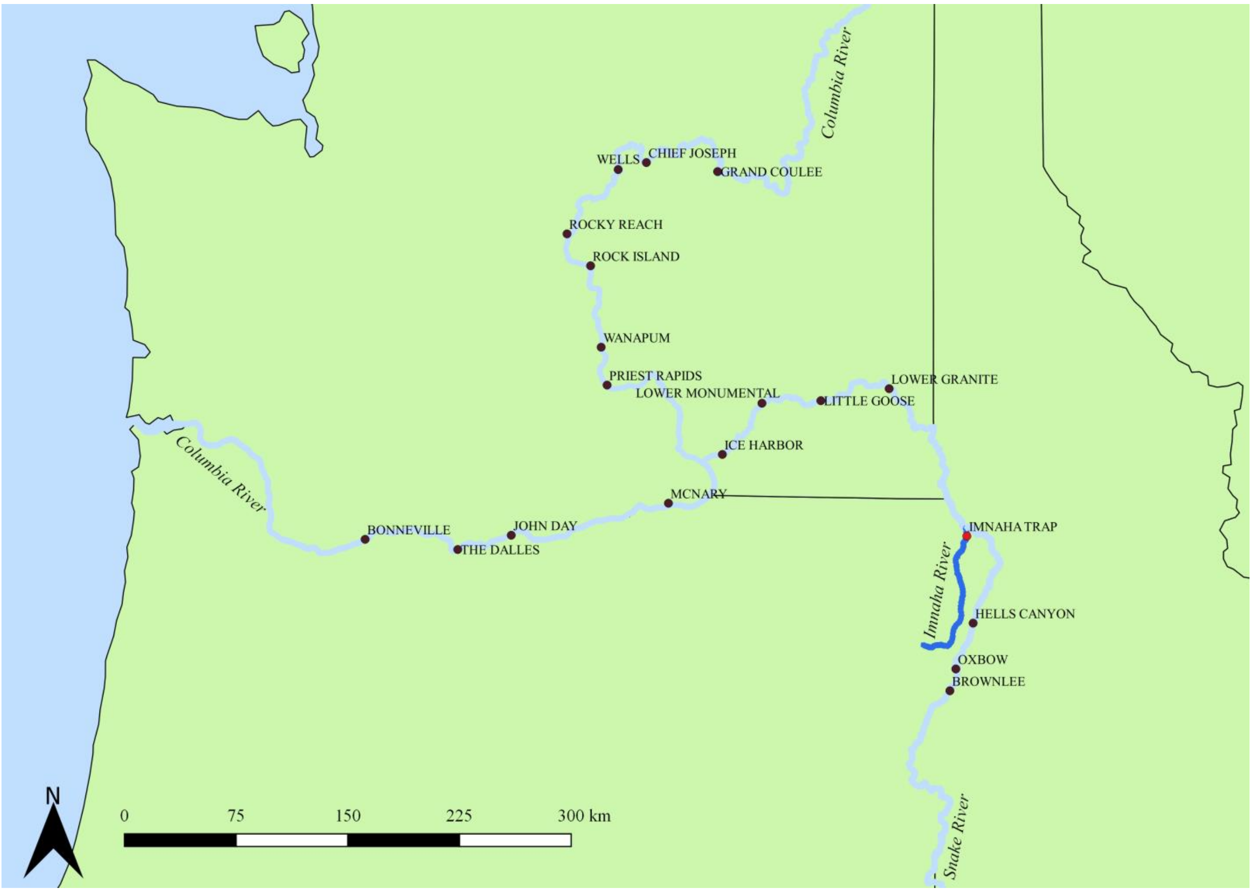

Figure 2. Map of the major dams (black circles) on the Snake and Columbia rivers (light blue), the Imnaha River (dark blue), and the Imnaha River trap (red circle).

Trapping and Tagging

Equipment Description

A rotary screw trap was used to capture emigrating juvenile Chinook Salmon and steelhead in the Imnaha River. The trap was deployed just downstream of the Cow Creek Bridge on the Imnaha River at N 45.76381 W -116.74802, about seven river kilometers (rkm) upstream from the confluence with the Snake River. The trap location was as close to the confluence as possible while still providing road access. Two different rotary screw traps (both manufactured by EG Solutions, Inc., Corvallis, OR) were fished during the sampling season. The rotary screw trap fished during higher flow conditions in the spring has a rotating cone that is 2.1 m 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). The rotary screw trap fished during lower flow conditions in the fall, winter, and early summer has a cone that is 1.5 m in diameter and sits atop two 4.9 m long pontoons, with a live box and debris drum.

A tent was setup on the river bank adjacent to the trap to provide a clean and dry area out of the elements to process the catch from the trap. Equipment for processing fish was housed in the tent and included a station with tubs and buckets for anesthetizing fish, a Biomark® HPR Plus PIT tag reader and tagging supplies, electronic balance, and a digitizer board for recording lengths, conditional comments, and other biological data. The PIT tag reader, electronic balance, and digitizer board are connected to a laptop computer and synchronized for electronic data collection using P4 Field Tagging Software (PTAGIS, Pacific States Marine Fisheries Commision, Portland, Oregon). PIT tags designated for natural Chinook Salmon and steelhead are purchased using BPA and LSRCP funds and allocated annually by species. PIT tags designated for Bull Trout are obtained from Idaho Power.

Figure 3. The Imnaha River trap (2.1m diameter) in operation.

Fish Trapping and Tagging

Trapping for MY2017 began October 5, 2016 and ended July 10, 2017. The trap was operated continuously, seven days per week, throughout the sampling season, except during late June and early July when trapping occurred on alternate weeks. Additionally, trapping operations were intermittently terminated throughout the sampling season due to high flows, high stream temperatures, cattle crossings upriver, and ice events. Tagging was discontinued when water temperatures exceeded 17°C; handling was reduced to netting, enumerating by species, and returning fish to the river when water temperatures exceeded 20°C; and at greater than 23°C screw trap operations ceased.

The trap was checked daily at about 0800 and several times throughout each day and night, if warranted by high numbers of fish, high flows, or excessive debris. Target species includes juvenile Chinook Salmon and steelhead, and lamprey spp. All other species and adult salmonids were considered incidental catch. Individuals of incidental catch that were too large to handle and safely anesthetize were removed from the live box first, identified to species, enumerated, and returned to the river downstream of the trap. Bull trout were then removed from the live box, placed in aerated buckets, and transported to the tagging tent. Lastly, all remaining fish were removed from the live box, placed in aerated buckets, and transported to the tagging tent (this was done in batches if numbers of fish in the live box were high).

Fish were anesthetized in a bath of MS-222 (6 ml of 10% stock solution per 16 L of water) buffered with PolyAqua® until they could be effectively handled, then sorted by species. Five fish of each species of incidental catch were weighed (nearest 0.1 g), measured for fork length (nearest mm), and placed in an aerated recovery bucket. Remaining incidental catch were enumerated by species, placed in an aerated recovery bucket, and returned to the river downstream of the trap after recovery from the anesthesia. All natural Chinook Salmon and steelhead juveniles and Bull Trout were examined for existing external marks (e.g. fin clips and tags) and scanned for a PIT tag. If a fish had been previously PIT-tagged, it was recorded as a recapture, weighed, measured for fork length, checked for overall condition, and placed in a recovery bucket. If a natural Chinook Salmon or steelhead did not have a PIT tag and was ≥65 mm in fork length, a PIT tag was inserted into the abdominal cavity using a Biomark® MK25 implant gun with a single-use, pre-loaded needle (12mm FDX PIT tag), and the fish was scanned to record the unique identification code, weighed, measured for fork length, checked for overall condition, and placed in an aerated recovery bucket. Bull Trout without a PIT tag that were ≥200 mm in fork length received a PIT tag in the dorsal sinus and then were processed the same as natural Chinook Salmon and steelhead. Natural Chinook Salmon and steelhead and Bull Trout that did not receive a PIT tag because of size, poor condition, or the daily quota had been reached for the species, were weighed, measured for fork length, checked for overall condition, and placed in a recovery bucket. The number of juvenile natural Chinook Salmon and steelhead selected to receive a PIT tag on a specific day was based on the average daily catch, the projected proportion of emigrants remaining in the system, and the current PIT tag inventory. Untagged Bull Trout that met the size requirement received a PIT tag as long as tagging supplies lasted. All captured hatchery Chinook Salmon and steelhead smolts were scanned for a PIT tag, if a PIT tag was detected the fish was weighed, measured for fork length, checked for overall condition, and placed in a recovery bucket. A daily subsample of at least 10 untagged hatchery Chinook Salmon and 10 untagged hatchery steelhead were weighed and measured for fork length. All other untagged hatchery smolts were enumerated by species and placed in a recovery bucket. All lamprey were identified to species, weighed, measured for total length, and placed in a recovery bucket.

After the daily trap catch had recovered from the anesthesia, incidental catch species, hatchery Chinook Salmon and steelhead, Bull Trout, lamprey, and recaptures were released downstream of the trap. Daily trap efficiency was estimated by randomly selecting 50 newly tagged individuals of each species of natural Chinook Salmon and steelhead and releasing them after dark about one kilometer upstream of the trap. All other newly PIT-tagged, natural Chinook Salmon and steelhead were held in perforated recovery containers downstream of the trap and released after dark. During summer flow conditions and water temperatures, tagged fish are placed in recovery containers that allow volitional release immediately after recovering from the anesthetic.

Figure 4. A natural Chinook Salmon smolt on the measuring table at the Imnaha River trap.

Figure 5. A natural steelhead smolt on the measuring table at the Imnaha River trap.

Figure 6. A Chinook Salmon smolt about to be PIT-tagged at the Imnaha River trap.

Trap Subsampling

During peak hatchery smolt emigration the trap capture rates occasionally exceeded the number of fish that could be safely held in the trap box and processed by the crew. Therefore, the trap was equipped with a bypass door in the trap box that, when opened, allowed fish to passively move through a PIT tag antenna out the side of the trap box back to the river. The PIT tag antenna interrogated all previously tagged fish that pass through the trap. The bypass door was used in conjunction with a partition door in the trap to subsample during periods of high fish catch.

The first subsampling procedure was used proactively based upon predictions of hatchery smolt arrival. Technicians would arrive at the trap in the evening, typically just after sundown and clear the trap box. Fish removed were processed with the methods described above. Technicians would check and clear the trap box of fish frequently and record the time on each interval the trap box was cleared. When the rate of fish captured exceeded what could be safely processed, the partition door would be closed and the bypass door would be opened to bypass incoming fish through a PIT tag antenna and begin the subsampling procedure. The fish trapped in the back of the trap box composed the subsample to be processed. All incoming fish thereafter were bypassed until the end of that subsample period. Once the trap box was cleared the bypass door was closed and the partition door opened to capture fish for another subsample. After a manageable number fish were captured the partition door was closed and the bypass door opened to isolate the subsample and bypass fish once again while the subsample was processed. This was repeated throughout the shift until the rate of fish captured did not exceed the rate at which the crew could safely process fish. An estimate of the abundance and composition of fish bypassed during the proactive subsampling procedure was calculated for each species and origin type and each subsample period by expanding the number of processed fish using the following equation.

$$N = \left(\left(\frac{C_1 - R}{t_1/t_2}\right) - (C_1 + C_2)\right)$$

Where

N = estimated number of individuals
C_1 = number of individuals captured in the sub sample
C_2 = number of previously PIT-tagged individuals interrogated during bypass
R = recaptured individuals
t_1 = time the sub sample was collected
t_2 = time captured fish were bypassed

The second subsampling procedure was used reactively when the number of fish already captured could not be processed as a subsample without jeopardizing the health of the fish remaining in the live box, even if all newly incoming fish were bypassed. Similar to above, the partition door was closed and the bypass door opened diverting bypassed fish through a PIT tag antennae. The composition of fish captured in the trap box was determined by subsampling and processing net-fulls of fish. This was accomplished by removing a manageable number of net-fulls of fish from the live box to be processed as a subsample and then removing equally-sized net-fulls of the remaining fish to determine the total number of net-fulls that were in the trap box. All net-fulls of fish that were not processed were passed through a PIT tag antenna to interrogate any previously PIT-tagged fish. Once the trap box was cleared, subsamples would be collected for a recorded period of time and fish would be bypassed as described in the proactive subsampling procedure above until the rate of fish captured slowed. An estimate of the abundance and composition of fish bypassed during the reactive subsampling procedure was calculated for each species and origin type using the following equation.

$$N = \left(\left(\frac{C_1 - R}{Nets_1/Nets_2}\right) - (C_1 + C_2)\right)$$

where

N = estimated number of individuals

C_1 = number of individuals captured in the sub sample
C_2 = number of previously PIT-tagged individuals interrogated during bypass
R = recaptured individuals
$Nets_1$ = number of nets collected and processed for sub sample
$Nets_2$ = number of nets bypassed

The PIT tag data collected during subsampling events was incorporated into recapture numbers and trap efficiency calculations. The expanded fish numbers were included in the number of fish handled, the number passing the trap, and incidental species counts. All other calculations within this document were based on actual fish counts or PIT tags, not expanded numbers of fish handled.

Hatchery Release

Hatchery Chinook Salmon and steelhead smolts were released by LSRCP facilities managed by the Oregon Department of Fish and Wildlife (LSRCP 2017). Hatchery Chinook Salmon smolts began acclimation at the Gumboot Acclimation Facility on March 23, 2017. Volitional release from the acclimation facility started on April 3, 2017 and ended on April 13, 2017 when the remaining smolts were forced from the pond. A separate group of Chinook Salmon smolts were released directly into the Imnaha River at the Gumboot Acclimation Facility on April 13, 2017. Steelhead smolts were acclimated at the Little Sheep Creek Acclimation Facility beginning

February 22, 2017. Steelhead smolts were released volitionally from April 1, 2017 through April 28, 2017 when the remaining smolts were forced out of the pond (Mike Fletcher ODFW Personal Communication). Refer to Appendix D for a summary of hatchery release numbers, dates, and associated data.

Population Dynamics

Juvenile Emigrant Abundance Estimates at the Imnaha River Trap

Natural smolt emigrant abundance estimates at the Imnaha trap

Emigrant abundance was estimated (hereafter referred to as population estimate) for natural Chinook Salmon and steelhead by trapping period, season, and migration year. Consecutive daily trap data with similar trap efficiency were grouped into trapping periods and each trapping period had at least seven recaptured fish (as suggested by Steinhorst et al. 2004). Population estimates were calculated for each trapping period, season, and migration year for natural Chinook Salmon presmolts and smolts and natural steelhead smolts using a Baily adjusted Lincoln-Petersen population estimator and 95% parametric bootstrap confidence intervals were estimated using 1,000 iterations (see Steinhorst et al. 2004 for details). Data analysis was performed using package cuyem (Version 0.1.0) in Program R (Version 3.4.0). Coefficients of variation (CV) were calculated by dividing the standard error by the population estimate as an indicator of precision.

Hatchery smolt emigrant abundance estimates at the Imnaha River trap

Hatchery Chinook Salmon and steelhead smolt abundance estimates were calculated at the Imnaha River trap by applying the estimated survival from release to the trap (post-release survival) to the total number of smolts released. The standard error of the survival estimate from hatchery release to the trap was applied to the total number of hatchery fish released (a census count with no reported standard error) to generate a standard error for the abundance estimate at the trap, which was then used to generate 95% confidence intervals around the point estimate. Survival estimation methods are discussed in detail below.

Juvenile Emigration Timing of Imnaha River Chinook Salmon and Steelhead

Arrival timing and 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 is assumed that juvenile emigrant arrival at the trap represents emigration from the Imnaha River to the Snake River. Arrival timing at the Imnaha River trap was calculated for natural and hatchery juvenile emigrants. First, 10^{th} percentile, median, 90^{th} percentile, and last arrival dates were calculated for each emigrant group arriving at the Imnaha River trap. Cumulative emigration from the Imnaha River was quantified for each group of natural and hatchery Chinook Salmon and steelhead juveniles. Cumulative emigration of natural Chinook Salmon and steelhead smolts was compared to cumulative emigration of hatchery

Chinook Salmon and steelhead smolts at the trap using a two-sample Kolmogorov-Smirnov test (K-S test; $\alpha = 0.05$). Species specific daily mean catch (CPUE; fish/hour) at the Imnaha River trap and Imnaha River daily mean discharge (ft^3/sec) were plotted by date and visually examined to assess the relationship between catch and discharge. Imnaha River discharge data were obtained from Idaho Power's river gauge at Imnaha, Oregon (https://idastream.idahopower.com/).

Arrival timing and emigration at Lower Granite Dam

Arrival timing at LGR was calculated for natural and hatchery Chinook Salmon and steelhead using PIT tag interrogation data queried from the Pacific States Marine Fisheries Commission's PIT Tag Information System database (PTAGIS). First, 10^{th} percentile, median, 90^{th} percentile, and last arrival dates were calculated for each emigrant group arriving at LGR. Cumulative emigration differences between these paired groups were evaluated using a two-sample K-S test ($\alpha = 0.05$). We also calculated the proportion of Imnaha River emigrants from each group that had passed LGR prior to the date of initiation of collections for transportation. Collections for transportation (barging or trucking) at juvenile collection facilities at LGR, Little Goose Dam, and Lower Monumental Dam began on May 1, 2017. Collections for transportation at McNary Dam were discontinued in 2013. It was assumed that fish arriving at LGR prior to May 1, 2017 were not transported, while those arriving on that date or later would be transported if collected at any of the transport dams and not part of the PIT tag group designated to be bypassed back to the river (Brandon Chockley FPC personal communication). Collection efficiencies referenced in this report were estimated by the Fish Passage Center, and are available in their annual report for 2017 (FPC 2018).

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

Travel time for PIT-tagged emigrants from the Imnaha River trap to LGR was calculated as the number of days from interrogation at the trap to the first detection at LGR. Interrogation detections at LGR for each emigrant group were grouped by week and mean travel time was calculated. Simple linear regression was used to evaluate the relationship between weekly mean travel time and weekly mean Snake River discharge. Snake River discharge data were provided by the USGS gauge 13334300 at Anatone, Washington (http://waterdata.usgs.gov/usa/nwis/uv).

Proportion of juveniles likely to be transported at LGR

The proportion of juveniles likely to be transported at LGR was calculated by emigrant group. This calculation is the product of the cumulative proportion of juveniles within an emigrant group which passed while transportation operations were occurring and the collection efficiency of that emigrant group at the LGR juvenile bypass facility (FPC 2017).

Life-stage and Reach Specific Estimates of Juvenile Emigrant Survival

Survival and detection probabilities were estimated for each emigrant group using the Cormack-Jolly-Seber model (Cormack, 1964; Jolly, 1965; Seber, 1965) in program PITPRO (version 4.19.8; Westhagen and Skalski 2009). Program SURPH (version 3.5.2; Lady et al. 2013) was used to compare survival and detection probabilities for the paired emigrant groups using a likelihood ratio test ($\alpha = 0.05$). Data for PITPRO were obtained from PTAGIS.

Survival and detection probabilities were estimated for hatchery Chinook Salmon and steelhead smolts from their point of release to the Imnaha River trap at river kilometer seven. Hatchery Chinook Salmon smolts were volitionally released after a period of acclimation from the LSRCP Gumboot Acclimation Facility on the Imnaha River and directly released from the Gumboot adult weir. Hatchery steelhead were volitionally released after a period of acclimation from the LSRCP Little Sheep Creek Acclimation Facility.

Survival and detection probabilities were estimated for natural and hatchery Chinook Salmon and steelhead smolts and natural Chinook Salmon presmolts from the Imnaha River trap to LGR and the Imnaha River trap to MCN. Natural Chinook Salmon were evaluated independently by life-stage (presmolt and smolt) and by cohort. Natural steelhead smolts trapped during the fall are excluded from analysis due to insufficient numbers for estimating PIT tag based survival and detection probabilities. For estimates of juvenile survival through the entire Columbia River hydrosystem see the Comparative Survival Study reports (http://www.fpc.org/documents/css.html).

The population estimate of each emigrant group at the Imnaha River trap is multiplied by is respective survival probability from the Imnaha River trap to LGR to provide an estimated number of smolt equivalents at LGR. The variance and standard deviation used to estimate 95% confidence intervals for the smolt equivalent estimate is calculated using the following 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 annual emigrant survival from the Imnaha River trap to MCN, mean annual Snake River discharge (ft^3/sec), mean spring spill (ft^3/sec), and mean percent spring spill for MY1998 through MY2017 was evaluated with multiple linear regression using the car package (Version 2.1-6) in program R (Version 3.4.0). Snake River discharge at Anatone was averaged from April through June 20 in each year (the period of mandated spring spill). Spill, and percent spill were also averaged from April through June 20 over the four Snake River dams in each year. Pairs plots and variance inflation factors suggested strong collinearity between spill and percent spill for each model so mean spill was removed from the analysis. All discharge data were obtained from either http://www.cbr.washington.edu/dart or http://waterdata.usgs.gov/usa/nwis/uv?site_no=13334300.

Size and Condition of Juveniles at Emigration

Chinook Salmon and steelhead emigrants captured at the Imnaha River trap were measured for fork length (nearest mm) and weight (nearest 0.1 g). Length frequency distributions and condition factors were calculated for emigrant group. Condition factor was calculated using Fulton condition factor: $K = (\text{weight}/\text{length}^3)*100{,}000$ (Anderson and Neumann 1996). A Welch two-sample t-test ($\alpha = 0.05$) was used to test for significant differences in mean fork length, weight, and condition factor between the paired emigrant groups (e.g., natural steelhead and hatchery steelhead smolts).

Smolt to Adult Return Rates

The smolt to adult return (SAR) rates calculated 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 were interrogated at a juvenile bypass facility during emigration through the hydrosystem. Though many juveniles were first interrogated at dams downstream of LGR, we included them with the number which passed LGR assuming they were not interrogated when they migrated past LGR. For LGR – LGR SAR rates, adult PIT tag detections at LGR are totaled by their emigrant group, SbyC mode (monitor or survival), and brood year (Chinook Salmon) or migration year (steelhead).

PIT-tagged Chinook Salmon and steelhead emigrating from the Imnaha River will travel through the hyrdrosystem in one of two predetermined designations; monitor mode or survival mode. The SbyC system allows PIT-tagged fish interrogated at the juvenile bypass facilities to be segregated by these two actions depending on specific PIT tag codes. Survival mode fish are always bypassed back to the river in an effort to assess in-river survival of emigrating juveniles. Monitor mode fish are treated as the run-at-large fish, same as non-PIT-tagged emigrants, and barged or bypassed depending on the management actions at any given time at each juvenile bypass facility. Previously, this report only analyzed SAR rates for survival mode tagged fish, which did not represent the run at large. Given sufficient numbers of monitor mode tags in recent years, we report SAR rates for monitor mode fish in this document and plan to include monitor mode SAR rates in future annual reports as well.

Smolt to adult return rates were calculated for both survival and monitor mode PIT-tagged natural Chinook Salmon presmolts and smolts and survival and monitor mode hatchery Chinook Salmon smolts recaptured at the Imnaha River trap for brood years 2007 through 2012. Steelhead SAR rates were calculated for survival and monitor mode natural steelhead PIT-tagged at the Imnaha River trap for migration years 2010 through 2014. The PIT-tagged natural steelhead smolts from the Imnaha River trap include juveniles of unknown brood years, making analysis by brood year impossible for natural steelhead. Hatchery steelhead SAR rates were calculated by brood year and migration year for PIT-tagged hatchery steelhead smolts recaptured at the Imnaha River trap during emigration.

Results and Discussion

Trapping and Tagging

Trap Operations

The Imnaha River smolt monitoring trapping season spanned 277 days in MY2017, from October 6, 2016 through July 10, 2017. There were a total of 88 days the Imnaha River trap was not operated due to icy conditions, high flows, or heavy debris; and 17 days the trap was not operated due to equipment repair and maintenance or staffing schedules. Non-operational days were more numerous than normal due to severe winter conditions. Additionally, sample periods were shortened (i.e., a sample period was less than 24 hours) on four occasions due to ice, four occasions due to rising water and debris, and three occasions due to equipment repair and maintenance. See Appendix A for a summary of total hours fished and the daily catch.

Target Catch

The catch of MY2017 natural Chinook Salmon totaled 5,283 fish including 2,329 presmolts trapped in the fall of 2016 and 2,954 smolts trapped during spring and summer 2017; of which, 106 smolts were estimated as part of a bypass that occurred on April 4, 2017 (Appendix A). Nine Chinook Salmon < 60 mm in length were caught in the spring of 2017 and were not tagged and therefore excluded from trap efficiency and population estimates. These small fry and parr were likely either fall Chinook Salmon or BY2017 spring Chinook Salmon. Genetic samples were collected on a subset of these fish to determine their run designation but results are currently unavailable. A total of 2,313 natural Chinook Salmon presmolts were tagged at the Imnaha River trap during fall 2016 and 2,775 smolts were tagged during the spring and summer of 2017 (Appendix B). Trap efficiency was calculated with 1,498 presmolts during fall and 1,930 smolts during spring and summer. Ten (three recaptures in the fall and seven recaptures in the spring) of the 1,000 natural Chinook Salmon that were previously PIT-tagged by the ODFW Early Life History Program during August and September of 2016 were recaptured at the Imnaha River trap (Appendix C).

The catch of MY2017 natural steelhead totaled 2,905; of which, 20 smolts were estimated as part of bypass that occurred on April 4, 2017. One natural steelhead smolt was tagged in the fall 2016 and 2,809 were tagged in spring and summer of 2017 (Appendix B). Trap efficiency was calculated with 1,518 steelhead smolts in the spring and summer of 2017.

A total of 19,445 hatchery Chinook Salmon smolts representing BY2015 were captured at the Imnaha River trap during the 2017 spring and summer trapping period, of which 49 were estimated as part of bypass procedures on April 4, 2017 (Appendix A). Hatchery Chinook Salmon smolts that were captured at the Imnaha River trap were from an acclimated volitional release group (283,041 smolts) released from the Imnaha River Gumboot acclimation facility (rkm 74) from April 3, 2017 through April 13, 2017, when all remaining smolts were forced out (Joseph Feldhause ODFW personal communication). Additionally, 208,085 hatchery Chinook

Salmon smolts were directly released into the Imnaha River near the Gumboot Acclimation Facility on April 13, 2017. A total of 20,688 smolts released in MY2017 were PIT-tagged at Lookingglass Hatchery and 760 of these were recaptured at the Imnaha River trap (Appendix D).

A total of 13,192 hatchery steelhead smolts representing BY2016 were captured at the Imnaha River trap during the spring and summer trapping of 2017; of which, 1,231 were estimated as part of bypass procedures on April 4, 2017 (Appendix A). Hatchery steelhead smolts that were captured at the Imnaha River trap were from a volitional release of 216,930 smolts from the LSRCP Little Sheep Creek acclimation facility beginning April 1, 2017 and ending April 28, 2017 when all remaining fish were forced out of the acclimation pond (Mike Flesher ODFW personal communicatioin). A total of 14,894 smolts released in MY2017 were PIT-tagged at Irrigon Hatchery and 798 of these fish were recaptured at the Imnaha River trap (Appendix D).

Incidental Catch

The incidental catch during MY2017 was 1,921 fish comprised of five families: Salmonidae, Centrarchidae, Catostomidae, Cyprinidae and Cottidae. The catch of Salmonidae consisted of 70 adult steelhead, 962 Rainbow Trout, 94 Mountain Whitefish (*Prosopium williamsoni*), and 23 Bull Trout. Bull Trout were divided into adults 300 mm and greater (n = 13), and sub-adults less than 300 mm (n = 10). Juvenile Rainbow Trout were determined to be resident fish based on morphological characteristics and were not enumerated as natural steelhead juveniles in this report. The catch of Centrarchidae consisted of 27 Smallmouth Bass (*Micropterus dolomieui*). The catch of the Catostomidae family consisted of 335 sucker *spp*. The catch of Cyprinidae included 36 Chiselmouth (*Acrocheilus alutaceus*), 282 Longnose Dace (*Rhinichthys cataractae*), 2 Speckled Dace (*Rhinichthys osculus*), 34 Northern Pikeminnow (*Ptychocheilus oregonensis*), 16 Redside Shiner (*Richardsonius balteatus*) and 12 Peamouth Chub (*Mylocheilus caurinus*). The catch of the Cottidae family consisted of 28 sculpin *spp*. See Appendix E for a summary of the MY2017 incidental catch data. Three juvenile Pacific Lamprey (*Lampetra tridentata*) in the family Petromyzontidae were caught during MY2017. Lamprey are considered "target species" by the Fish Passage Center. See Appendix F for Pacific Lamprey catch and biological data.

Trapping and Tagging Mortality

Target catch mortalities handled at the Imnaha River trap during the MY2017 trapping season included 39 natural and 61 hatchery Chinook Salmon emigrants and 27 natural and 37 hatchery steelhead emigrants. Six of the natural Chinook Salmon presmolt mortalities occurred during the fall and accounted for 0.26% of the natural Chinook Salmon presmolt catch and included two from trapping (including predation in the trap live box), three from tagging, and one that was determined to be dead on arrival. Thirty-three natural Chinook Salmon smolt mortalities occurred during the spring and summer and accounted for 1.12% of the natural Chinook Salmon smolt catch and included 14 from trapping (including predation in the trap live box), 11 from tagging, two from handling, and six were determined to be dead on arrival. Sixty-one hatchery Chinook Salmon smolt mortalities occurred during the spring and accounted for 0.31% of the hatchery Chinook Salmon smolt catch and included 58 from trapping (including predation in the trap live box) and three were determined to be dead on arrival. Twenty-seven natural steelhead smolt mortalities occurred during the spring and accounted for 0.94% of the natural steelhead smolt catch and included 23 from trapping (including predation in the trap live box), one from tagging, and three were determined to be dead on arrival. Thirty-seven hatchery steelhead smolt mortalities occurred during the spring and accounted for 0.28% of the hatchery steelhead smolt catch and all were attributed to trapping (including predation in the trap live box). See Appendix G for mortality details.

Sixteen incidental catch mortalities occurred at the Imnaha River trap during the MY2017 trapping season. All of these occurred during the spring and were attributed to trapping (including predation in the trap live box) and included six sculpin *spp*., four Smallmouth Bass, two sucker *spp*., and four Rainbow Trout.

Performance Measures for MY2017

<u>Emigrant Abundance at the Imnaha River Trap</u>

Natural Chinook Salmon and steelhead emigrant abundance

Mark-recapture at the Imnaha River trap estimated 62,308 (43,808 – 102,857) [estimate (95% confidence interval)] natural Chinook Salmon presmolts with a CV of 26.9%. Presmolt trap efficiency averaged 0.05 and ranged between 0.02 to 0.28 for the fall trapping season (Table 1). The spring and summer population estimate for natural Chinook Salmon smolts was 34,904 (28,453 – 43,322) with a CV of 12.2%. Trap efficiencies averaged 0.08 and ranged from 0.03 to 0.11 through the spring trapping season (Table 1). The natural Chinook Salmon cohort (all captured Chinook Salmon juveniles) population estimate was 97,212 (75,800 – 129,311) with a CV of 16.5% (Table 1). Presmolts and smolts comprised 64% and 36% of the natural Chinook Salmon cohort, respectively. The MY2017 cohort estimate was 8.05% less than the MY2016 cohort estimate.

Table 1. Natural Chinook Salmon presmolt and smolt number of fish captured, marked, and, recaptured, and trap efficiency (TE), population estimate (N), lower 95% confidence interval (Lower CI), upper 95% confidence interval (Upper CI), and standard error (SE) for each trapping period and overall total for MY2017.

Trapping Period	Capture	Mark	Recap	TE	N	Lower CI	Upper CI	SE
10/07/16-10/23/16	338	264	8	0.03	9,952	5,035	20,473	4,597
10/24/16-10/26/16	447	100	15	0.15	2,822	1,814	4,667	732
10/28/16-11/10/16	614	489	8	0.02	33,429	18,204	67,991	15,594
11/11/16-11/27/16	408	336	15	0.05	8,594	5,392	14,728	2,449
11/28/16-12/12/16	323	219	9	0.04	7,106	4,033	13,156	2,596
12/13/16-12/16/16	117	89	25	0.28	405	290	581	75
Presmolt Total	2,247	1,497	80	0.05	62,308	43,808	102,857	16,757
Trapping Period	Capture	Mark	Recap	TE	N	Lower CI	Upper CI	SE
01/27/17-02/09/17	167	165	11	0.07	2,310	1,346	4,289	735
02/13/17-03/09/17	260	230	7	0.03	7,508	3,845	14,553	3,430
03/10/17-03/18/17	184	166	10	0.06	2,793	1,622	5,206	963
03/27/17-04/07/17	1,285	528	58	0.11	11,521	9,139	14,748	1,458
04/12/17-04/14/17	112	109	9	0.08	1,232	675	2,377	469
04/15/17-04/21/17	267	261	12	0.05	5,381	3,098	8,834	1,536
04/22/17-05/04/17	379	365	39	0.11	3,468	2,541	4,774	590
05/05/17-05/19/17	79	69	7	0.10	691	345	1,418	287
Smolt Total	2,733	1,893	153	0.08	34,904	28,453	43,322	4,262
Chinook Cohort Total	4,980	3,390	233	0.07	97,212	75,800	129,311	16,011

The population estimate for natural steelhead smolts was 27,269 (22,803 – 33,111) with a CV of 9.6%. Trap efficiencies for natural steelhead averaged 0.10 and ranged from 0.07 to 0.13 (Table 2).

Table 2. Natural steelhead smolt number of fish captured, marked, and recaptured, and trap efficiency (TE), population estimate (N), lower 95% confidence interval (Lower CI), upper 95% confidence interval (Upper CI), and standard error (SE) for each trapping period and overall total for MY2017.

Trapping Period	Capture	Mark	Recap	TE	N	Lower CI	Upper CI	SE
02/28/17-04/07/17	367	304	25	0.08	4,305	2,893	6,608	934
04/12/17-04/22/17	324	321	21	0.07	4,742	3,155	7,291	1,082
04/23/17-05/03/17	927	550	64	0.12	7,858	6,241	10,172	1,003
05/04/17-05/17/17	727	199	18	0.09	7,653	5,052	12,528	1,810
05/18/17-05/29/17	360	127	16	0.13	2,711	1,710	4,260	649
Smolt Total	2,705	1,501	144	0.10	27,269	22,803	33,111	2,613

The Imnaha River trap did not operate during late summer, high flows, heavy debris, icy conditions, maintenance and repair, or scheduled weekends and holidays off (Appendix A). When the trap was not operating the number of juveniles passing the trap was not estimated. Therefore, the estimates of natural juvenile emigrant abundance presented above for the Imnaha River during MY2017 should be considered minimum estimates.

Hatchery smolt emigrant abundance estimates at the Imnaha River Trap

See post-release survival of hatchery smolts below.

Emigration Timing of Imnaha River Chinook Salmon and Steelhead

Timing of juvenile emigration from the Imnaha River

Arrival of natural juvenile emigrants at the Imnaha River trap is assumed to represent the natural timing of emigration from the Imnaha River. Natural Chinook Salmon smolt emigration was highly protracted compared to hatchery Chinook Salmon smolts. The first natural smolts arrived at the Imnaha River trap on January 27, 2017, 10% of smolts had passed on February 16, 2017, median arrival occurred on April 3, 2017, 90% of smolts had passed on April 28, 2017, and the last smolt(s) arrived on July 10, 2017 (Table 3). Hatchery Chinook Salmon smolts rapidly emigrated past the trap in a unimodal pulse of fish. The first hatchery Chinook smolt was captured April 4, 2017 and over 90% of the total catch had migrated past the Imnaha River trap by April 13, 2017 (Table 3). The last hatchery Chinook Salmon smolt was captured on May 20, 2017 (Table 3). Results of the two-sample K-S test suggests that emigration of natural and hatchery Chinook Salmon smolts was significantly different (D statistic = 0.510, $p < 0.001$, n = 2,798 natural smolts and 19,445 hatchery smolts) and maximum difference between emigration timing at the Imnaha River trap occurred on April 3, 2017 (Figure 7).

The first natural steelhead smolt was captured at the trap February 5, 2017, 10% of smolts had passed on April 4, 2017, median arrival occurred on May 1, 2017, 90% of smolts had passed on

May 19, 2017, and the last smolt was captured on June 16, 2017 (Table 3). Hatchery steelhead smolts were first captured at the Imnaha River trap on April 2, 2017, 10% and median arrival occurred on April 3, 2017 and April 6, 2017, respectively, 90% of smolts had passed on May 5, 2017, and the last smolt was captured July 7, 2017 (Table 3). Emigration of natural and hatchery steelhead smolts past the Imnaha River trap was significantly different (two-sample K-S test, D statistic = 0.306, p = 0.002, n = 2,726 natural smolts and 13,192 hatchery smolts). The maximum difference in hatchery and natural steelhead emigration timing occurred on April 12, 2017. The pattern of natural and hatchery steelhead emigration was more disparate than in some prior years with a large pulse of hatchery smolts emigrating just after release followed by a gradual merging of cumulative emigration curves (Figure 8).

Table 3. First, 10th percentile, median, 90th percentile, and last arrival emigration dates of natural smolts at the Imnaha River trap.

Emigrant group	First arrival	10th percentile	Median	90th percentile	Last arrival
Natural Chinook smolts	01/27/17[a]	02/16/17	04/03/17	04/28/17	07/10/17[b]
Hatchery Chinook smolts	04/04/17	04/05/17	04/07/17	04/13/17	05/20/17
Natural Steelhead smolts	02/05/17	04/04/17	05/01/17	05/19/17	06/16/17
Hatchery Steelhead smolts	04/02/17	04/03/17	04/06/17	05/05/17	07/07/17

[a] 01/27/17 was the first day of trapping for 2017
[b] trapping ceased on 07/10/17

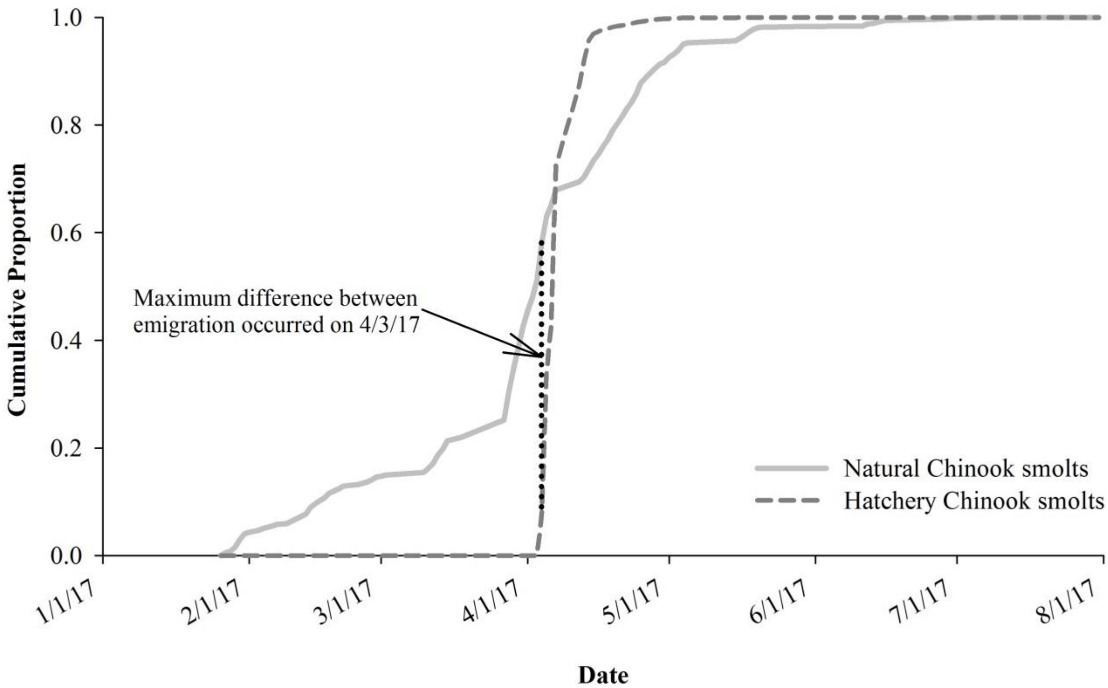

Figure 7. Cumulative proportion and date of natural and hatchery Chinook Salmon smolts at the Imnaha River trap.

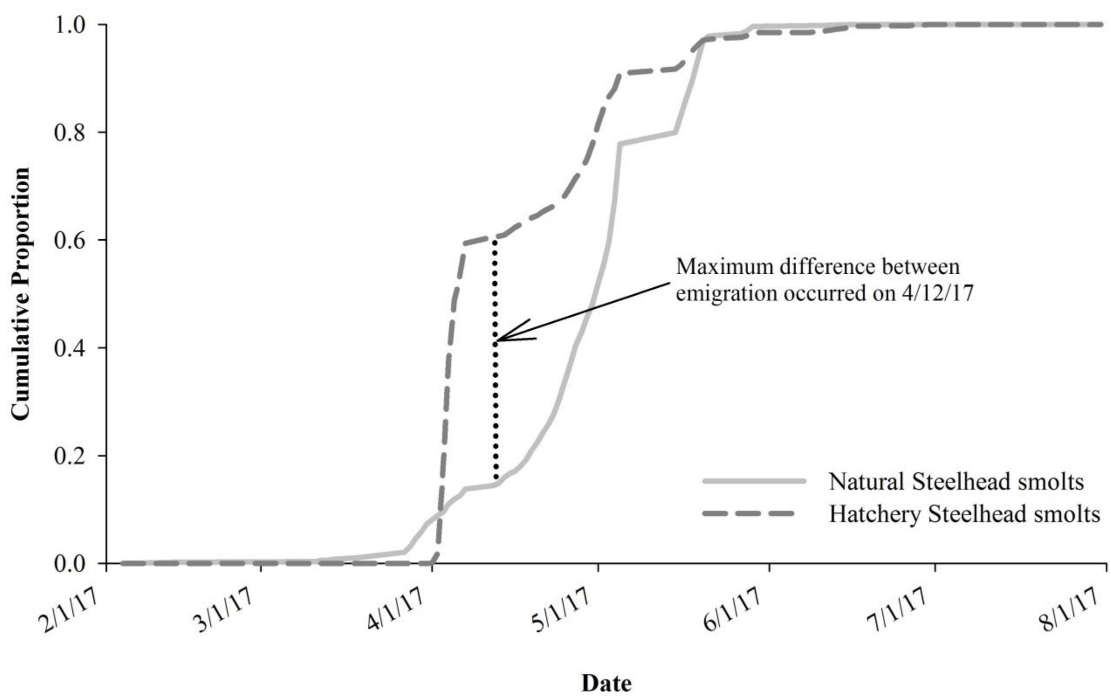

Figure 8. Cumulative proportion and date of natural and hatchery steelhead smolts at the Imnaha River trap.

Peak emigration timing in relation to Imnaha River discharge

High flows and freezing temperatures limited trapping during MY2017 leading to gaps in daily mean catch per unit effort (CPUE; mean number of fish per trap hour) and therefore the relationship between trap catch and discharge is less apparent. Chinook Salmon presmolt CPUE was stochastic for MY2017. Increases in presmolt catch often coincided with increases in the discharge from October through December, but varied in magnitude (Figure 9). Presmolt catch peaked in late October with a daily catch of about 11 fish/hour, which coincided with a peak in the hydrograph (about 450 ft^3/sec; Figure 9). During the spring of 2017, Chinook Salmon smolt CPUE was highest from mid-March through mid-April which coincided with the beginning of an extended spring run-off and declined gradually through the remaining trapping period (Figure 10). Natural steelhead smolt CPUE remained low until the beginning of April and peaked at the beginning of May (Figure 11). No substantial steelhead smolt emigration response was seen during the first several increases in the hydrograph (Figure 11).

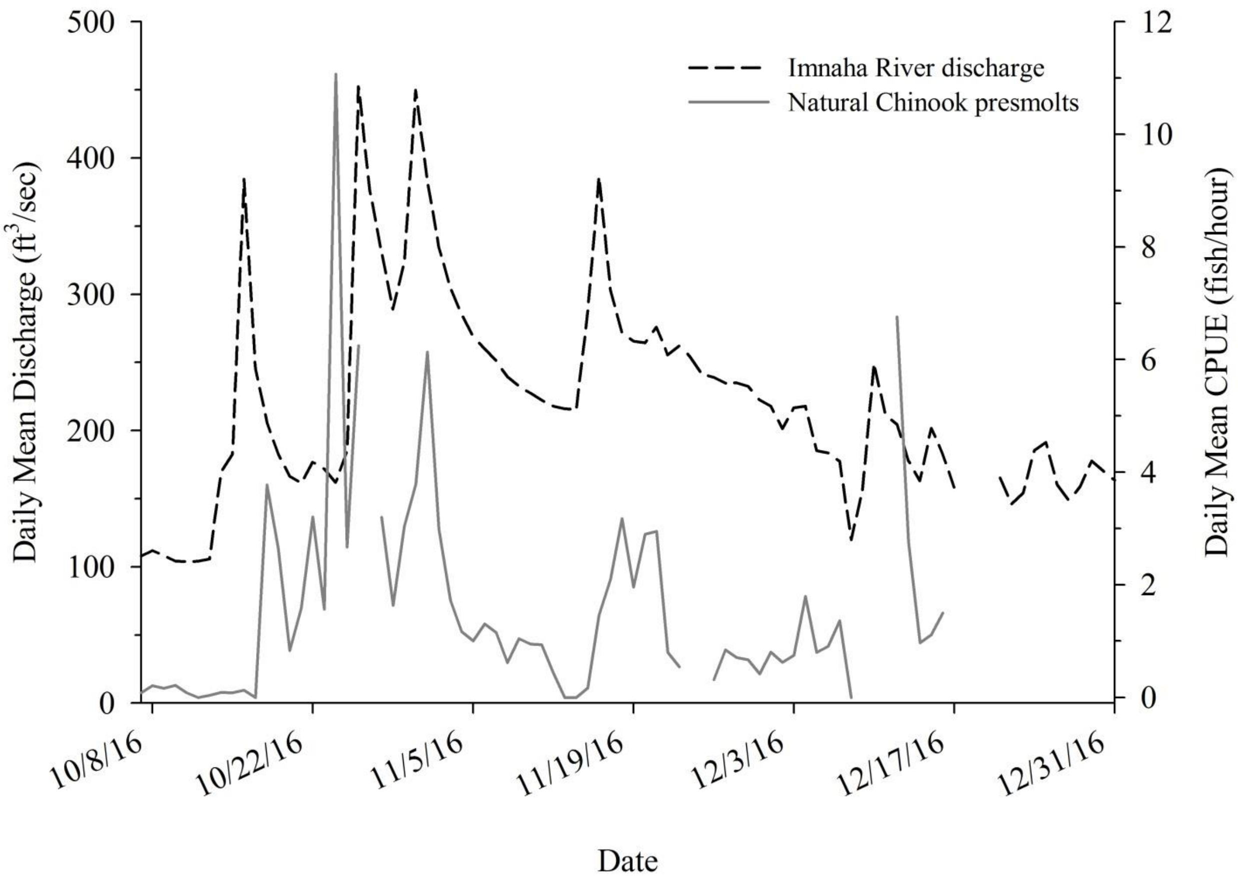

Figure 9. Daily mean Imnaha River discharge and daily mean catch per unit effort (CPUE) at the Imnaha River trap for natural Chinook Salmon presmolts.

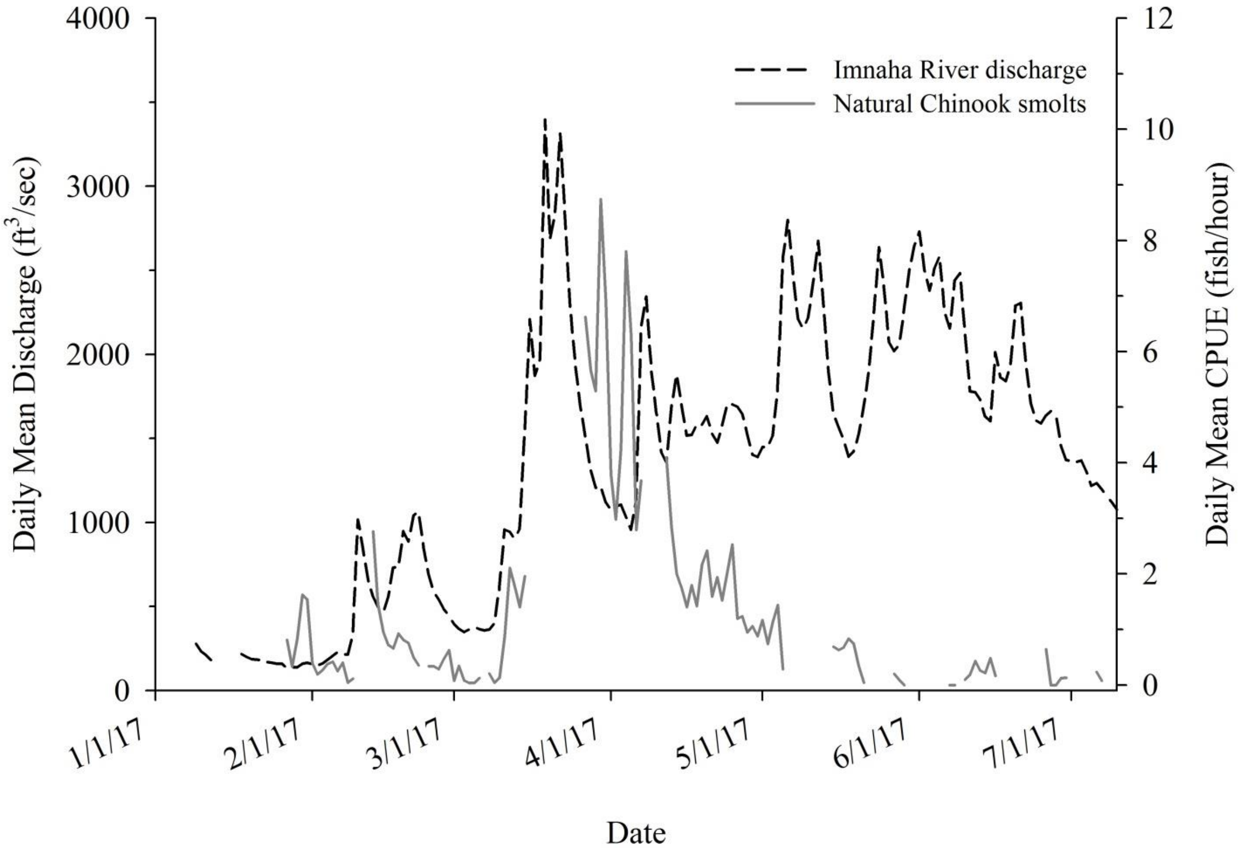

Figure 10. Daily mean Imnaha River discharge and daily mean catch per unit effort (CPUE) at the Imnaha River trap for natural Chinook Salmon smolts.

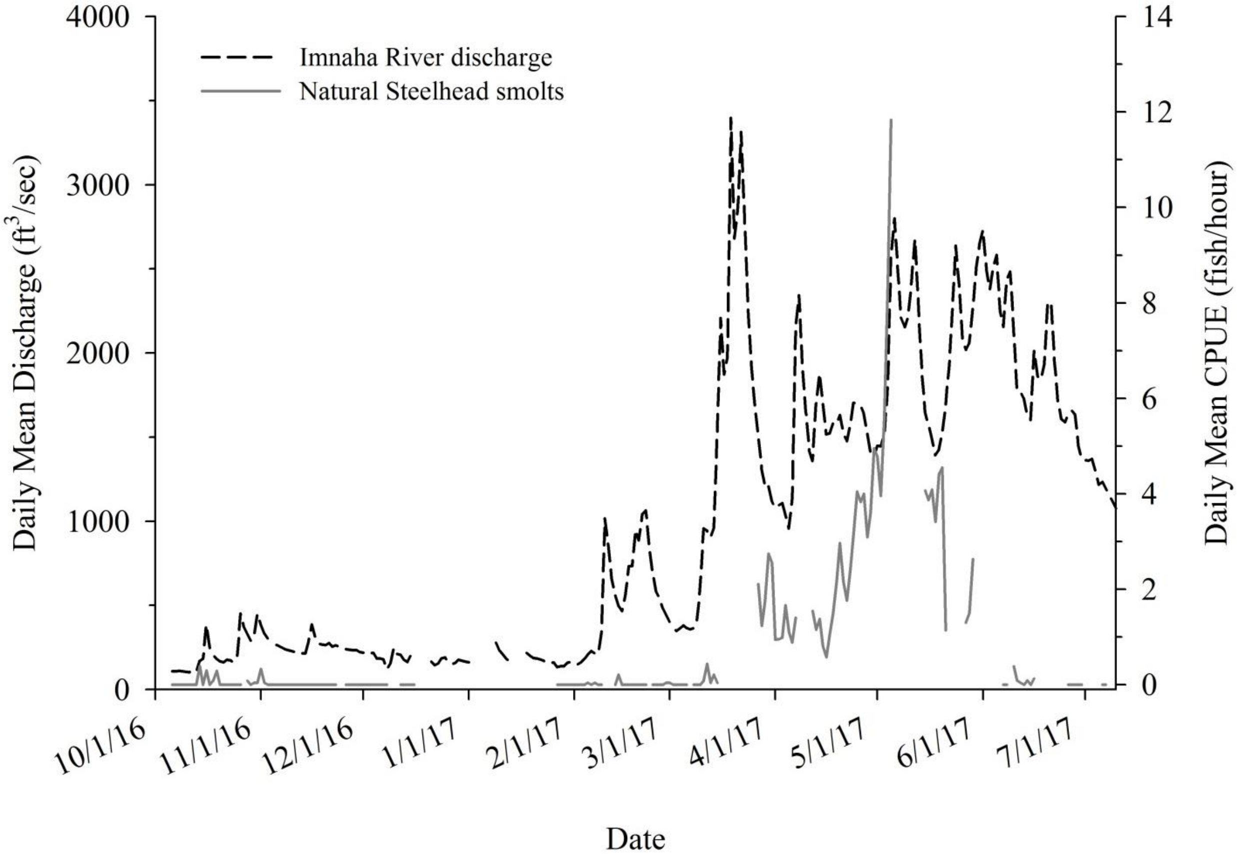

Figure 11. Daily mean Imnaha River discharge and daily mean catch per unit effort (CPUE) at the Imnaha River trap for natural steelhead smolts.

Chinook Salmon arrival timing at LGR

As would be expected given their proximity while overwintering in the Snake River, PIT tag interrogations indicated that a higher proportion of natural Chinook Salmon presmolts arrived at LGR earlier than natural Chinook Salmon smolts (Table 4; Figure 12). Results of the two-sample K-S test suggest that emigration of natural Chinook Salmon presmolts and smolts was significantly different at LGR (D statistic = 0.446, $p < 0.001$, n = 211 presmolts and 611 smolts) and maximum difference in emigration occurred on April 19, 2017 (Figure 12). When collections for smolt transportation began on May 1, 2017, 99.5% of presmolts had passed LGR, compared to 82.5% of smolts. Collection efficiencies were lower in 2017 than in 2016 at the LGR collection facility and was estimated at 32% for natural Chinook Salmon; resulting in and estimated 0.2% of presmolts and 5.6% of smolts emigrating from the Imnaha River being transported at LGR (Table 5).

Table 4. First arrival, 10th percentile, median, 90th percentile, and last arrival interrogation dates of emigrant groups at Lower Granite Dam.

Emigrant group	First arrival	10th percentile	Median	90th percentile	Last arrival
Natural Chinook presmolts	03/24/17	04/04/17	04/15/17	04/19/17	05/01/17
Natural Chinook smolts	03/23/17	04/09/17	04/21/17	05/06/17	07/06/17
Hatchery Chinook smolts	04/09/17	04/26/17	05/05/17	05/10/17	05/28/17
Natural Steelhead smolts	04/01/17	04/22/17	05/06/17	05/24/17	06/21/17
Hatchery Steelhead smolts	04/04/17	04/15/17	05/09/17	06/04/17	07/18/17

Table 5. Cumulative proportion of Imnaha River emigrants that had passed Lower Granite Dam before May 1, 2017 when collections for transportation began, the collection efficiency, and the proportion likely transported at Lower Granite Dam.

Emigrant group	Passed before transportation (%)	Collection efficiency (%)	Likely transported (%)
Natural Chinook presmolts	99.5	32	0.2
Natural Chinook smolts	82.5	32	5.6
Hatchery Chinook smolts	28.5	21	15.0
Natural Steelhead smolts	30.7	31	21.5
Hatchery Steelhead smolts	26.6	24	17.6

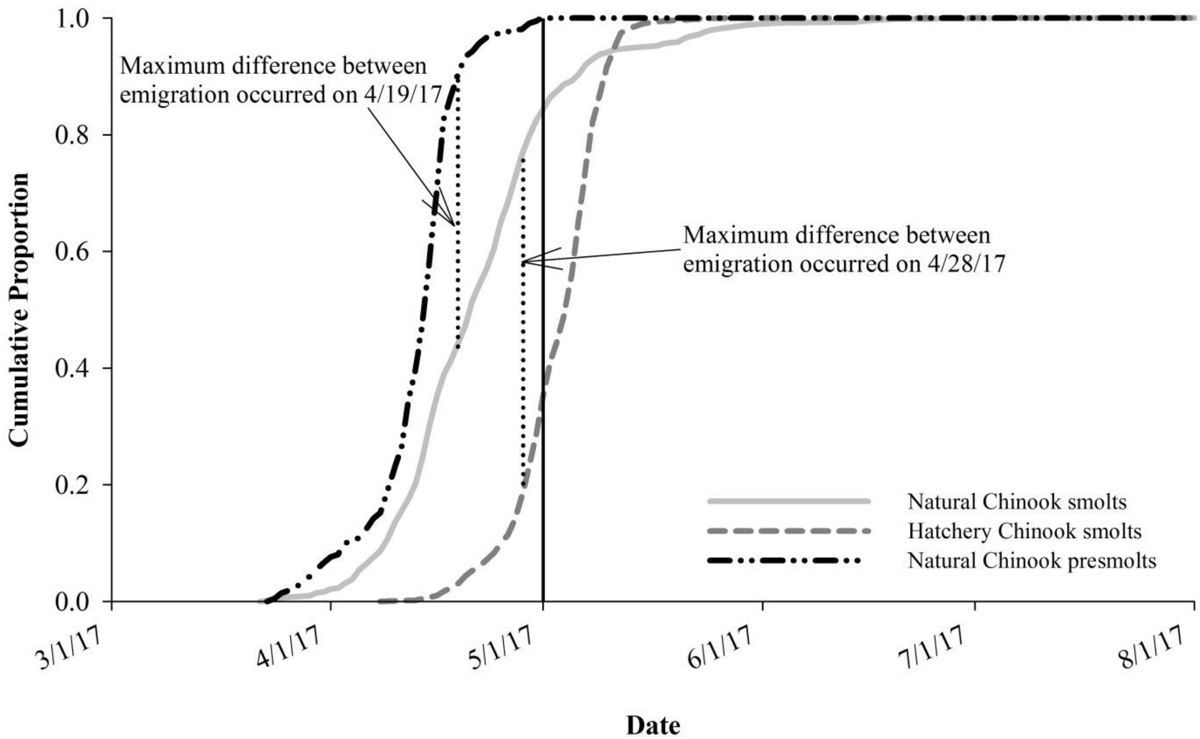

Figure 12. Cumulative proportion and date of natural Chinook Salmon presmolts and smolts and hatchery Chinook Salmon smolts at Lower Granite Dam. The solid vertical line represents the start of transportation collections at Lower Granite Dam.

Hatchery Chinook Salmon smolt cumulative emigration quickly surpassed natural Chinook Salmon smolt emigration at the Imnaha River trap (Figure 7), but hatchery smolt emigration was delayed upon entering the Snake River and natural smolts arrived at LGR earlier than hatchery smolts for about 95% of the cohort (Figure 12). Cumulative hatchery smolt emigration timing surpassed natural smolt emigration timing on May 11, 2017 when 94.5% of natural smolts and 94.7% of hatchery smolts had passed LGR (Figure 12). The right tail of the natural smolt emigration lagged slightly behind the last hatchery individuals. Ninety percent of natural smolts had arrived just four days before 90% of hatchery smolts arrived at LGR, but the last natural smolt arrived 39 days after the last hatchery smolt (Table 4). Results of the two-sample K-S test suggests that emigration between natural and hatchery Chinook Salmon smolts was significantly different at LGR (D statistic = 0.284, $p = 0.003$, $n = 611$ natural smolts and 3130 hatchery smolts) and maximum difference between the two groups occurred on April 28, 2017 (Figure 12). During May, June, and July about 32% of the natural Chinook Salmon smolt catch ($n = 75$) at the Imnaha River trap, excluding recaptures, consisted of smolts < 90 mm. Given the smaller size of these emigrants, it is possible that these were fall Chinook Salmon, which have been observed spawning above the trap in recent years (Adult Technical Team 2010).

A greater proportion of natural smolts (82.5%) than hatchery smolts (28.5%) had passed LGR prior to the start of collection for transportation; however, transport collection efficiencies were higher for natural smolts (32%) than hatchery smolts (21%; Table 5). This resulted in an estimated 5.6% of natural and 15.0% of hatchery Chinook Salmon smolts that were likely transported during the spring 2017.

Steelhead arrival timing at LGR

Hatchery steelhead smolt arrival timing at LGR was earlier overall but similar in pattern to that of natural steelhead smolt arrival timing (Figure 13). The first natural and hatchery steelhead smolts were observed at LGR April 1, 2017 and April 4, 2017, respectively. Ten percent of natural steelhead smolts passed LGR by April 22, 2017, 50% by May 6, 2017, and 90% by May 24, 2017. The last natural smolt was observed at LGR June 21, 2017 (Table 4). Ten percent of hatchery smolts passed LGR by April 15, 2017, 50% by May 9, 2017, 90% by June 4, 2017, and the last emigrating hatchery smolt was observed on July 18, 2017 (Table 4). Though their cumulative distributions appeared similar in pattern, a two-sample K-S test revealed a significant difference in arrival of hatchery and natural steelhead smolts at LGR (D statistic = 0.535, $p < 0.001$, $n = 694$ natural and 3265 hatchery), and maximum difference in arrival occurred on May 7, 2017 (Figure 13). Though the difference between arrival distributions of hatchery and natural steelhead smolts was significant, they were similar enough that it is likely the two groups experienced similar environmental conditions as emigrated from the Imnaha River trap to LGR in MY2017.

More steelhead than Chinook Salmon smolts were likely transported during MY2017. By the start of transportation collection efforts on May 1, 2017, 30.7% of natural steelhead smolts and 26.6% of hatchery steelhead smolts had passed LGR. Collection efficiencies were 24% for hatchery steelhead and 31% for natural steelhead in 2017. Given the collection efficiencies and the proportion of each origin emigrating during transportation operations, an estimated 21.5% of natural and 17.6% of hatchery steelhead smolts were likely transported at LGR during MY2017 (Table 5).

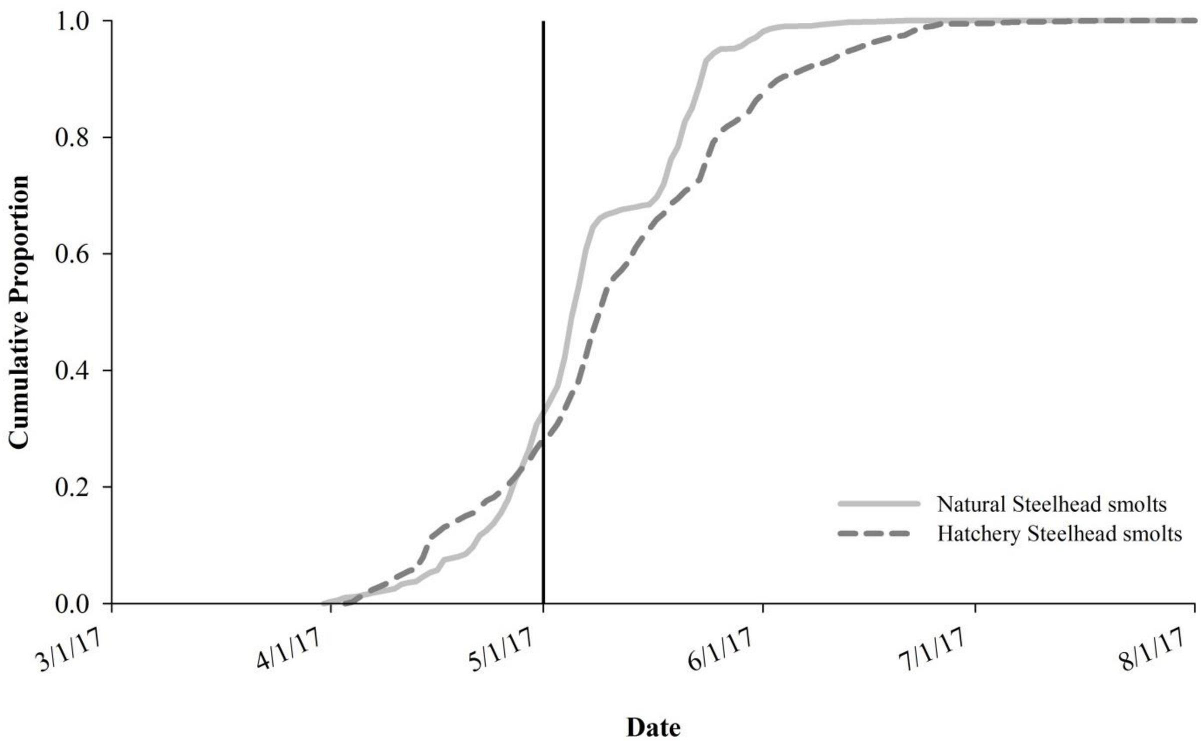

Figure 13. Cumulative proportion of natural and hatchery steelhead smolts at Lower Granite Dam. The solid vertical line represents the start of transportation collections at Lower Granite Dam.

Travel Time from Imnaha River Trap to Lower Granite Dam in Relation to Snake River Flow

Juvenile Chinook Salmon emigrant travel time

Juvenile Chinook Salmon travel times from the Imnaha River trap to LGR were calculated in 2017. Individual travel times varied from 3 – 38 days for hatchery smolts and 3 – 85 days for natural smolts (Table 6). During the limited six week period when hatchery smolts were observed at LGR, their mean weekly travel times were shorter than natural smolts during the first two weeks and longer in the last four weeks when the majority of the hatchery Chinook Salmon smolts were observed (116 out of 123 total observations; Figure 14). Mean weekly travel times for hatchery and natural smolts ranged from four to 36 days and four to 53 days, respectively (Table 6; Figure 14). There was no relationship for natural smolts between mean weekly travel time and Snake River mean weekly discharge ($p = 0.457$; $R^2 = 0.043$). No hatchery Chinook Salmon were detected at LGR past the second week of May (Figure 15), which resulted in limited range of dates to evaluate the relationship between Snake River discharge and mean weekly travel time. Given this caveat, there was a positive non-significant relationship between hatchery smolt mean weekly travel time and Snake River mean weekly discharge ($p = 0.296$; $R^2 = 0.265$). As in past years, hatchery smolt travel time appeared to be more influenced by release date than environmental cues because travel time increased steadily throughout most of the short period they were detected at LGR (Figure 14). Given the rapid emigration from the acclimation facility to the trap, it appears a majority of the hatchery smolt cohort delay entering the Snake River, which is likely the main driver of longer travel times for hatchery Chinook Salmon smolts in the latter half of their cumulative arrival at LGR.

Table 6. Week of detection at Lower Granite Dam (LGR), count of fish, mean travel time (days), and travel time range (days) from the Imnaha River trap to Lower Granite Dam for natural Chinook Salmon presmolts and smolts and hatchery Chinook Salmon smolts. Weekly mean Snake River discharge (ft^3/sec) at Anatone, Washington.

	Natural Chinook presmolts			Natural Chinook smolts			Hatchery Chinook smolts			
Week of LGR Detection	Count	Mean travel time	Travel time range	Count	Mean travel time	Travel time range	Count	Mean travel time	Travel time range	Snake River discharge (ft^3/sec)
03/19/2017	3	136	125 - 147	4	19	8 - 34	-	-	-	126,414
03/26/2017	13	133	108 - 156	9	33	3 - 58	-	-	-	110,363
04/02/2017	16	143	112 - 163	40	24	4 - 67	-	-	-	101,398
04/09/2017	93	152	114 - 179	133	23	5 - 76	1	4	4 - 4	94,841
04/16/2017	77	155	121 - 183	147	23	3 - 81	6	12	4 - 16	99,330
04/23/2017	7	173	137 - 192	155	17	3 - 85	32	21	11 - 25	97,536
04/30/2017	2	176	162 - 190	65	11	3 - 36	51	26	3 - 32	93,212
05/07/2017	-	-	-	27	15	3 - 39	32	30	18 - 38	133,010
05/14/2017	-	-	-	8	24	4 - 46	1	36	36 - 36	107,378
05/21/2017	-	-	-	15	12	3 - 57	-	-	-	98,044
05/28/2017	-	-	-	4	7	3 - 11	-	-	-	118,165
06/04/2017	-	-	-	1	53	53 - 53	-	-	-	124,112
06/11/2017	-	-	-	3	4	3 - 4	-	-	-	99,323
06/18/2017	-	-	-	1	4	4 - 4	-	-	-	92,777
06/25/2017	-	-	-	-	-	-	-	-	-	67,371
07/02/2017	-	-	-	1	21	21 - 21	-	-	-	49,525

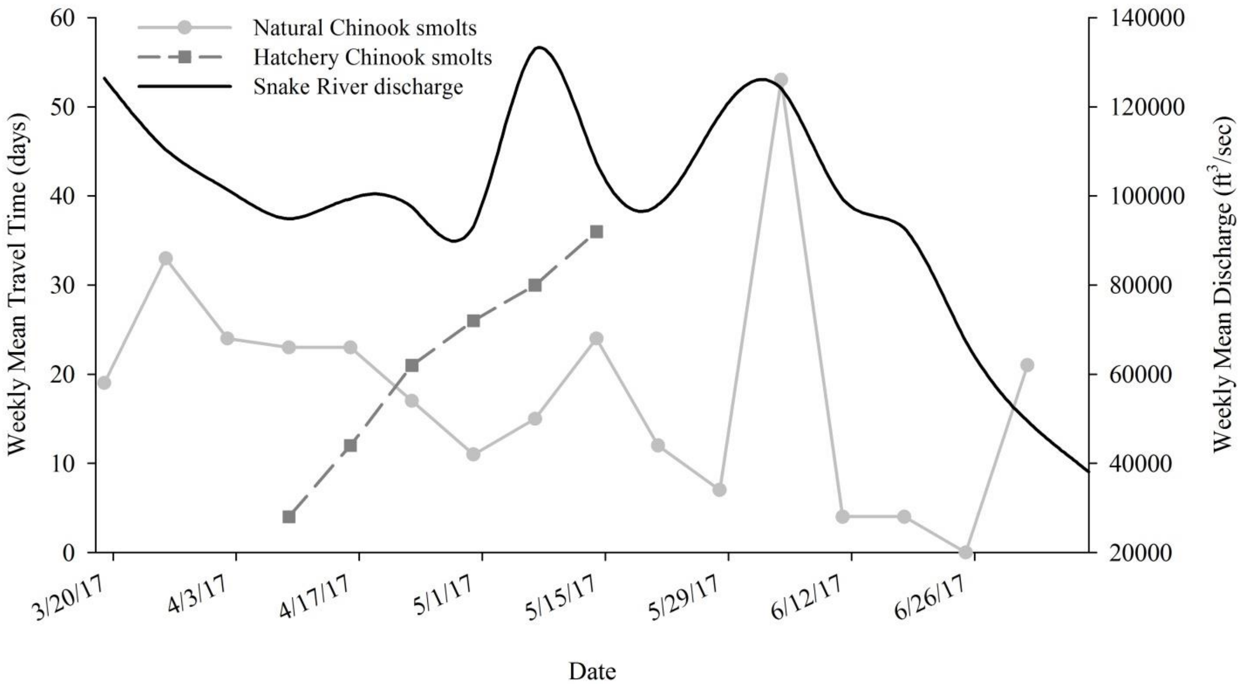

Figure 14. Weekly mean travel time for PIT-tagged natural and hatchery Chinook Salmon smolts from the Imnaha River trap to Lower Granite Dam and weekly mean discharge (ft^3/sec) of the Snake River at Anatone, Washington.

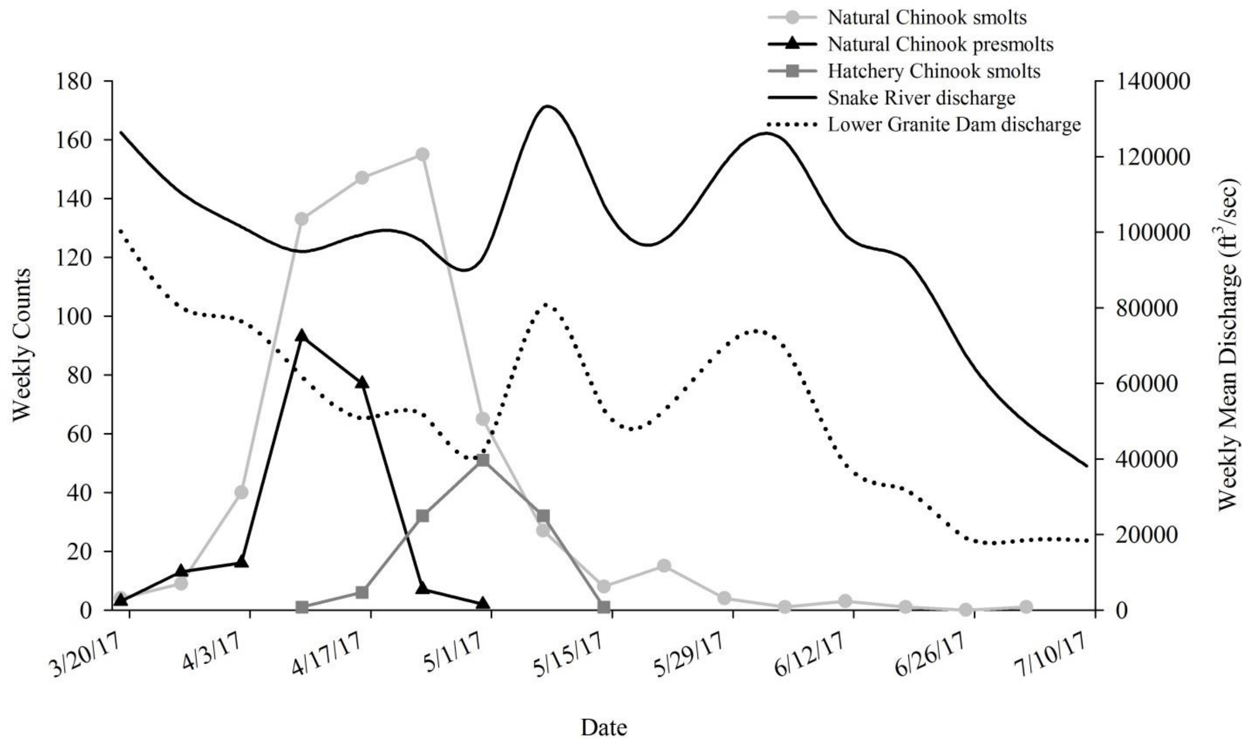

Figure 15. Weekly counts of PIT-tagged natural and hatchery Chinook Salmon emigrants interrogated at Lower Granite Dam, weekly mean discharge (ft^3/sec) of the Snake River at Anatone, Washington, and weekly mean discharge at Lower Granite dam.

Steelhead juvenile emigrant travel time

Steelhead smolt travel times from the Imnaha River trap to LGR were generally shorter in duration than for travel time for Chinook Salmon smolts (Tables 6 and 7). Natural steelhead smolts traveled the 143 km from the Imnaha River trap to LGR in as little as two days. Travel times for hatchery steelhead smolts ranged from one to 96 days and two to 85 days for natural steelhead smolts (Table 7). Travel times were generally shorter for natural steelhead smolts than hatchery steelhead smolts through much of the emigration period. Mean weekly travel times ranged from three to 96 days for hatchery steelhead smolts and four to 85 days for natural steelhead smolts (Table 7). Mean weekly travel times were four to 10 days in March and April when the majority of natural steelhead smolts were detected, then increased slightly to four to 11 days in May (Table 7). In June, a single natural steelhead smolt detected at LGR had a travel time of 85 days. Travel times for hatchery steelhead smolts exhibited a similar distribution to natural steelhead smolts (Figure 16). Mean weekly travel times were between three and 20 days in April when the majority of hatchery smolts were detected at LGR. Mean weekly travel times increased in May ranging from 17 to 26 days. Hatchery steelhead smolt travel times in June and July were highly variable ranging from three days in mid-June to 96 days it took a single individual to travel to LGR in July. The relationship between mean weekly travel time and Snake River mean weekly discharge was not significant for natural (p value = 0.474, R^2 = 0.047) or hatchery steelhead smolts (p value = 0.259, R^2 = 0.105).

Table 7. Week of detection at Lower Granite Dam (LGR), count of fish, mean travel time (days), and travel time range (days) from the Imnaha River trap to Lower Granite Dam for natural steelhead smolts and hatchery steelhead smolts. Weekly mean Snake River discharge at Anatone, Washington.

	Natural Steelhead smolts			Hatchery Steelhead smolts			
Week of LGR Detection	Count	Mean travel time	Travel time range	Count	Mean travel time	Travel time range	Snake River discharge (ft^3/sec)
03/26/2017	2	5	4 - 5	-	-	-	110,363
04/02/2017	11	4	2 - 8	16	3	1 - 6	101,398
04/09/2017	24	10	3 - 24	17	8	3 - 12	94,841
04/16/2017	44	8	2 - 67	11	14	5 - 18	99,330
04/23/2017	105	6	2 - 33	34	20	2 - 26	97,536
04/30/2017	192	6	2 - 36	34	20	2 - 34	93,212
05/07/2017	91	7	2 - 44	36	26	3 - 38	133,010
05/14/2017	75	4	2 - 38	14	17	2 - 44	107,378
05/21/2017	116	5	2 - 57	18	18	2 - 51	98,044
05/28/2017	26	11	2 - 77	10	19	2 - 57	118,165
06/04/2017	3	19	16 - 21	4	58	39 - 66	124,112
06/11/2017	4	9	2 - 27	8	3	2 - 4	99,323
06/18/2017	1	85	85 - 85	2	41	3 - 79	92,777
06/25/2017	-	-	-	-	-	-	67,371
07/02/2017	-	-	-	1	5	5 - 5	49,525
07/09/2017	-	-	-	1	96	96 - 96	38,078

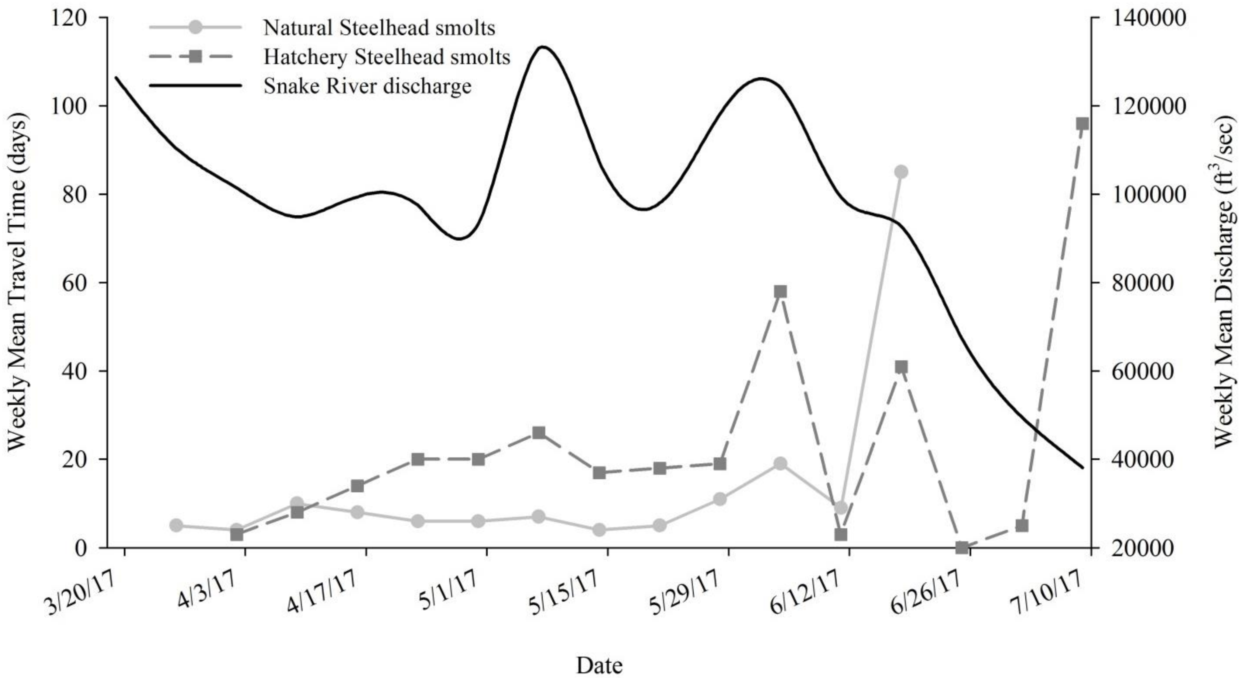

Figure 16. Weekly mean travel time for PIT-tagged natural and hatchery steelhead smolts from the Imnaha River trap to Lower Granite Dam and weekly mean discharge (ft^3/sec) of the Snake River at Anatone, Washington.

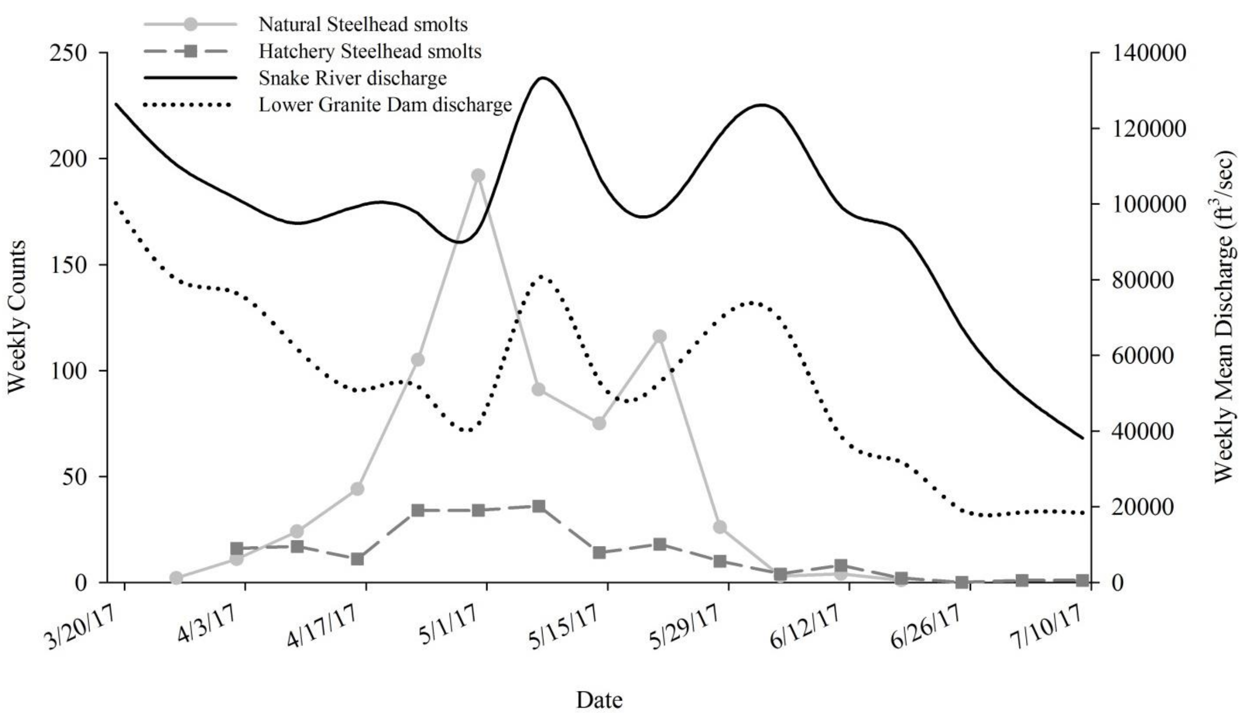

Figure 17. Weekly counts of PIT-tagged natural and hatchery steelhead smolts interrogated at Lower Granite Dam, weekly mean discharge (ft^3/sec) of the Snake River at Anatone, Washington, and weekly mean discharge at Lower Granite Dam.

Life-Stage and Reach Specific Estimates of Juvenile Emigrant Survival

Post-release survival of hatchery smolts

Survival of hatchery Chinook Salmon smolts to the Imnaha River trap was higher than the long term average (0.91) in 2017. Estimated post-release survival of acclimated hatchery Chinook Salmon smolts from the Gumboot acclimation facility to the Imnaha River trap was 0.93 (0.73 – 1.27) [estimate (95% confidence interval)] resulting in an estimated 456,747 (328,720 – 584,774) hatchery Chinook Salmon smolts emigrating past the Imnaha River trap during spring 2017 (Table 8).

Table 8. Hatchery Chinook Salmon and steelhead smolt survival estimates and 95% confidence intervals (95% CI) from release to the Imnaha trap, mean survival from 1994 – 2017 from release to the Imnaha River trap, and estimated number of smolt equivalents and 95% confidence intervals at the Imnaha River trap.

Hatchery group	Survival (95% CI)	Mean survival 1994 - 2017	Smolt equivalents (95% CI)
Chinook Salmon	0.93 (0.73-1.27)	0.91	456,747 (328,720 – 584,774)
Steelhead	0.90 (0.80-1.03)	0.83	195,237 (171,016 – 219,458)

Estimated survival of hatchery steelhead smolts to the Imnaha River trap during MY2017 was 0.07 higher than the long-term mean survival (Table 8). An estimated 195,237 (171,016 – 219,458) hatchery steelhead smolts passed the Imnaha River trap in MY2017 (Table 8).

Survival from Imnaha River trap to Lower Granite Dam

Natural Chinook Salmon survival from the trap to LGR was estimated for presmolts and smolts independently and collectively during MY2017 (BY2015). Estimated survival of presmolts was 0.34 (0.31 – 0.37) compared to 0.76 (0.73 – 0.80) for smolts. A likelihood ratio test was used to test the difference between natural Chinook Salmon presmolt and smolt detection and survival at LGR. Detection probability at LGR was similar (test statistic = 1.201, p-value = 0.272) but survival was significantly different (test statistic = 315.0, p-value < 0.00) between Chinook Salmon presmolts and smolts. The MY2017 natural Chinook Salmon cohort survival estimate from the Imnaha River trap to LGR was 0.57 (0.54 – 0.59). Survival of hatchery Chinook Salmon smolts from the Imnaha River trap to LGR was 13% higher than natural Chinook Salmon smolts (Table 9). A likelihood ratio test was used to test the difference between natural and hatchery Chinook Salmon smolt detection and survival at LGR. Detection probability at LGR was similar (test statistic = 3.736, p-value = 0.053) but survival was significantly different (test statistic = 14.004, p-value < 0.0002) for natural and hatchery Chinook Salmon smolts.

Natural and hatchery steelhead smolt survival from the Imnaha River trap to LGR for MY2017 was estimated at 0.82 (0.77 – 0.87) and 0.90 (0.81 – 1.02), respectively (Table 9). A likelihood ratio test suggests that detection probability at LGR was similar (test statistic = 0.840, p-value =

0.359) and survival from the Imnaha River trap to LGR was similar (test statistic = 2.123, p-value = 0.145) for natural and hatchery steelhead smolts.

Smolt equivalents at Lower Granite Dam

The natural Chinook Salmon presmolt survival estimate of 0.34 converted to an estimated 21,185 ± 11,160 (smolt equivalents ± 95% confidence interval) smolts at LGR. The natural Chinook Salmon smolt survival estimate of 0.76 converted to an estimated 26,527 ± 6,501 smolts at LGR. The natural Chinook Salmon cohort survival estimate of 0.57 converted to an estimated 55,411 ± 17,907 smolts at LGR. The hatchery Chinook Salmon smolt survival estimate of 0.70 converted to an estimated 319,723 ± 115,176 smolts at LGR. The natural steelhead smolt survival estimate of 0.82 converted to an estimated 22,361 ± 4,416 smolts at LGR. The hatchery steelhead smolt survival estimate of 0.90 converted to an estimated 175,713 ± 29,030 smolts at LGR (Table 9).

Survival from Imnaha River to McNary Dam

Our analysis provides estimates of emigrant survival to the Imnaha River trap, LGR, and MCN, but does not provide detailed results of juvenile survival through the entire hydrosystem. A more comprehensive analysis of in-river transportation and migration route effects on emigrant survival, and resulting adult returns, can be found in the 2017 Comparative Survival Study report due to be released in August (CSS 2017).

Overall survival of natural Chinook Salmon emigrants to MCN was low in MY2017. Survival of natural Chinook Salmon presmolts from the Imnaha River trap to MCN was an estimated 0.22 (0.19 – 0.28). Survival of natural Chinook Salmon smolts to MCN was estimated at 0.76 (0.73 – 0.80). The natural Chinook Salmon cohort survival to MCN was estimated to be 0.57 (0.54 – 0.59; Table 9).

Table 9. Estimated survival and 95% confidence intervals (95% CI) of natural and hatchery Chinook Salmon and steelhead emigrants from the Imnaha River trap to Lower Granite Dam (LGR), the Imnaha River trap to McNary Dam (MCN), and the estimated number of smolt equivalents and 95% confidence intervals at LGR.

Emigrant group	Survival to LGR (95% CI)	Survival to MCN (95% CI)	Smolt equivalents at LGR ± 95% CI
Natural Chinook Salmon presmolts	0.34 (0.31-0.37)	0.22 (0.19-0.28)	21,185 ± 11,160
Natural Chinook Salmon smolts	0.76 (0.73-0.80)	0.71 (0.60-0.79)	26,527 ± 6,501
Natural Chinook Salmon cohort	0.57 (0.54-0.59)	0.47 (0.41-0.51)	55,411 ± 17,907
Hatchery Chinook Salmon smolts	0.70 (0.57-0.90)	0.35 (0.24-0.52)	319,723 ± 115,176
Natural Steelhead smolts	0.82 (0.77-0.87)	0.78 (0.57-0.86)	22,361 ± 4,416
Hatchery Steelhead smolts	0.90 (0.81-1.02)	0.67 (0.46-0.80)	175,713 ± 29,030

Size and Condition of Juveniles at Emigration

Mean fork length, weight, and condition varied by species and origin-type. Natural Chinook Salmon presmolts, on average, were smaller and had a lower condition factor than natural and hatchery Chinook Salmon smolts (Table 10). Natural Chinook Salmon smolts had a smaller mean fork length and weight and lower mean condition factor than hatchery Chinook Salmon smolts (Table 10 and Figure 20), which has been the trend over the years (Appendix H). Similarly, natural steelhead smolts consistently had a smaller mean fork length and weight and lower mean condition factor than hatchery steelhead smolts (Table 10, Figure 19, and Appendix I). Hatchery Chinook Salmon smolts had a significantly different mean metrics than natural Chinook Salmon smolts (Welch two sample t-test, all p values < 0.001, n = 2,655 natural smolts and 999 hatchery smolts; Table 10). Hatchery steelhead smolts had significantly different mean metrics than natural steelhead smolts (Welch two sample t-test, all p values < 0.001, n = 2,717 natural steelhead and 1,138 hatchery steelhead).

Table 10. Sample size, mean, minimum, maximum, and standard deviation of fork length, weight, and Fulton condition factor for natural and hatchery Chinook Salmon and steelhead emigrants captured at the Imnaha River trap.

Attribute	Statistic	Natural Chinook presmolts	Natural Chinook smolts	Hatchery Chinook smolts	Natural Steelhead smolts	Hatchery Steelhead smolts
Fork length (mm)	Sample size	2,225	2,655	999	2,717	1,138
	Mean	87	93	115	173	209
	Minimum	55	49	79	71	127
	Maximum	135	131	142	268	283
	Standard deviation	9.1	9.1	7.9	25.1	19.9
Weight (g)	Sample size	2,225	2,655	999	2,717	1,138
	Mean	7.1	9.3	17.8	54.5	96.5
	Minimum	1.3	1.5	4.1	3.4	21.7
	Maximum	26.3	25.3	30.9	182.4	230.8
	Standard deviation	2.4	2.7	3.7	24.2	28.7
Fulton condition factor	Sample size	2,225	2,655	999	2,717	1,138
	Mean	1.06	1.12	1.17	0.99	1.03
	Minimum	0.23	0.54	0.43	0.50	0.61
	Maximum	1.98	2.13	1.95	1.54	1.84
	Standard deviation	0.13	0.14	0.13	0.10	0.09

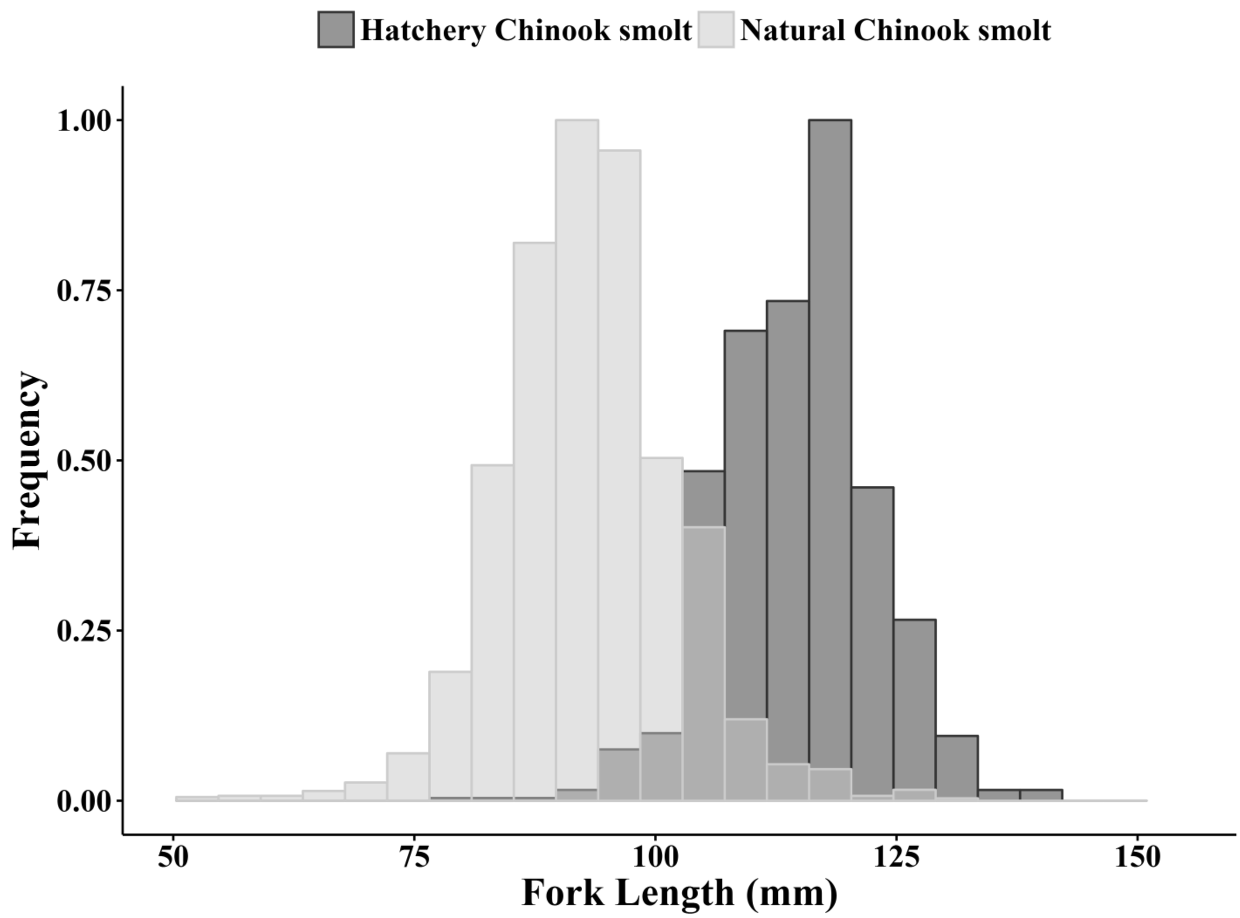

Figure 18. Fork length frequency distributions of natural and hatchery Chinook Salmon smolts captured at the Imnaha River trap during the spring trapping season.

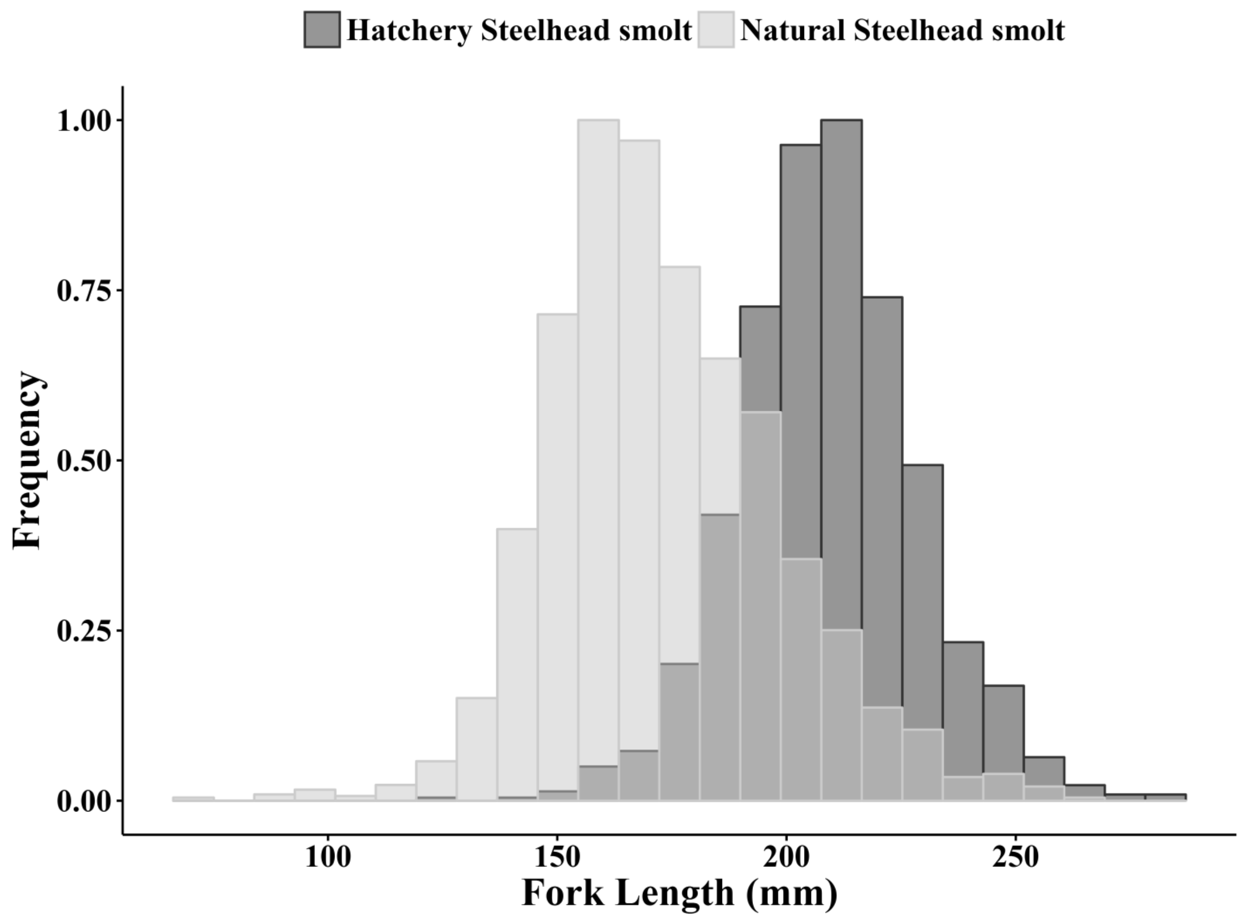

Figure 19. Fork length frequency distributions of natural and hatchery steelhead smolts captured at the Imnaha River trap during the spring trapping season.

Performance Measures Over Multiple Years

Imnaha River Natural Salmon and Steelhead Production Over Time

The Imnaha River trap has been operating since MY1992. However, trap efficiency tests have only been conducted since MY2007. This operational limitation restricted the estimates of Chinook Salmon and steelhead emigrants from the Imnaha River to MY2007 through MY2017.

Natural Chinook Salmon production

The estimated number of natural Chinook Salmon emigrating from the Imnaha River has varied over the last 11 years. Natural Chinook Salmon cohort population estimates have ranged from a low of 73,384 MY2008 to a high of 200,213 in MY2012 (Figure 20; Table 11). The average population estimate of natural Chinook Salmon cohort from 2007 – 2017 was 120,747 individuals with a CV of 31.7%. The production of natural Chinook Salmon in MY2017 was ranked eighth out of the 11 years of population estimates. The proportion of natural Chinook Salmon emigrating from the Imnaha River as presmolts was greater than 50% in eight of the 11 years of population estimates. In MY2017, presmolts consisted of 64% of the combined population estimate (Figure 21). The proportion of Chinook Salmon emigrating as presmolts is moderately correlated (Pearson correlation coefficient = 0.64) with cohort population estimate. Therefore, it is possible the proportion of Chinook Salmon leaving as presmolts is an indication of density dependence within the Imnaha River watershed. With a high density of juveniles, a higher proportion may choose to leave the Imnaha River at earlier ages in search of less crowded rearing habitat. However, a recent study of density dependence in tributaries to the Clearwater and Salmon rivers in Idaho showed no relationship between the number of adult spawners and the proportion of juveniles that emigrate as presmolts versus smolts (Walters et al. 2013). However, the trapping locations in Walters et al. 2013 were largely located within or just below spawning habitat, while the Imnaha River trap is well below spawning and rearing habitat for spring/summer Chinook Salmon in the Imnaha River. It is possible that juveniles studied by Walters et al. 2013 overwintered below the trapping locations but did not migrate to mainstem sites as presmolts. Therefore, it is unknown whether the correlation between cohort population estimates and the proportion of presmolt emigrants in Imnaha River is unique or if other Snake River basin tributaries show similar patterns. While the Snake River may offer productive rearing habitat for presmolts, overwintering survival is thought to be low as suggested by low presmolt survival from the Imnaha River trap to Lower Granite Dam (see previous annual reports).

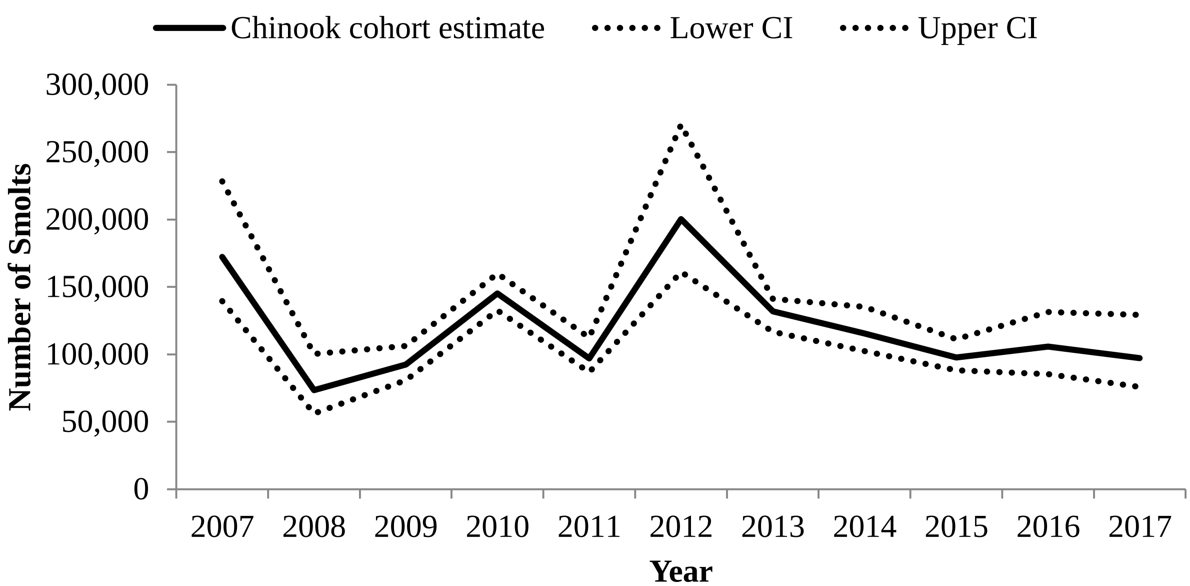

Figure 20. Natural Chinook Salmon cohort population estimates and 95% confidence intervals (CI) for Imnaha River emigrants for migration years 2007-2017.

Table 11. Population estimates and 95% confidence intervals (CI) for natural Chinook Salmon and steelhead emigrating from the Imnaha River for migration years 2007 - 2017.

	Natural Chinook Salmon					Natural Steelhead		
Migration year	Presmolt estimate	Smolt estimate	Cohort estimate	Cohort lower 95% CI	Cohort upper 95% CI	Population estimate	Lower 95% CI	Upper 95% CI
2007	106,305	65,795	172,100	139,357	228,282	59,504	54,695	65,001
2008	34,120	39,264	73,384	56,000	100,325	50,311	39,688	64,576
2009	27,593	64,780	92,373	80,823	106,105	56,298	45,378	71,595
2010	76,292	68,887	145,179	132,673	159,930	57,051	47,627	71,530
2011	64,945	32,047	96,992	86,687	112,464	37,314	29,342	47,728
2012	163,022	37,191	200,213	161,147	270,268	43,881	38,319	50,366
2013	93,469	38,440	131,909	116,728	141,183	54,270	48,674	60,708
2014	58,991	56,472	115,463	103,022	132,236	53,550	48,571	59,748
2015	35,806	56,458	97,677	88,233	111,198	56,581	50,707	63,359
2016	57,350	48,369	105,719	85,179	131,384	42,150	28,488	64,220
2017	62,308	34,904	97,212	75,800	129,311	27,269	22,803	33,111
Mean	70,927	49,328	120,747	102,332	147,517	48,925	41,299	59,267
SD	38,952	13,671	38,244	31,638	53,944	10,089	10,453	11,417
CV	54.9	27.7	31.7	30.9	36.6	20.6	25.3	19.3

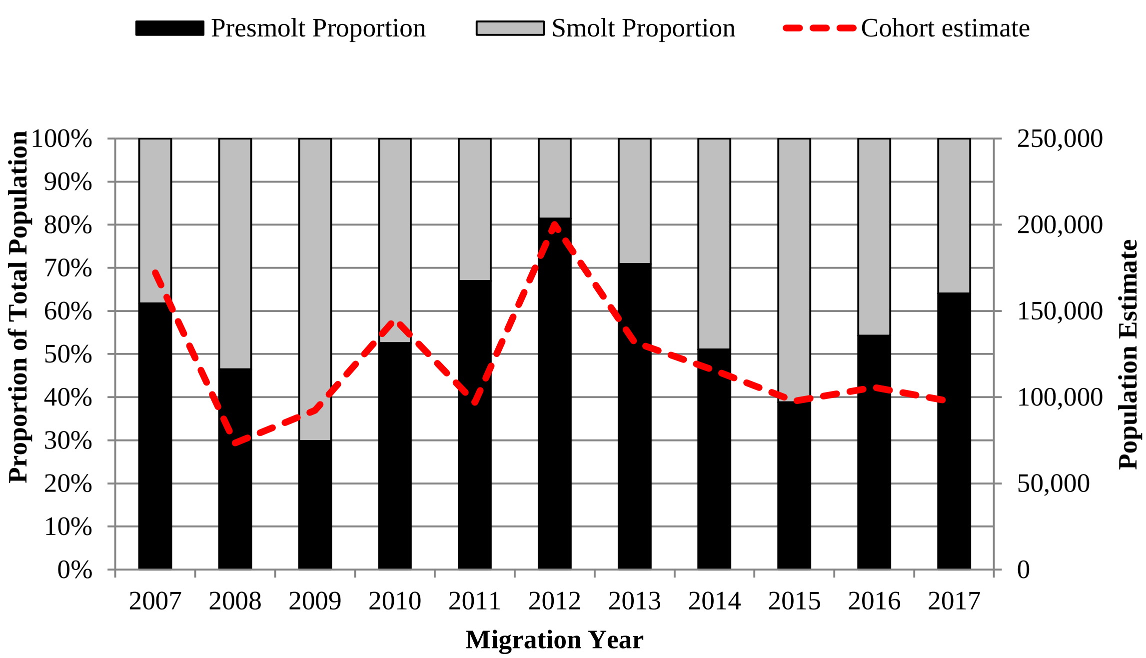

Figure 21. The proportion of natural Chinook Salmon emigrating from the Imnaha River as presmolts and smolts and the cohort population estimate for migration years 2007 through 2017.

Natural Steelhead production

Imnaha River natural steelhead population estimates have been less variable than natural Chinook Salmon emigrant population estimates from MY2007 to MY2017. Population estimates have ranged from a low of 27,269 smolts in MY2017 to a high of 59,504 in MY2007 (Figure 22; Table 11). The mean population estimate of steelhead emigrants was 48,925 with a CV of 20.6%. The steelhead smolt population estimate in MY2017 ranked 11 out of the 11 years of population estimates. As mentioned previously, steelhead population estimates are for spring emigrating smolts only as the catch of fall emigrating *O. mykiss* is too small to generate trap efficiency estimates. Steelhead smolt and Chinook Salmon cohort population estimates appear to be independent with little correlation (Pearson correlation coefficient = 0.21). However, the population estimates of spring emigrating smolts of both species display similar patterns (Figure 23) and are strongly correlated (Pearson correlation coefficient = 0.76). The strong correlation between the spring population estimates could be explained by similar environmental conditions in rearing habitat which can affect the overwinter survival and recruitment of juvenile steelhead and Chinook Salmon. Seasonal trap bias and out of basin factors, such as ocean conditions that impact returning adult abundances, could also be related to yearly abundance estimates of spring smolts.

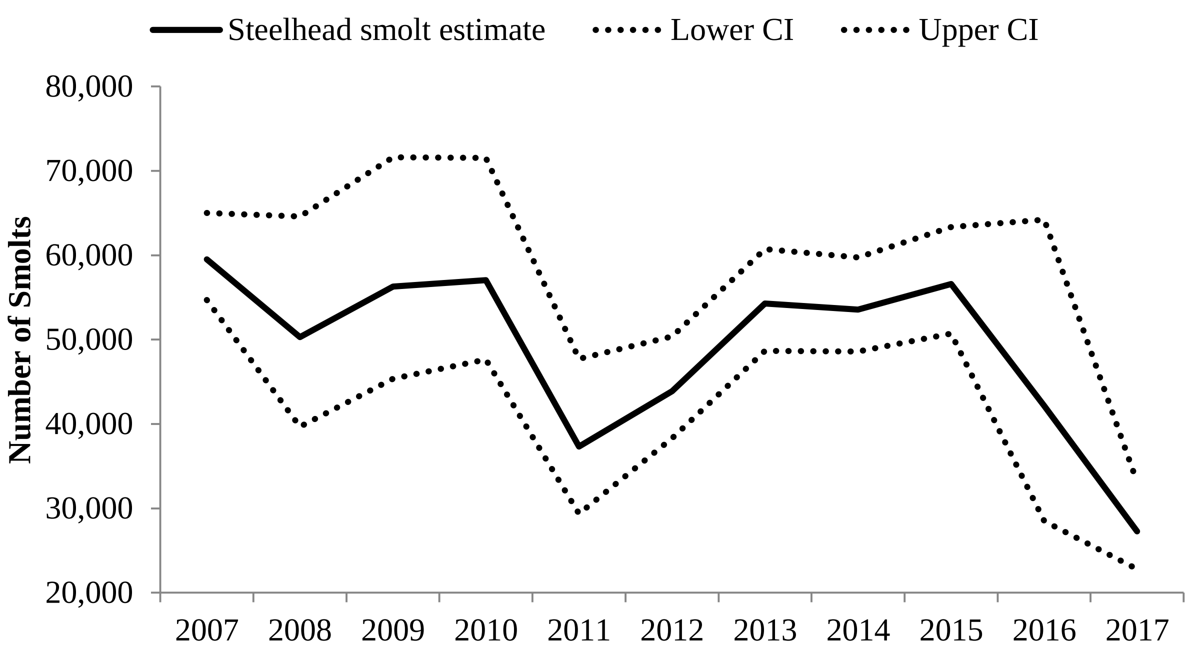

Figure 22. Population estimates and 95% confidence intervals (CI) of natural steelhead emigrating from the Imnaha River for migration years 2007-2017.

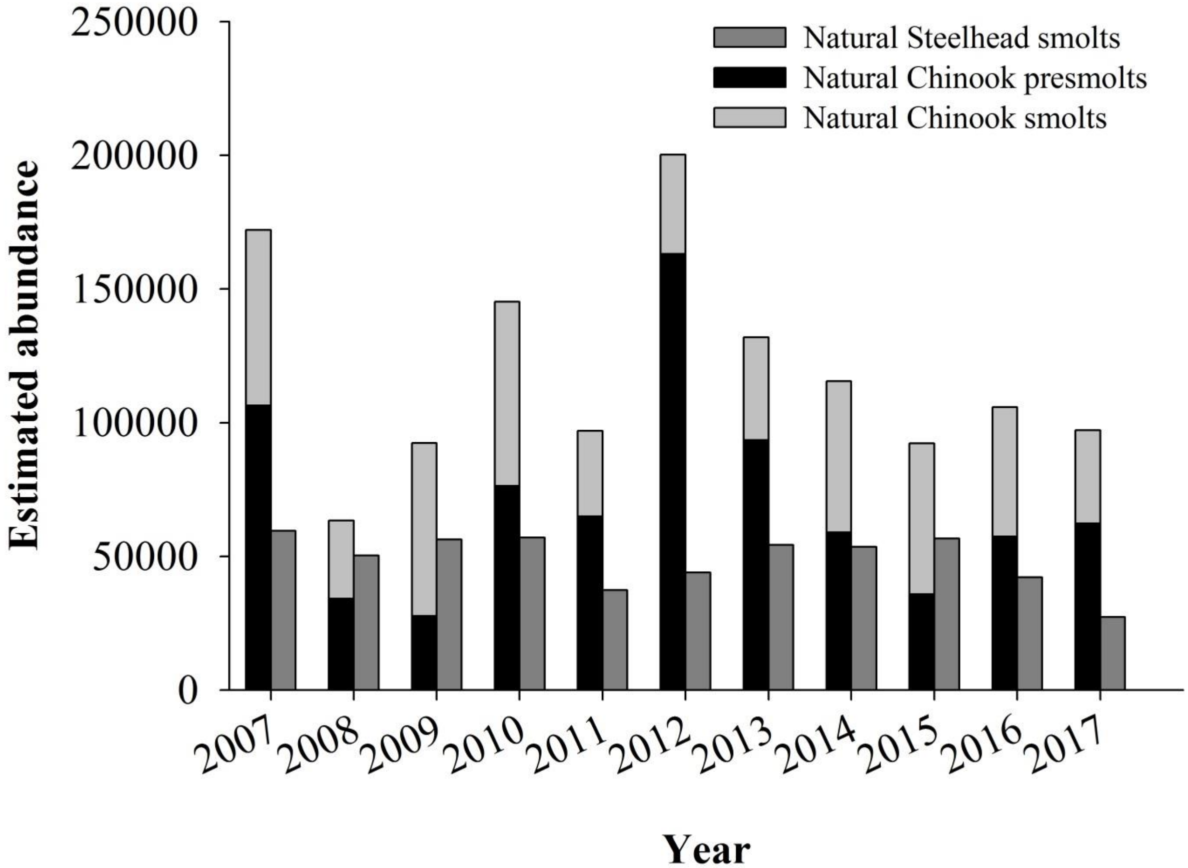

Figure 23. The estimated number of natural Chinook Salmon presmolts and smolts, and natural steelhead smolts emigrating from the Imnaha River during migration years 2007 – 2017.

Trends in Juvenile Survival Migration Years 1993 through 2017

Survival of hatchery smolts was estimated from release to the Imnaha River trap and from the Imnaha River trap to LGR and MCN. Survival for natural smolts was estimated from the Imnaha River trap to LGR and MCN. Some estimates are unavailable during the earliest years of the project.

Post-release survival of hatchery smolts

Hatchery Chinook Salmon smolt survival estimates from release to the Imnaha River trap averaged 0.91 ± 0.11 (mean ± standard deviation) for migration years 1994 – 2017. Hatchery Chinook Salmon smolt post-release survival from ranged from 0.63 (0.61 – 0.65) [estimate (95% confidence interval)] in migration year 2006 to 1.0 (0.86 – 1.14) and 1.0 (0.89 – 1.11) in migration years 1994 and 2012, respectively (Figure 24). Survival was fairly stable over the period evaluated (Figure 24).

Hatchery steelhead smolt survival estimates from release to the Imnaha River trap averaged 0.83 ± 0.08 for migration years 1994 – 2017. Hatchery steelhead smolt post-release survival from ranged from 0.56 (0.48 – 0.64) in migration year 1994 to 1.0 (0.91 – 1.09) in migration year 2003 (Figure 25).

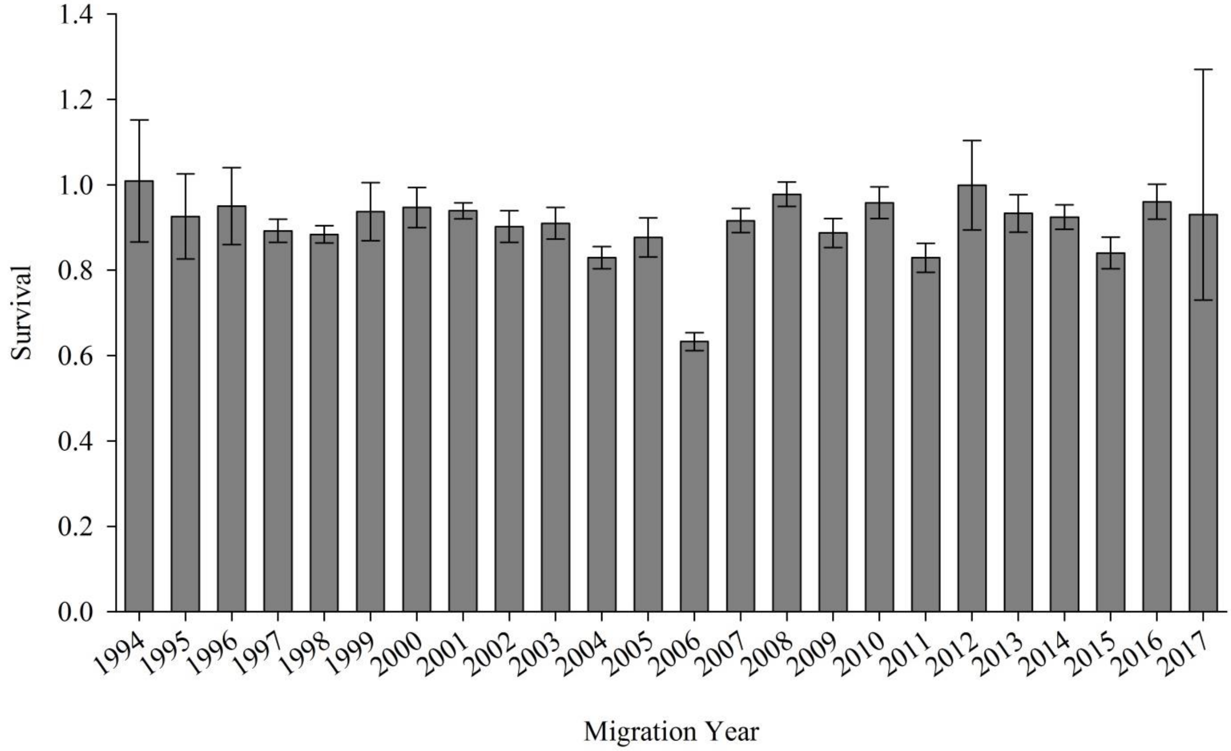

Figure 24. Hatchery Chinook Salmon smolt survival estimates and 95% confidence intervals from release to the Imnaha River trap for migration years 1994 – 2017.

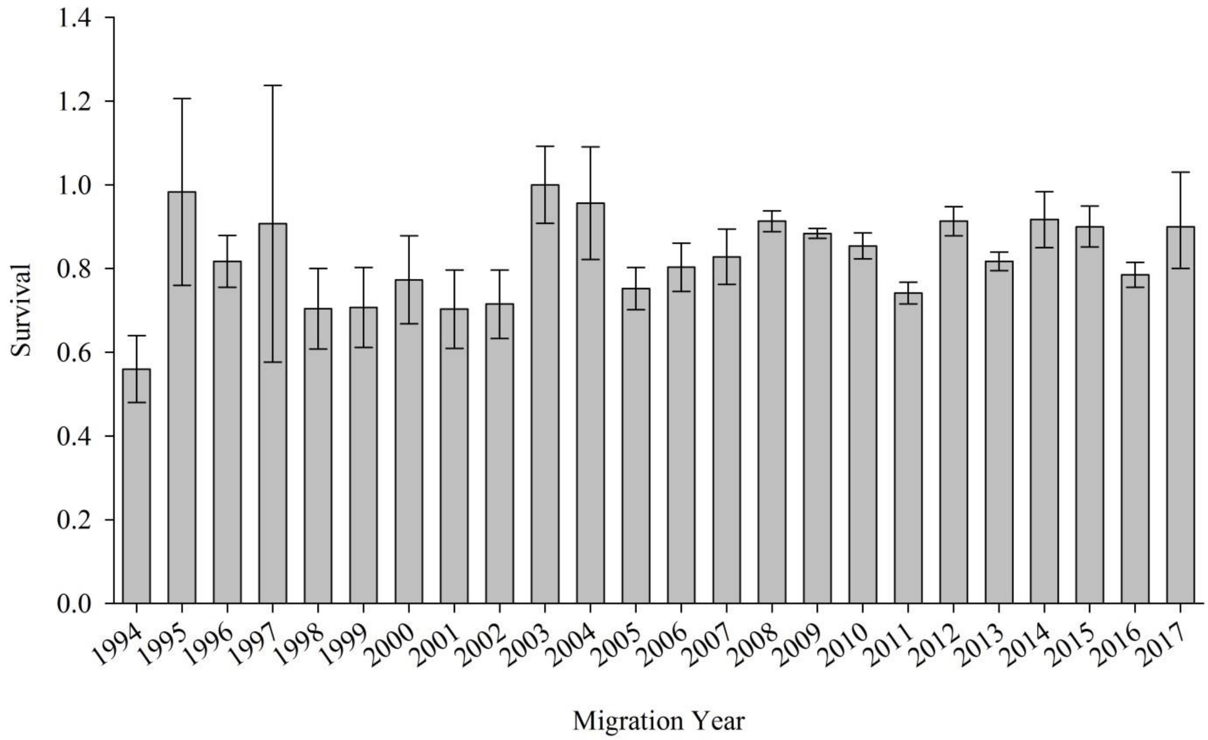

Figure 25. Hatchery steelhead smolt survival estimates and 95% confidence intervals from release to the Imnaha River trap for migration years 1994 – 2017.

Survival from the Imnaha River trap to Lower Granite Dam

Chinook Salmon smolt survival to LGR

Chinook Salmon smolt survival from the Imnaha River trap to LGR was estimated for natural smolts (migration years 1993 – 2017) and hatchery smolts (migration years 1994 – 2017). Natural Chinook smolt survival to LGR averaged 0.80 ± 0.06 for migration years 1993 – 2017 and ranged from 0.67 (0.65 – 0.69) to 0.91 (0.84 – 0.98) in migration years 2016 and 1995, respectively. Generally, survival was above average during the mid to late 1990s and below average from migration years 2003 – 2008. Survival from migration years 2011 – 2013 was below average in all three years but recently migration year 2016 had the lowest estimated survival to LGR on record (Figure 26). Simple linear regression suggested a significant negative trend in survival of natural Chinook Salmon smolts to LGR over time ($p = 0.001$, $R^2 = 0.376$).

Hatchery Chinook Salmon smolt survival to LGR was generally lower than natural Chinook Salmon smolt survival. Hatchery survival from the Imnaha River trap to LGR averaged 0.72 ± 0.05 for migration years 1994 – 2017 and ranged from 0.61 (0.57 – 0.65) to 0.80 (0.72 – 0.88) in migration years 2005 and 1997, respectively (Figure 26). Simple linear regression suggested a weak negative, but non-significant, trend in survival of hatchery Chinook Salmon smolts to LGR over time ($p = 0.405$, $R^2 = 0.032$; Figure 26). Survival estimates for hatchery and natural smolts from the Imnaha River trap to LGR had a moderately strong, positive correlation (Pearson correlation coefficient = 0.64), potentially suggesting that environmental conditions encountered during migration affect the two origin types similarly.

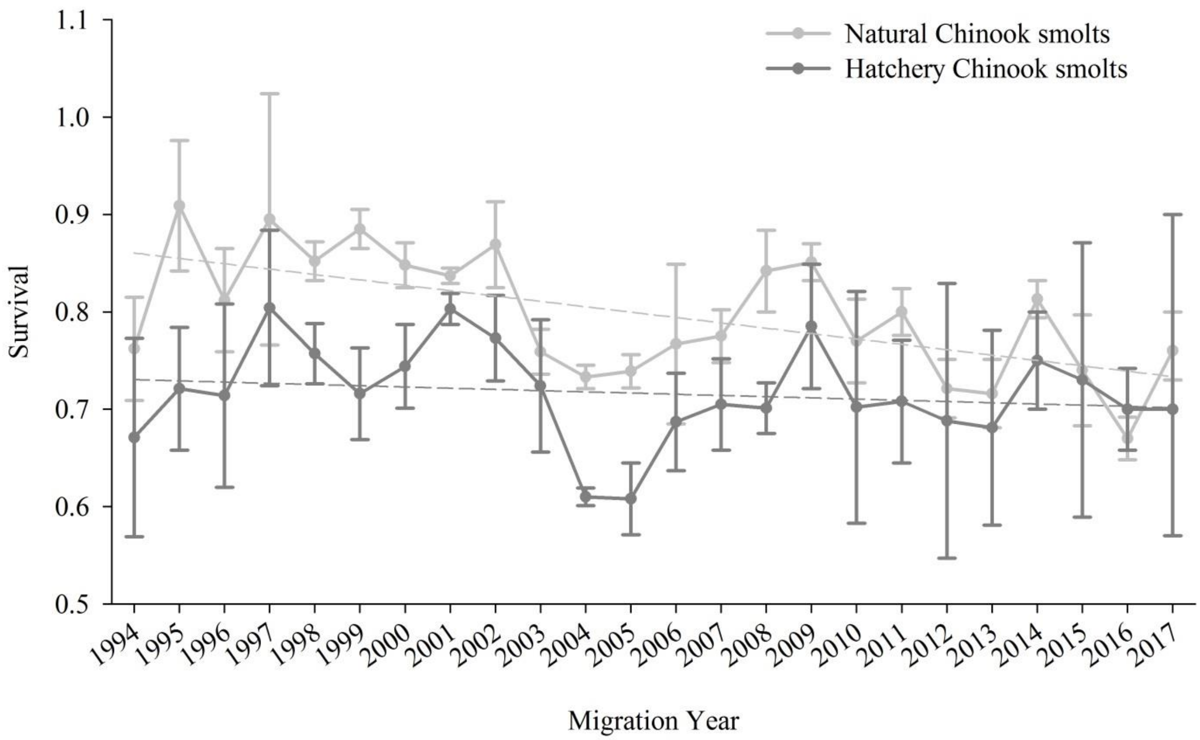

Figure 26. Survival estimates and 95% confidence intervals for natural and hatchery Chinook Salmon smolts from the Imnaha River trap to Lower Granite Dam during migration years 1994 – 2017. The dashed lines represent the line of best fit from a simple linear regression for each emigrant group.

Steelhead smolt survival to LGR

Steelhead smolt survival from the Imnaha River trap to LGR was estimated for natural and hatchery smolts (migration years 1995 – 2017). Natural steelhead smolt survival to LGR averaged 0.86 ± 0.05 for migration years 1995 – 2017 and ranged from 0.79 (0.74 – 0.83) to 1.0 (0.85 – 1.15) in migration years 2007 and 2013, respectively. Simple linear regression suggested a weak positive, but non-significant, trend in survival over time for natural steelhead smolts (p = 0.314, R^2 = 0.048; Figure 27). Survival was slightly higher over the last half of the record but with higher interannual variation than the first half of the record (Figure 27). Survival for migration year 2017 was very similar to the estimated survival for migration year 2016 (Figure 27).

Mean survival from the Imnaha River trap to LGR for migration years 1995 – 2017 was similar for hatchery and natural steelhead smolts but survival varied considerably between the two origin types within years (Figure 27). Hatchery survival to LGR averaged 0.87 ± 0.07 for migration years 1995 – 2017 and ranged from 0.65 (0.60 – 0.69) to 1.0 (0.85 – 1.15) in migration years 1996 and 2010, respectively. Simple linear regression suggested a significant positive trend in survival over time for hatchery steelhead smolts ($p = 0.001$, $R^2 = 0.437$). Survival of hatchery steelhead smolts in migration year 2017 was slightly higher (0.90) than the overall average. Unlike Chinook Salmon smolts, there was no strong relationship between survival of natural and hatchery steelhead smolts (Pearson correlation coefficient = -0.11). Therefore, environmental conditions that lead to increased mortality or residualization of one origin type does not necessarily have the same effects on the other origin type.

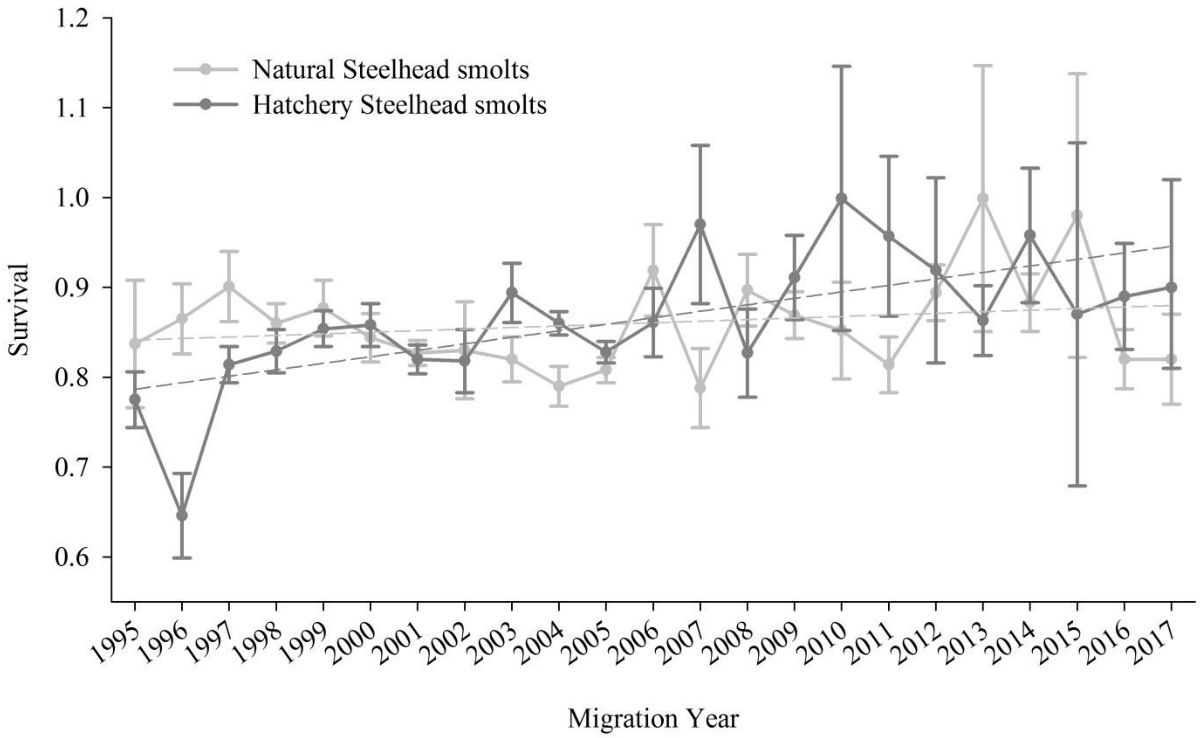

Figure 27. Survival estimates and 95% confidence intervals for natural and hatchery steelhead smolts from the Imnaha River trap to Lower Granite Dam during migration years 1995 – 2017. The dashed lines represent the line of best fit from a simple linear regression for each emigrant group.

Survival from the Imnaha River trap to McNary Dam

Chinook Salmon smolt survival to MCN

Natural Chinook Salmon smolts had the highest average survival from the Imnaha River trap to MCN of all the species origin types. Natural Chinook Salmon smolt survival averaged 0.63 ± 0.09 and ranged from 0.47 (0.46 – 0.49) to 0.79 (0.72 – 0.86) in migration years 2001 and 1998, respectively (Figure 28). Simple linear regression suggested no significant trend in survival over time for natural Chinook Salmon smolts (p = 0.701, R^2 = 0.008). Migration year 2017 was the fourth highest survival estimated for natural Chinook Salmon smolts.

Hatchery Chinook Salmon smolt survival averaged 0.56 ± 0.09 from the Imnaha River trap to MCN and ranged from 0.35 (0.24 – 0.52) to 0.67 (0.53 – 0.81) in 2017 and 2009, respectively. Simple linear regression suggested no significant trend in survival over time for hatchery Chinook Salmon smolts (p = 7117, R^2 = 0.008). Migration year 2017 was the lowest survival for hatchery Chinook salmon smolts of all years estimated. Survival from the Imnaha River trap to MCN for natural and hatchery Chinook Salmon smolts had a moderately strong, negative correlation (Pearson correlation coefficient = -0.40).

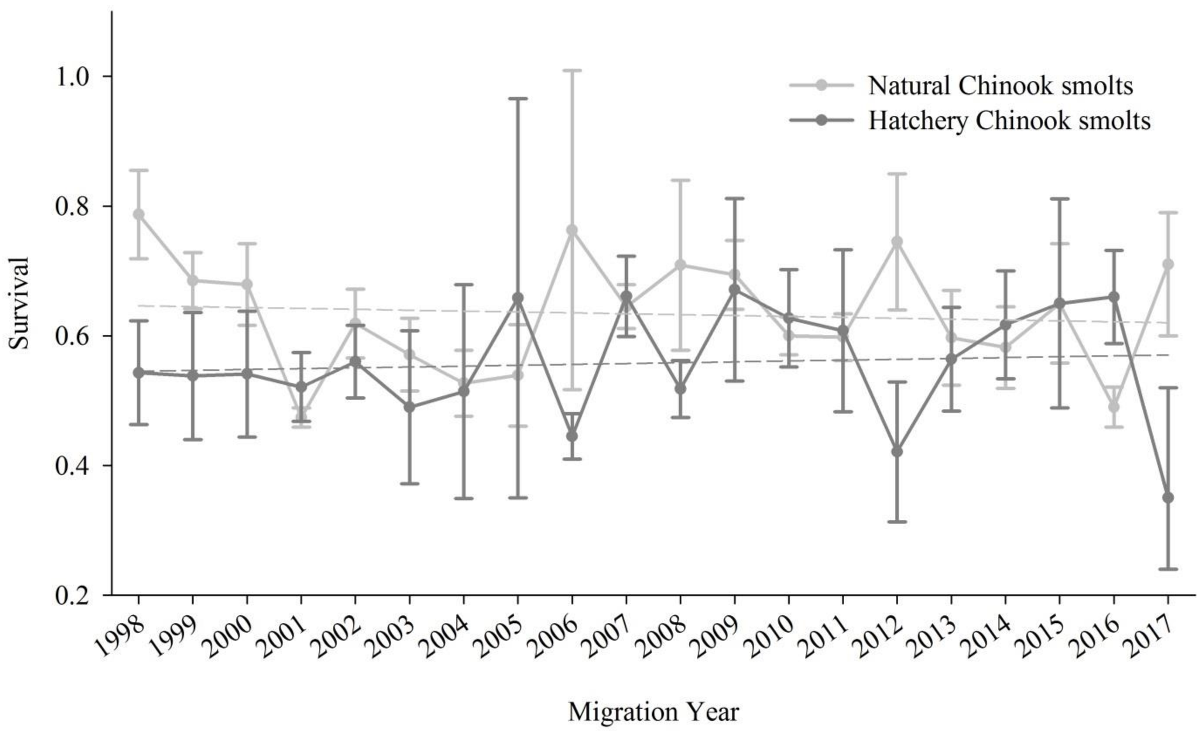

Figure 28. Survival estimates and 95% confidence intervals for natural and hatchery Chinook Salmon smolts from the Imnaha River trap to McNary Dam during migration years 1998 – 2017. The dashed lines represent the line of best fit from a simple linear regression for each emigrant group.

Steelhead smolt survival to MCN

Natural steelhead smolt survival from the Imnaha River trap to MCN averaged 0.56 ± 0.14 and ranged from 0.18 (0.15 – 0.22) to 0.78 (0.57 – 0.86) in 2001 and 2017, respectively. Simple linear regression suggested no significant trend in survival over time for natural steelhead smolts (p = 0.116, R^2 = 0.132). Survival from the Imnaha River trap to MCN was the highest of all years estimated in migration year 2017 (Figure 29).

Hatchery steelhead smolt survival from the Imnaha River trap to MCN averaged 0.62 ± 0.19 and ranged from 0.14 (0.10 – 0.18) to 0.89 (0.66 – 1.12) in 2001 and 2012, respectively (Figure 29). Simple linear regression suggested a significant positive trend in survival over time for hatchery steelhead smolts ($p = 0.004$, $R^2 = 0.385$). Survival from the Imnaha River trap to MCN in migration year 2017 was 0.67 (0.46 – 0.80). Steelhead smolt survival estimates generally have wider confidence limits than Chinook Salmon survival estimates (Figures 29 and 30).

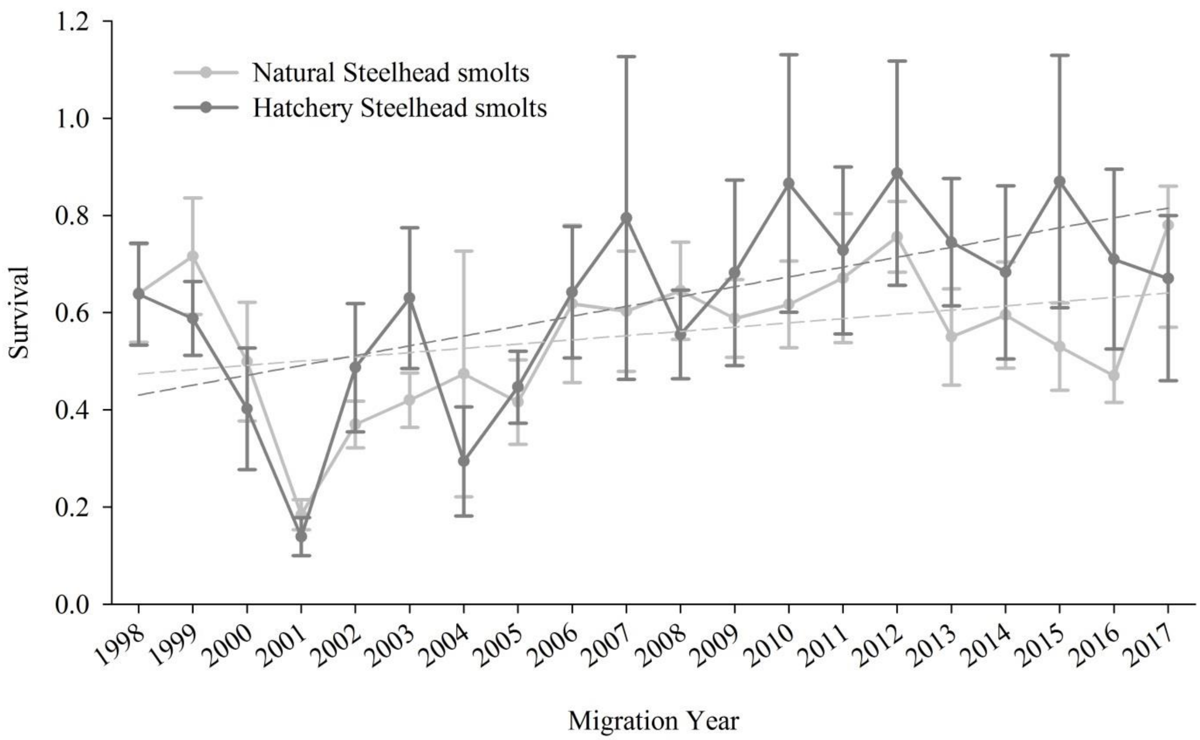

Figure 29. Survival estimates and 95% confidence intervals for natural and hatchery steelhead smolts from the Imnaha River trap to McNary Dam during migration years 1998 – 2017. The dashed lines represent the line of best fit from a simple linear regression for each emigrant group.

Smolt survival to MCN and hydrologic variability

In 2006, management of the hydrosystem changed the proportion and volume of water that is spilled at the four Snake River dams (i.e., Lower Granite, Little Goose, Lower Monumental, and Ice Harbor) when salmon smolts are emigrating. We evaluated the relationship between smolt survival from the Imnaha River trap to MCN and migration year, Snake River discharge (ft^3/sec), spill volume (ft^3/sec), and percent spill to investigate whether survival has changed in response to the altered spill regime. Discharge, spill volume, and percent spill were averaged for each migration year over the mandated spring spill period (April 1 to June 20) across the four Snake River Dams. Survival estimates were available for migration years 1998 – 2017. Data for discharge and spill at each of the dams was obtained from Columbia River DART (http://www.cbr.washington.edu/dart).

Multiple linear regression was used to evaluate the relationship between survival from the Imnaha River trap to MCN and migration year, mean discharge, mean spill volume, and mean percent spill for natural and hatchery smolts. Mean spill volume was removed from all models after variance inflation factors and pairs plots showed strong collinearity with mean discharge and mean percent spill.

Natural Chinook Salmon smolt survival had a significant negative trend over time (p = 0.015). Hatchery Chinook Salmon smolt and natural and hatchery steelhead smolt survival had no significant trend over time (p = 0.941, p = 0.724, and p = 0.103, respectively; Table 12). Natural steelhead smolt survival significantly increased by 0.003 with every 1,000 ft^3/sec increase in in Snake River discharge (p = 0.005). Hatchery Chinook Salmon smolt survival significantly decreased by 0.002 with each 1,000 ft^3/sec increase in Snake River discharge (p-value = 0.016; Table 12). Natural Chinook Salmon and hatchery steelhead did not have a significant response in survival associated with changes in Snake River discharge. Survival increased with increases in percent spill for all emigrant groups; however, this relationship was not significant for hatchery Chinook Salmon smolts (p = 0.403). Natural Chinook Salmon smolt and natural and hatchery steelhead smolt survival significantly increased by 0.005, 0.006, and 0.01, respectively, with every 1% increase in percent spill (Table 12). Multiple R^2 values suggest that three of the four models accounted for greater than 60% of the variance in the survival data. The model for hatchery Chinook Salmon smolt survival only accounted for 32% of the variance in the survival data (Table 12).

Table 12. P-values of predictor variables and model multiple R^2 from multiple linear regression evaluating the relationship between natural and hatchery smolt survival from the Imnaha River trap to McNary Dam and migration year, Snake River discharge (ft^3/sec), and percent spill for migration years 1998 – 2017. Statistically significant p-values are italicized and bold ($\alpha = 0.05$).

Emigrant group	Migration year	Discharge (ft^3/sec)	Percent spill	Multiple R^2
Natural Chinook	***0.015***	0.090	***0.002***	0.639
Hatchery Chinook	0.941	***0.016***	0.403	0.322
Natural Steelhead	0.724	***0.005***	***0.004***	0.737
Hatchery Steelhead	0.103	0.601	***0.001***	0.694

Management of water through the hydrosystem changed in 2006 as the result of a court decision that mandated increased spill at the dams from April 1 through June 20 of each year. Mean discharge was 10.8% higher during the spring spill period in the years after the implementation of court ordered spill in 2006 (Table 13; Figure 30). This change in the hydrograph is a combination of natural upriver patterns in precipitation and the management of releases from upstream reservoirs. Mean spill volume across the four Snake River dams for the spring spill period before 2006 was 25,391 ft^3/sec. Mean spill volume increased to 38,304 ft^3/sec from 2006 – 2017; an increase of 50.9% (Table 13; Figure 30). Correspondingly, the mean percent spill increased from 27.4% pre 2006 to 43.1% post 2006; a 15.7% increase. An increase in percent spill has the broadest benefit to the Imnaha River smolt survival (Table 12). The largest sources for the change in spill volume and percent spill can be attributed to increases at Little Goose and Lower Monumental dams, which averaged 18% and 14% spill during the spring spill period before court ordered spill began.

Table 13. Mean discharge, spill volume, and percent spill across the four Snake River dams during the spring spill period (April 1 to June 20) for 1998 – 2017. Values are separated before and after court ordered spill began in 2006.

Time Period	Mean discharge (ft^3/sec)	Mean spill (ft^3/sec)	Mean percent spill
1998 - 2005	83,174	25,391	27.4
2006 - 2016	92,160	38,304	43.1
Difference	8,986	12,913	-
% Change	10.8	50.9	15.7

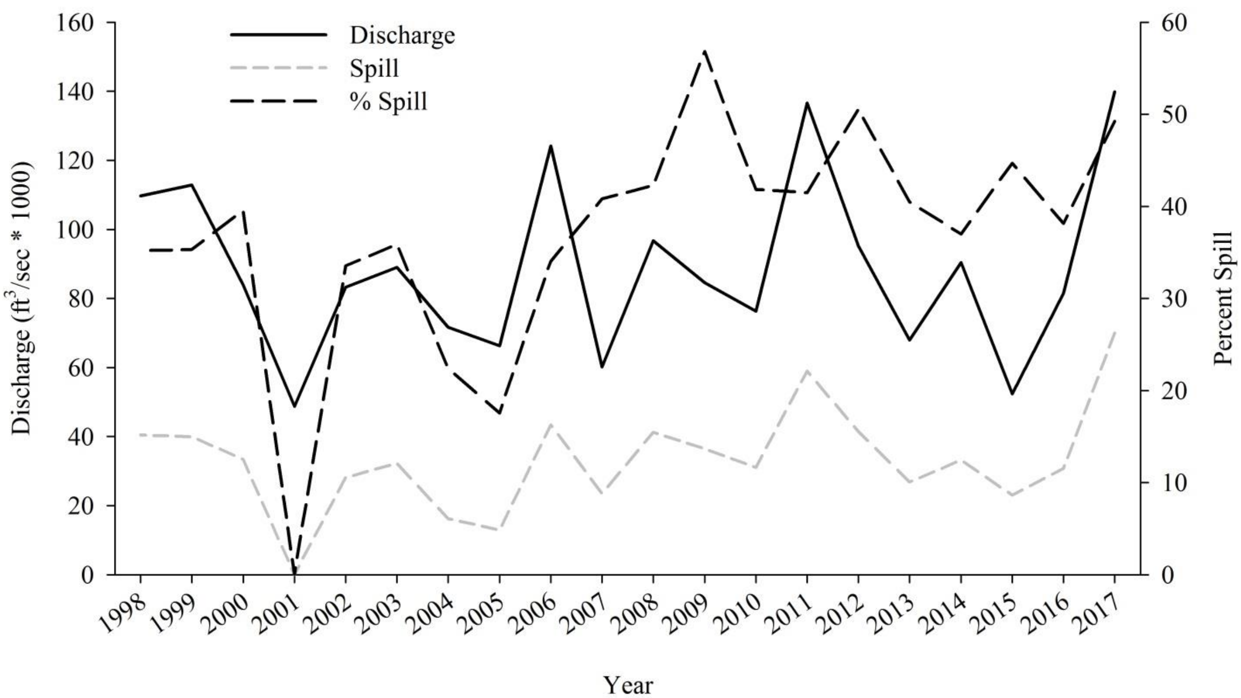

Figure 30. Mean discharge (ft^3/sec), spill volume (ft^3/sec), and percent spill across the four Snake River dams during the spring spill period (April 1 to June 20) for 1998 – 2017. Court ordered spill began in 2006.

Geometric mean survival from the Imnaha River trap to LGR decreased for natural Chinook Salmon smolts (-0.046), was nearly the same for hatchery Chinook Salmon smolts (-0.003) and increased for natural and hatchery steelhead smolts (0.044 and 0.064, respectively) in the years after the court ordered spill. In contrast, survival from the Imnaha River trap to MCN increased for all smolt groups after 2006. Survival increased by 0.041 for natural Chinook Salmon smolts and 0.011 for hatchery Chinook Salmon smolts after 2006. The increases in survival were dramatic for natural and hatchery steelhead smolts, 0.178 and 0.317, respectively (Table 14).

Table 14. Geometric mean survival from the Imnaha River trap to Lower Granite Dam (LGR) and the Imnaha River trap to McNary Dam (MCN) for natural and hatchery Chinook Salmon and steelhead smolts. Values are separated into the period before and after court ordered spring spill began in 2006.

	Time Period	Natural Chinook	Hatchery Chinook	Natural Steelhead	Hatchery Steelhead
Survival to LGR	1998 - 2005	0.813	0.714	0.832	0.845
	2006 - 2017	0.767	0.711	0.876	0.909
	Difference	-0.046	-0.003	0.044	0.064
Survival to MCN	1998 - 2005	0.603	0.544	0.435	0.413
	2006 - 2017	0.644	0.555	0.613	0.730
	Difference	0.041	0.011	0.178	0.317

Our results suggest that survival from the Imnaha River trap to MCN has improved during the years when the court ordered spring spill was in effect (2006 – 2017) compared to the years prior to court ordered spill. However, causality cannot be determined from our results and in a large heteroscedastic system such as the Snake River, a host of confounding natural and anthropogenic factors likely influence survival regardless of spill management. Additionally, many other changes in management above and within the hydrosystem have been aimed at increasing survival of emigrating smolts. However, the change from lower survival for Chinook Salmon smolts from the Imnaha River trap to LGR to a higher survival from the Imnaha River trap to MCN in the post-spill years suggests that alterations in management of the hydrosystem are a source of increased survival. If this were not the case, then increases in survival might be expected for Chinook Salmon smolts to LGR, before entering the hydrosystem, as well as to MCN. Furthermore, the magnitude of the increase in survival after 2006 for natural and hatchery steelhead smolts reinforces the assumption that changes in spill are positively effecting survival. Our results discussed above support the survival findings of the Comparative Survival Study. In the post spill years the Comparative Survival Study has found a dramatic reduction in travel time through the hydrosystem and a concomitant increase in survival.

Smolt to adult return rates

Smolt to adult return rates for Chinook Salmon

Adult returns in 2017 allowed for the estimation of smolt to adult return (SAR) rates for up to BY2012 for Chinook Salmon. Smolt to adult return rates for BY1995 – BY2005 for Chinook Salmon can be found in the Imnaha River Smolt Monitoring Program annual report for MY2010 (Hatch et al. 2014). Reports prior to MY2014 only provide SAR rates for survival mode tags. In this report, SAR rates from LGR to LGR are reported for survival mode and monitor mode SbyC tags.

Adult detections in 2017 completed the estimation of SAR rates for BY2012 Chinook Salmon. Relying on PIT tag interrogations resulted in small sample sizes (i.e., few or no adult PIT tag detections) during some years. Due to low numbers of tags recaptured at Imnaha River trap for hatchery Chinook Salmon smolts and overwinter mortality for natural Chinook Salmon presmolts, the number of survival and monitor mode tags for SAR estimation from LGR to LGR for these two groups was only about one quarter to half the number available for natural smolts (Tables 15). Therefore, confidence in the accuracy of SAR rates for natural Chinook Salmon smolts is higher than for presmolts or hatchery smolts.

Survival mode tagged Chinook Salmon SAR rates were highest for BY2006 natural and hatchery smolts and from BY2008 for natural presmolts. In general, SARs were higher for BY2006 – BY2008 and dropped in later brood years. SAR rates for presmolts were as high as 3.79% for BY2008 and as low as 0.33% for BY2009. Presmolts had a mean SAR from LGR to LGR of 2.02%, which was the highest of the three survival tagged Chinook Salmon groups (Table 15). Hatchery Chinook Salmon smolts had the next highest mean SAR at 1.27%. Hatchery Chinook Salmon SAR rates ranged from a high of 4.64% in BY2006 to a low of 0% in BY2010 and BY2011. However, there were only 50 and 48 juvenile tags available for LGR to LGR SAR estimation in BY2010 and BY2011, respectively (Table 15). Natural Chinook Salmon smolts had the lowest mean SAR of 1.12% and rates ranged from 3.15% in BY2006 to 0.0% in BY2011 (Table 15).

Table 15. Smolt to adult return (SAR) rates from Lower Granite Dam (LGR) to LGR for survival mode tagged natural and hatchery Chinook Salmon for brood years 2006 – 2012.

Brood year	Emigrant detections at Imnaha trap	Smolt detections at LGR	Adult detections at LGR	Age at Return			SAR
Hatchery Chinook smolts				III	IV	V	
2006	911	517	24	14	10	--	4.64%
2007	537	318	5	--	5	--	1.57%
2008	966	379	8	4	3	1	2.11%
2009	523	291	1	1	--	--	0.34%
2010	91	50	--	--	--	--	0.00%
2011	572	48	--	--	--	--	0.00%
2012	906	502	1	1	--	--	0.20%
Mean							1.27%
Natural Chinook presmolts							
2006	1,198	378	10	4	4	2	2.65%
2007	1,336	471	15	2	11	2	3.18%
2008	4,607	554	21	9	11	1	3.79%
2009	1,037	303	1	--	1	--	0.33%
2010	4,582	1195	26	6	20	--	2.18%
2011	925	176	2	--	1	1	1.14%
2012	1,795	574	5	1	3	1	0.87%
Mean							2.02%
Natural Chinook Smolts							
2006	1,642	1,144	36	5	24	7	3.15%
2007	3,076	2288	43	5	30	8	1.88%
2008	3,962	2006	23	5	13	5	1.15%
2009	2,069	1,414	3	--	3	--	0.21%
2010	517	329	3	--	2	1	0.91%
2011	1,462	751	--	--	--	--	0.00%
2012	3,279	2,285	12	--	8	4	0.53%
Mean							1.12%

Monitor mode tagged Chinook Salmon SAR rates were highest for BY2006 for all origins and life history types (Table 16). Smolt to adult return rate patterns were similar to survival mode tagged emigrants with higher rates for BY2006 – BY2008 and lower rates for BY2009 – BY2012. Natural Chinook Salmon presmolts were as high as 5.89% for BY2006 and as low as

0.58% for BY2009. Similar to survival mode tagged Chinook Salmon, presmolts had a mean SAR rate from LGR to LGR of 2.48%, which was the highest of the three monitor tagged Chinook Salmon groups (Table 15). Given that presmolts of both the survival and monitor mode tag groups displayed the highest SARs, the presmolt strategy of overwintering in the Snake River may provide a survival benefit throughout the rest of their life history. Possible mechanisms for this benefit may be larger size or earlier timing during outmigration when environmental conditions are more favorable. Monitor mode tagged hatchery Chinook Salmon smolts had the next highest mean SAR rate at 2.05% followed by natural smolts at 1.29%. Hatchery Chinook Salmon smolt SAR rates ranged from a high of 5.86% for BY2006 to a low of 0.15% for BY2009 (Table 16). Natural Chinook Salmon smolt SAR rates ranged from 2.92% for BY2006 to 0.36% for BY2009 (Table 16). Hatchery Chinook Salmon smolts (survival and monitor tags combined) returned at earlier ages than natural smolts and presmolts (Table 17).

Table 16. Smolt to adult return (SAR) rates from Lower Granite Dam (LGR) to LGR for monitor mode tagged natural and hatchery Chinook Salmon for brood years 2006 – 2012.

Brood year	Emigrant detections at Imnaha trap	Smolt detections at LGR	Adult detections at LGR	Age at Return			SAR
Hatchery Chinook smolts				III	IV	V	
2006	2,326	1349	79	47	30	2	5.86%
2007	1,185	709	20	7	13	--	2.82%
2008	2,306	939	20	13	7	--	2.13%
2009	1,228	671	1	--	1	--	0.15%
2010	257	129	1	1	--	--	0.78%
2011	1,397	578	12	8	2	2	2.08%
2012	1,988	1,103	6	2	4	--	0.54%
Mean							2.05%
Natural Chinook presmolts							
2006	6,027	1,902	112	24	79	9	5.89%
2007	1,337	473	11	--	10	1	2.33%
2008	4,607	490	18	7	10	1	3.67%
2009	3,139	856	5	1	3	1	0.58%
2010	4,230	1,076	12	3	9	--	1.12%
2011	5,339	962	23	5	13	5	2.39%
2012	2,254	707	10	2	7	1	1.41%
Mean							2.48%
Natural Chinook smolts							
2006	1,627	1,132	33	5	21	7	2.92%
2007	3,066	2,269	48	6	28	14	2.12%
2008	3,997	2,010	26	4	19	3	1.29%
2009	2,007	1,380	5	--	5	--	0.36%
2010	2,418	1,475	15	3	12		1.02%
2011	3,171	1,658	15	--	10	5	0.90%
2012	3,401	2,310	9	1	6	2	0.39%
Mean							1.29%

Table 17. The total returns at age (survival and monitor mode tags combined) for natural and hatchery Chinook Salmon from brood years 2006 – 2012.

Emigrant group	Total Returns	Returns at Age III	Returns at Age IV	Returns at Age V	Returned at Age III	Returned at Age IV	Returned at Age V
Hatchery Chinook smolts	178	98	75	5	55.1%	42.1%	2.8%
Natural Chinook presmolts	271	64	182	25	23.6%	67.2%	9.2%
Natural Chinook smolts	271	34	181	56	12.5%	66.8%	20.7%

Smolt to adult return rates for steelhead

Natural steelhead smolts emigrate at variable ages; therefore, it was not possible to analyze their brood year SAR rates. For this analysis we evaluated migration year SAR rates assuming that these largely represented a single cohort as they passed the trap. Analysis for brood year and migration year are presented for hatchery steelhead smolts. As with Chinook Salmon, tagged steelhead were segregated into survival and monitor mode groups for survival analysis through the hydrosystem.

Adult returns in 2017 completed the MY2015 SAR rate analyses for steelhead. Steelhead SAR rates for MY2000 – MY2008 can be found in the Imnaha River Smolt Monitoring Program annual report for MY2010 (Hatch et al. 2014). Like Chinook Salmon, the sample size of hatchery steelhead survival mode tags at LGR was much smaller than natural steelhead tags. Therefore, our confidence in the accuracy of SAR rates is higher for natural steelhead than for hatchery steelhead.

Steelhead SAR rates did not demonstrate successive annual decreases as did Chinook Salmon SAR rates but were variable within respective origin and tag type groups, though there was a decrease for all groups from MY2013 – MY2015 (Table 18). The highest survival mode tagged natural steelhead SAR was 2.37% for MY2010 and the lowest was 0.10% for MY2015. Survival mode tagged natural steelhead had a mean SAR of 1.61% (Table 18). Monitor mode tagged natural steelhead SAR rates ranged from 4.16% for MY2009 to 0.19% for MY2015 and the mean SAR was the highest of the steelhead groups at 2.33% (Table 18). Survival mode tagged hatchery steelhead SAR rates were highest for MY2010 (3.07%) and lowest for MY2015 (0%).

The mean SAR for survival mode tagged hatchery steelhead was similar to survival mode tagged natural steelhead (Table 18). Monitor mode tagged hatchery steelhead SAR rates ranged from 2.24% for MY2009 and MY2010 to 0.57% for MY2015. Monitor mode tagged hatchery steelhead had a mean SAR of 1.74% which was lower than the monitor mode tagged natural steelhead (2.33%; Table 18). Hatchery steelhead tended to return at a younger age than natural steelhead (Table 19).

Table 18. Smolt to adult return (SAR) rates from Lower Granite Dam (LGR) to LGR for survival and monitor mode tagged natural and hatchery steelhead for migration years 2009 – 2015.

Brood year	Migration year	Emigrant detections at Imnaha Trap	Smolt detections at LGR	Adult detections at LGR	Ocean Age at Return			SAR
Survival tagged hatchery steelhead					I	II	III	
2008	2009	607	468	10	9	1	--	2.14%
2009	2010	566	358	11	9	2	--	3.07%
2010	2011	288	211	3	1	2	--	1.42%
2011	2012	511	323	7	2	5	--	2.17%
2012	2013	831	484	8	7	1	--	1.65%
2013	2014	894	549	7	4	3	--	1.28%
2014	2015	709	309	--	--	--	--	0.00%
Mean								1.68%
Monitor tagged hatchery steelhead								
2008	2009	1,179	894	20	11	9	--	2.24%
2009	2010	1,212	713	16	12	4	--	2.24%
2010	2011	712	541	9	5	4	--	1.66%
2011	2012	1,070	651	10	5	5	--	1.54%
2012	2013	1,852	1,060	21	12	9	--	1.98%
2013	2014	1,820	1,133	22	16	6	--	1.94%
2014	2015	798	352	2	--	2	--	0.57%
Mean								1.74%
Survival tagged natural steelhead								
	2009	2,596	1,903	45	25	20	--	2.36%
	2010	3,072	1,645	39	22	16	1	2.37%
	2011	1,260	866	6	5	1	--	0.69%
	2012	2,467	1,604	35	24	11	--	2.18%
	2013	3,479	1,924	48	19	28	1	2.49%
	2014	3,531	2,314	25	17	8	--	1.08%
	2015	3,091	1,050	1	1	--	--	0.10%
Mean								1.61%
Monitor tagged natural steelhead								
	2009	2,569	1,970	82	42	39	1	4.16%
	2010	3,090	1,645	49	25	24	--	2.98%
	2011	1,350	1,185	12	5	7	--	1.01%
	2012	2,997	2,067	63	28	35	--	3.05%
	2013	3,518	1,966	55	24	31	--	2.80%
	2014	3,557	2,341	49	28	21	--	2.09%
	2015	3,093	1,065	2	2	--	--	0.19%
Mean								2.33%

Table 19. The total returns at age of all returning adults (monitor and survival tags combined) for natural and hatchery steelhead for migration years 2009 – 2015.

Emigrant group	Total Returns	Ocean Age I	Ocean Age II	Ocean Age III	Ocean Age I	Ocean Age II	Ocean Age III
Hatchery steelhead	146	93	53	--	63.7%	36.3%	0.00%
Natural steelhead	511	267	241	3	52.3%	47.2%	0.59%

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Appendices

Appendix A. The number of hours sampled and the catch (includes recaptures and subsample estimates) of natural Chinook Salmon (12W), hatchery Chinook Salmon (12H), natural steelhead (32W), and hatchery steelhead (32W) emigrants at the Imnaha River trap from October 6, 2016 to July 10, 2017. N/O indicates the trap was not operated on that date.

Sample End Date	Hours Fished	12H	12W	32H	32W
10/6/2016	15.5	0	0	0	0
10/7/2016	24	0	2	0	0
10/8/2016	24	0	5	0	0
10/9/2016	25	0	4	0	0
10/10/2016	23	0	5	0	0
10/11/2016	24	0	2	0	0
10/12/2016	23.75	0	0	0	0
10/13/2016	25.75	0	1	0	0
10/14/2016	23	0	2	0	9
10/15/2016	24.5	0	2	0	0
10/16/2016	23.5	0	3	0	7
10/17/2016	9	0	0	0	0
10/18/2016	22	0	83	0	2
10/19/2016	23.75	0	63	0	7
10/20/2016	24	0	20	0	0
10/21/2016	24	0	38	0	0
10/22/2016	24	0	77	0	0
10/23/2016	25.5	0	40	0	0
10/24/2016	22.5	0	249	0	0
10/25/2016	24	0	64	0	0
10/26/2016	24	0	150	0	0
10/27/2016	N/0	0	0	0	0
10/28/2016	12.5	0	40	0	1
10/29/2016	24.5	0	40	0	0
10/30/2016	24	0	73	0	1
10/31/2016	24	0	91	0	1
11/1/2016	15	0	92	0	5
11/2/2016	23.75	0	71	0	1
11/3/2016	23.75	0	41	0	0

Sample End Date	Hours Fished	12H	12W	32H	32W
11/4/2016	24	0	28	0	0
11/5/2016	24	0	24	0	0
11/6/2016	24.5	0	32	0	0
11/7/2016	23.5	0	27	0	0
11/8/2016	24.25	0	15	0	0
11/9/2016	24	0	25	0	0
11/10/2016	24.25	0	23	0	0
11/11/2016	23.5	0	22	0	0
11/12/2016	25	0	11	0	0
11/13/2016	24	0	0	0	0
11/14/2016	24.25	0	0	0	0
11/15/2016	23.75	0	4	0	0
11/16/2016	23.25	0	34	0	0
11/17/2016	15.25	0	32	0	0
11/18/2016	24.25	0	77	0	0
11/19/2016	24	0	47	0	0
11/20/2016	24.5	0	71	0	0
11/21/2016	23.75	0	70	0	0
11/22/2016	23.75	0	19	0	0
11/23/2016	24	0	13	0	0
11/24/2016	N/0	0	0	0	0
11/25/2016	N/0	0	0	0	0
11/26/2016	22	0	7	0	0
11/27/2016	19	0	16	0	0
11/28/2016	24	0	17	0	0
11/29/2016	24	0	16	0	0
11/30/2016	24	0	10	0	0
12/1/2016	23.5	0	19	0	0
12/2/2016	24	0	15	0	0
12/3/2016	24	0	18	0	0
12/4/2016	24.5	0	44	0	0
12/5/2016	23.75	0	19	0	0
12/6/2016	24.25	0	22	0	0
12/7/2016	23.5	0	32	0	0
12/8/2016	35	0	0	0	0
12/9/2016	N/0	0	0	0	0
12/10/2016	N/0	0	0	0	0
12/11/2016	N/0	0	0	0	0
12/12/2016	17.75	0	120	0	0

Sample End Date	Hours Fished	12H	12W	32H	32W
12/13/2016	22.5	0	62	0	0
12/14/2016	23.75	0	23	0	0
12/15/2016	24.25	0	27	0	0
12/16/2016	20	0	30	0	0
12/17/2016	N/0	0	0	0	0
12/18/2016	N/0	0	0	0	0
12/19/2016	N/0	0	0	0	0
12/20/2016	N/0	0	0	0	0
12/21/2016	N/0	0	0	0	0
12/22/2016	N/0	0	0	0	0
12/23/2016	N/0	0	0	0	0
12/24/2016	N/0	0	0	0	0
12/25/2016	N/0	0	0	0	0
12/26/2016	N/0	0	0	0	0
12/27/2016	N/0	0	0	0	0
12/28/2016	N/0	0	0	0	0
12/29/2016	N/0	0	0	0	0
12/30/2016	N/0	0	0	0	0
12/31/2016	N/0	0	0	0	0
1/1/2017	N/0	0	0	0	0
1/2/2017	N/0	0	0	0	0
1/3/2017	N/0	0	0	0	0
1/4/2017	N/0	0	0	0	0
1/5/2017	N/0	0	0	0	0
1/6/2017	N/0	0	0	0	0
1/7/2017	N/0	0	0	0	0
1/8/2017	N/0	0	0	0	0
1/9/2017	N/0	0	0	0	0
1/10/2017	N/0	0	0	0	0
1/11/2017	N/0	0	0	0	0
1/12/2017	N/0	0	0	0	0
1/13/2017	N/0	0	0	0	0
1/14/2017	N/0	0	0	0	0
1/15/2017	N/0	0	0	0	0
1/16/2017	N/0	0	0	0	0
1/17/2017	N/0	0	0	0	0
1/18/2017	N/0	0	0	0	0
1/19/2017	N/0	0	0	0	0

Sample End Date	Hours Fished	12H	12W	32H	32W
1/20/2017	N/0	0	0	0	0
1/21/2017	N/0	0	0	0	0
1/22/2017	N/0	0	0	0	0
1/23/2017	N/0	0	0	0	0
1/24/2017	N/0	0	0	0	0
1/25/2017	N/0	0	0	0	0
1/26/2017	N/0	0	0	0	0
1/27/2017	18.5	0	15	0	0
1/28/2017	24.25	0	8	0	0
1/29/2017	24	0	20	0	0
1/30/2017	24	0	39	0	0
1/31/2017	24	0	37	0	0
2/1/2017	22.75	0	9	0	0
2/2/2017	31.33	0	6	0	0
2/3/2017	18.33	0	5	0	0
2/4/2017	23.83	0	9	0	0
2/5/2017	24	0	10	0	1
2/6/2017	24	0	6	0	0
2/7/2017	24.75	0	10	0	1
2/8/2017	23.5	0	1	0	0
2/9/2017	25.75	0	3	0	0
2/10/2017	N/0	0	0	0	0
2/11/2017	N/0	0	0	0	0
2/12/2017	N/0	0	0	0	0
2/13/2017	17.75	0	49	0	0
2/14/2017	24.08	0	35	0	5
2/15/2017	23.17	0	22	0	0
2/16/2017	23.5	0	17	0	0
2/17/2017	24.25	0	16	0	0
2/18/2017	23.75	0	22	0	0
2/19/2017	17.25	0	14	0	0
2/20/2017	14.5	0	11	0	0
2/21/2017	26.25	0	13	0	0
2/22/2017	8.5	0	3	0	0
2/23/2017	N/0	0	0	0	0
2/24/2017	14.75	0	5	0	0
2/25/2017	23.5	0	8	0	0
2/26/2017	24.25	0	7	0	0

Sample End Date	Hours Fished	12H	12W	32H	32W
2/27/2017	25.33	0	12	0	0
2/28/2017	24	0	15	0	1
3/1/2017	24.17	0	2	0	1
3/2/2017	23.25	0	8	0	0
3/3/2017	23.75	0	2	0	0
3/4/2017	24.33	0	1	0	0
3/5/2017	24.58	0	1	0	0
3/6/2017	23.42	0	3	0	0
3/7/2017	N/0	0	0	0	0
3/8/2017	14.5	0	3	0	0
3/9/2017	23	0	1	0	0
3/10/2017	23.25	0	3	0	0
3/11/2017	24	0	21	0	2
3/12/2017	13.75	0	29	0	6
3/13/2017	23.5	0	42	0	1
3/14/2017	23.5	0	33	0	5
3/15/2017	24.5	0	48	0	1
3/16/2017	N/0	0	0	0	0
3/17/2017	N/0	0	0	0	0
3/18/2017	13	0	18	0	5
3/19/2017	N/0	0	0	0	0
3/20/2017	N/0	0	0	0	0
3/21/2017	N/0	0	0	0	0
3/22/2017	N/0	0	0	0	0
3/23/2017	N/0	0	0	0	0
3/24/2017	N/0	0	0	0	0
3/25/2017	N/0	0	0	0	0
3/26/2017	N/0	0	0	0	0
3/27/2017	13.75	0	91	0	29
3/28/2017	24.25	0	137	0	30
3/29/2017	24	0	127	0	42
3/30/2017	13.5	0	118	0	37
3/31/2017	17.25	0	119	0	44
4/1/2017	23.25	0	88	6	22
4/2/2017	25.17	0	75	244	24
4/3/2017	23.33	0	99	2103	23
4/4/2017	25.25	1441	197	2673	42
4/5/2017	22.75	5106	143	1397	25

Sample End Date	Hours Fished	12H	12W	32H	32W
4/6/2017	21.5	1763	60	606	19
4/7/2017	25	5761	92	801	35
4/8/2017	N/0	0	0	0	0
4/9/2017	N/0	0	0	0	0
4/10/2017	N/0	0	0	0	0
4/11/2017	N/0	0	0	0	0
4/12/2017	11	2925	45	157	17
4/13/2017	11.25	896	32	19	13
4/14/2017	22.5	730	45	30	31
4/15/2017	24.75	226	43	89	20
4/16/2017	24.25	83	34	99	14
4/17/2017	24	66	43	75	25
4/18/2017	23.92	33	34	49	36
4/19/2017	24	58	52	110	52
4/20/2017	14.5	35	35	56	43
4/21/2017	24.5	26	39	93	53
4/22/2017	23.75	28	46	67	42
4/23/2017	24.25	31	37	75	59
4/24/2017	24.25	59	49	114	77
4/25/2017	23.75	26	60	135	96
4/26/2017	24.25	18	29	213	93
4/27/2017	24.25	31	30	226	97
4/28/2017	24.25	21	23	187	75
4/29/2017	22.75	10	24	270	82
4/30/2017	14.75	11	13	366	73
5/1/2017	24	9	28	460	115
5/2/2017	24.25	11	18	421	96
5/3/2017	23	6	26	276	129
5/4/2017	24.33	15	35	189	205
5/5/2017	24.67	3	7	385	292
5/6/2017	N/0	0	0	0	0
5/7/2017	N/0	0	0	0	0
5/8/2017	N/0	0	0	0	0
5/9/2017	N/0	0	0	0	0
5/10/2017	N/0	0	0	0	0
5/11/2017	N/0	0	0	0	0
5/12/2017	N/0	0	0	0	0
5/13/2017	N/0	0	0	0	0

Sample End Date	Hours Fished	12H	12W	32H	32W
5/14/2017	N/0	0	0	0	0
5/15/2017	14.5	3	10	101	59
5/16/2017	23.75	3	15	96	92
5/17/2017	23.75	5	16	167	97
5/18/2017	24	3	20	177	82
5/19/2017	24	1	18	141	106
5/20/2017	23.75	2	8	128	108
5/21/2017	23.75	0	1	29	27
5/22/2017	N/0	0	0	0	0
5/23/2017	N/0	0	0	0	0
5/24/2017	N/0	0	0	0	0
5/25/2017	N/0	0	0	0	0
5/26/2017	N/0	0	0	0	0
5/27/2017	10	0	2	49	13
5/28/2017	10	0	1	38	15
5/29/2017	9.5	0	0	71	25
5/30/2017	N/0	0	0	0	0
5/31/2017	N/0	0	0	0	0
6/1/2017	N/0	0	0	0	0
6/2/2017	N/0	0	0	0	0
6/3/2017	N/0	0	0	0	0
6/4/2017	N/0	0	0	0	0
6/5/2017	N/0	0	0	0	0
6/6/2017	N/0	0	0	0	0
6/7/2017	11	0	0	4	0
6/8/2017	24	0	0	3	0
6/9/2017	N/0	0	0	0	0
6/10/2017	10.5	0	1	15	4
6/11/2017	11	0	2	14	1
6/12/2017	23.5	0	10	24	1
6/13/2017	11.5	0	3	20	0
6/14/2017	23	0	5	22	2
6/15/2017	14.5	0	7	14	0
6/16/2017	23.75	0	4	41	3
6/17/2017	N/0	0	0	0	0
6/18/2017	N/0	0	0	0	0
6/19/2017	N/0	0	0	0	0
6/20/2017	N/0	0	0	0	0

Sample End Date	Hours Fished	12H	12W	32H	32W
6/21/2017	N/0	0	0	0	0
6/22/2017	N/0	0	0	0	0
6/23/2017	N/0	0	0	0	0
6/24/2017	N/0	0	0	0	0
6/25/2017	N/0	0	0	0	0
6/26/2017	7.75	0	5	7	0
6/27/2017	26	0	0	11	0
6/28/2017	23.5	0	0	9	0
6/29/2017	24	0	3	8	0
6/30/2017	23	0	3	9	0
7/1/2017	N/0	0	0	0	0
7/2/2017	N/0	0	0	0	0
7/3/2017	N/0	0	0	0	0
7/4/2017	N/0	0	0	0	0
7/5/2017	N/0	0	0	0	0
7/6/2017	8.5	0	2	2	0
7/7/2017	25.25	0	2	1	0
7/8/2017	N/0	0	0	0	0
7/9/2017	N/0	0	0	0	0
7/10/2017	15.75	0	1	0	0
Total	3780	19445	5283	13192	2905

Appendix B. Weekly totals of natural Chinook Salmon and steelhead emigrants receiving a passive integrated transponder (PIT) tag at the Imnaha River trap during migration year 2017.

Start and End Date	Chinook Salmon PIT-tagged	Steelhead PIT-tagged
10/2/2016 - 10/8/2016	7	0
10/9/2016 - 10/15/2016	16	0
10/16/2016 - 10/22/2016	279	0
10/23/2016 - 10/29/2016	579	0
10/30/2016 - 11/5/2016	418	1
11/6/2016 - 11/12/2016	154	0
11/13/2016 - 11/19/2016	194	0
11/20/2016 - 11/26/2016	180	0
11/27/2016 - 12/3/2016	109	0
12/4/2016 - 12/10/2016	115	0
12/11/2016 - 12/17/2016	262	0
12/18/2016 - 12/24/2016	0	0
12/25/2016 - 12/31/2016	0	0
1/1/2017 - 1/7/2017	0	0
1/8/2017 - 1/14/2017	0	0
1/15/2017 - 1/21/2017	0	0
1/22/2017 - 1/28/2017	23	0
1/29/2017 - 2/4/2017	123	0
2/5/2017 - 2/11/2017	30	0
2/12/2017 - 2/18/2017	160	5
2/19/2017 - 2/25/2017	54	0
2/26/2017 - 3/4/2017	47	2
3/5/2017 - 3/11/2017	32	2
3/12/2017 - 3/18/2017	170	18
3/19/2017 - 3/25/2017	0	0
3/26/2017 - 4/1/2017	673	201
4/2/2017 - 4/8/2017	536	147
4/9/2017 - 4/15/2017	161	80
4/16/2017 - 4/22/2017	278	263
4/23/2017 - 4/29/2017	246	577
4/30/2017 - 5/6/2017	118	896
5/7/2017 - 5/13/2017	0	0
5/14/2017 - 5/20/2017	83	540
5/21/2017 - 5/27/2017	3	27
5/28/2017 - 6/3/2017	1	40

Start and End Date	Chinook Salmon PIT-tagged	Steelhead PIT-tagged
6/4/2017 - 6/10/2017	1	4
6/11/2017 - 6/17/2017	23	7
6/18/2017 - 6/24/2017	0	0
6/25/2017 - 7/1/2017	8	0
7/2/2017 - 7/8/2017	4	0
7/9/2017 - 7/15/2017	1	0
Fall Total	2313	1
Spring Total	2775	2809
Total	5088	2810

Appendix C. Juvenile Chinook Salmon tagged by the Oregon Department of Fish and Wildlife, Early Life History Program that were recaptured at the Imnaha River trap during the fall of 2016 and spring 2017. Fork length (nearest mm) and weight (nearest 0.1 g). Fulton condition factor (K) was calculated using the formula: $K = (\text{weight}/\text{length}^3)*100{,}000$.

PIT Tag ID	Date Tagged	Date Recaptured	Travel Time (Days)	Fork Length (mm)	Weight (g)	Condition Factor
3DA.1A19B3CDAD	8/8/2016	10/24/2016	77	104	13.5	1.20
3DA.1A19B3A911	8/9/2016	11/1/2016	84	86	6.3	0.99
3DA.1A19B3A968	8/8/2016	12/4/2016	118	77	4.9	1.07
3DA.1A19B3CD2D	8/3/2016	3/30/2017	239	106	11.6	0.97
3DA.1A19B36BA2	8/8/2016	4/3/2017	238	107	15.2	1.24
3DA.1A19B3B673	8/8/2016	4/4/2017	239	104	13.5	1.20
3DA.1A19B3C2BE	8/8/2016	4/4/2017	239	94	9	1.08
3DA.1A19B3CD05	8/8/2016	4/4/2017	239	98	11	1.17
3DA.1A19B3CBEB	8/8/2016	4/21/2017	256	81	5.8	1.09
3DA.1A19B3BD69	8/8/2016	4/29/2017	264	92	8	1.03

Appendix D. Hatchery Chinook Salmon and steelhead smolt releases into the Imnaha River subbasin by species, arrival date, number released, release date(s), number of fish released with a passive integrated transponder (PIT) tag, and release site for migration year 2017.

Species	Arrival Date at Acclimation Site	Number Released	Release Date(s)	PIT Tags Released	Release Site
Chinook Salmon	3/23/17	283,041	4/3/17 to 4/13/17	11,853	Gumboot Facility
Chinook Salmon	Direct Release	208,085	4/13/17	8,835	Imnaha River
Steelhead	2/22/17	216,930	4/1/17 to 4/28/17	14,894	Little Sheep Facility

Appendix E. Incidental fish catch during the 2017 migration year. Juvenile bull trout identified as individuals <300 mm. Catch totals include estimates made from subsampling.

Family	Common Name	Fall 2016	Spring 2017
Salmonidae	Adult Steelhead	0	70
	Rainbow Trout	362	600
	Mountain Whitefish	80	14
	Juvenile Bull Trout	8	2
	Adult Bull Trout	11	2
Centrarchidae	Smallmouth Bass	3	24
Catostomidae	Sucker spp.	35	300
Cyprinidae	Chislemouth	4	32
	Longnose Dace	0	282
	Speckled Dace	0	2
	Northern Pikeminnow	12	22
	Redside Shiner	4	12
	Peamouth Chub	0	12
Cottidae	Sculpin spp.	0	28
	Total Catch	519	1402

Appendix F. Pacific Lamprey (*Lampetra tridentate*) caught during migration year 2017. Table includes the trap date, developmental stage, total length (nearest mm), and weight (nearest 0.1 g).

Trap Date	Developmental Stage	Length (mm)	Weight (g)
4/21/2017	Ammocoete	172	9.3
5/5/2017	Ammocoete	157	6.6
5/17/2017	Ammocoete	154	5.7

Appendix G. Sources of mortality for Chinook Salmon and steelhead emigrants due to trapping, handling, passive integrated transponder (PIT) tagging, and individuals dead on arrival (DOA) at the Imnaha River trap during migration year 2017.

Fall 2016

	Chinook				Steelhead			
	Natural		Hatchery		Natural		Hatchery	
Source of Mortality	N	Total Trapped (%)	N	Total Trapped (%)	N	Total Trapped (%)	N	Total Trapped (%)
Trapping	2	0.09	0	0.00	0	0.00	0	0.00
Handling	0	0.00	0	0.00	0	0.00	0	0.00
Tagging	3	0.13	0	0.00	0	0.00	0	0.00
DOA	1	0.04	0	0.00	0	0.00	0	0.00
Total	6	0.26	0	0.00	0	0.00	0	0.00

Spring 2017

	Chinook				Steelhead			
	Natural		Hatchery		Natural		Hatchery	
Source of Mortality	N	Total Trapped (%)	N	Total Trapped (%)	N	Total Trapped (%)	N	Total Trapped (%)
Trapping	14	0.47	58	0.30	23	0.80	37	0.28
Handling	2	0.07	0	0.00	0	0.00	0	0.00
Tagging	11	0.37	0	0.00	1	0.03	0	0.00
DOA	6	0.20	3	0.02	3	0.10	0	0.00
Total	33	1.12	61	0.31	27	0.94	37	0.28

Appendix H. Natural and hatchery Chinook Salmon smolt mean fork length (nearest mm), standard deviation (SD) fork length, mean weight (nearest 0.1 g), standard deviation weight, Fulton condition factor (K), sample size, fish per pound, and survival rate from trap to Lower Granite Dam (LGR; %) at the Imnaha River trap by origin and migration year.

Migration Year	Origin	Mean Fork Length	SD Fork Length	Mean Weight (g)	SD Weight	condition (K)	Sample Size	Fish Per Pound	Survival Trap to LGR (%)
1994	Natural	102	9	11.7	3.4	1.10	3,190	38.77	76
1995	Natural	99	10	10.7	3.4	1.10	1,003	42.39	81
1996	Natural	101	8	11.4	3.0	1.11	1,797	39.79	81
1997	Natural	108	9	13.0	3.6	1.03	270	34.89	90
1998	Natural	106	8	12.7	3.2	1.07	3,969	35.72	85
1999	Natural	104	10	12.4	3.5	1.10	5,422	36.58	89
2000	Natural	110	10	14.1	3.8	1.06	4,330	32.17	85
2001	Natural	108	10	13.0	3.9	1.03	9,956	34.89	84
2002	Natural	104	11	12.3	5.4	1.09	2,333	36.88	87
2003	Natural	104	9	11.8	3.6	1.05	4,841	38.44	76
2004	Natural	100	10	11.4	3.2	1.13	9,847	39.79	73
2005	Natural	98	10	11.1	3.4	1.18	3,472	40.86	74
2006	Natural	98	10	10.6	3.4	1.13	1,158	42.79	77
2007	Natural	99	12	12.6	4.1	1.30	7,547	36.00	78
2008	Natural	99	10	11.5	3.3	1.20	3,269	39.44	84
2009	Natural	100	10	11.6	3.5	1.17	6,115	39.10	85
2010	Natural	99	10	10.7	3.2	1.10	8,020	42.39	77
2011	Natural	102	11	11.6	4.0	1.09	4,037	39.10	80
2012	Natural	95	10	9.6	3.3	1.12	2,999	47.25	72
2013	Natural	99	11	10.6	3.5	1.09	4,714	42.79	72
2014	Natural	95	10	10.2	3.4	1.19	6,768	44.47	81
2015	Natural	102	13	12.1	4.2	1.11	7,253	37.49	74
2016	Natural	97	11	10.2	3.7	1.10	4,449	44.47	67
2017	Natural	93	9	9.3	2.7	1.12	2,655	48.77	76
1994	Hatchery	126	13	21.6	4.8	1.08	9,034	21.00	67
1995	Hatchery	127	8	21.3	4.5	1.04	391	21.30	72
1996	Hatchery	131	9	26.0	6.1	1.16	11,896	17.45	71
1997	Hatchery	131	11	25.4	7.2	1.13	10,616	17.86	80
1998	Hatchery	135	11	27.2	8.4	1.11	3,098	16.68	76
1999	Hatchery	134	11	26.8	7.6	1.11	6,839	16.93	72
2000	Hatchery	132	10	26.7	6.8	1.16	2,399	16.99	74
2001	Hatchery	142	12	30.0	7.5	1.05	7,107	15.12	80
2002	Hatchery	139	17	28.5	11.9	1.06	3,918	15.92	77

Migration Year	Origin	Mean Fork Length	SD Fork Length	Mean Weight (g)	SD Weight	condition (K)	Sample Size	Fish Per Pound	Survival Trap to LGR (%)
2003	Hatchery	139	16	29.7	11.4	1.11	1,743	15.27	72
2004	Hatchery	118	10	18.7	5.3	1.14	2,694	24.26	61
2005	Hatchery	118	8	18.9	4.4	1.16	2,418	24.00	61
2006	Hatchery	121	10	20.1	5.0	1.13	1,462	22.57	69
2007	Hatchery	123	11	22.2	6.2	1.19	1,084	20.43	71
2008	Hatchery	124	11	22.8	6.6	1.19	1,754	19.89	70
2009	Hatchery	123	8	22.6	4.5	1.21	1,957	20.07	79
2010	Hatchery	128	8	24.0	4.9	1.14	2,442	18.90	70
2011	Hatchery	126	10	24.1	5.6	1.20	991	18.82	69
2012	Hatchery	120	9	20.0	4.9	1.16	379	22.68	68
2013	Hatchery	128	9	22.7	5.7	1.08	1,030	19.98	75
2014	Hatchery	119	10	20.9	5.6	1.24	2,282	21.70	75
2015	Hatchery	121	10	21.3	5.7	1.17	2,921	21.30	73
2016	Hatchery	118	9	19.1	4.6	1.14	1,225	23.75	70
2017	Hatchery	115	8	17.8	3.7	1.17	999	25.48	70

Appendix I. Natural and hatchery steelhead smolt mean fork length (nearest mm), standard deviation (SD) fork length, mean weight (nearest 0.1 g), standard deviation weight, Fulton condition factor (K), sample size, fish per pound, and survival rate from trap to Lower Granite Dam (LGR; %) at the Imnaha River trap by origin and migration year.

Migration Year	Origin	Mean Fork Length	SD Fork Length	Mean Weight (g)	SD Weight	condition (K)	Sample Size	Fish Per Pound	Survival Trap to LGR (%)
1994	Natural	172	19	52.4	17.0	1.03	2,228	8.66	
1995	Natural	173	20	52.7	18.2	1.02	568	8.61	84
1996	Natural	175	19	56.9	17.8	1.06	3,786	7.97	87
1997	Natural	175	20	55.8	18.9	1.04	864	8.13	90
1998	Natural	177	21	56.8	20.7	1.02	2,843	7.99	86
1999	Natural	184	19	62.3	19.8	1.00	2,517	7.28	88
2000	Natural	184	21	62.0	22.2	1.00	4,668	7.32	84
2001	Natural	178	24	55.5	24.3	0.98	3,733	8.17	83
2002	Natural	172	20	51.1	17.3	1.00	4,738	8.88	83
2003	Natural	174	23	53.9	20.7	1.02	5,961	8.42	82
2004	Natural	170	21	50.5	19.6	1.04	5,652	8.98	79
2005	Natural	169	19	51.4	17.1	1.07	4,541	8.82	81
2006	Natural	171	20	53.7	18.0	1.07	2,298	8.45	92
2007	Natural	169	19	53.5	18.5	1.11	7,195	8.48	79
2008	Natural	166	19	50.4	17.4	1.10	2,524	9.00	90
2009	Natural	173	18	54.5	16.9	1.05	5,163	8.32	87
2010	Natural	167	19	46.8	16.7	1.00	6,159	9.69	85
2011	Natural	173	21	55.0	22.0	1.06	2,540	8.25	81
2012	Natural	170	18	50.9	16.2	1.04	5,299	8.91	89
2013	Natural	169	21	51.4	20.1	1.06	6,993	8.82	100
2014	Natural	170	21	52.7	20.0	1.07	6,710	8.61	91
2015	Natural	173	22	54.5	22.4	1.01	6,204	8.32	98
2016	Natural	173	22	53.8	20.9	1.00	4,778	8.43	82
2017	Natural	173	25	54.5	24.2	0.99	2,717	8.32	82
1994	Hatchery	209	19	89.0	27.8	0.97	3,229	5.10	
1995	Hatchery	208	19	86.1	25.6	0.96	1,537	5.27	78
1996	Hatchery	201	18	80.9	24.0	1.00	31,094	5.61	65
1997	Hatchery	210	20	88.0	26.1	0.95	7,345	5.15	81
1998	Hatchery	218	20	102.0	30.4	0.98	3,890	4.45	83
1999	Hatchery	216	18	98.3	1.0	0.98	6,444	4.61	85
2000	Hatchery	224	18	106.8	27.1	0.95	5,751	4.25	86
2001	Hatchery	217	23	98.2	31.6	0.96	4,365	4.62	82

Migration Year	Origin	Mean Fork Length	SD Fork Length	Mean Weight (g)	SD Weight	condition (K)	Sample Size	Fish Per Pound	Survival Trap to LGR (%)
2002	Hatchery	216	21	102.7	31.4	1.02	2,428	4.42	82
2003	Hatchery	222	23	110.6	34.0	1.01	5,397	4.10	89
2004	Hatchery	216	22	100.5	31.8	1.00	4,498	4.51	86
2005	Hatchery	217	22	107.5	35.5	1.05	6,596	4.22	83
2006	Hatchery	218	22	109.9	35.0	1.06	1,993	4.13	86
2007	Hatchery	215	24	105.0	37.9	1.06	2,360	4.32	97
2008	Hatchery	211	21	100.1	31.0	1.07	1,030	4.53	83
2009	Hatchery	218	23	110.2	38.6	1.06	1,923	4.12	91
2010	Hatchery	214	25	100.2	39.1	1.02	2,124	4.53	100
2011	Hatchery	220	22	111.3	34.2	1.05	634	4.08	96
2012	Hatchery	213	19	95.9	26.1	0.99	1,906	4.73	92
2013	Hatchery	205	19	90.2	23.9	1.05	1,859	5.03	86
2014	Hatchery	206	20	94.0	27.0	1.08	2,608	4.83	96
2015	Hatchery	212	19	96.7	26.5	0.99	1,426	4.69	73
2016	Hatchery	211	31	98.1	30.6	1.01	1,425	4.62	89
2017	Hatchery	209	20	96.5	28.7	1.03	1,138	4.70	90