Emigration of Juvenile Chinook Salmon and Steelhead from the Imnaha River

Progress Report for Migration Year 2018

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 2018

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

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BPA Project Number: 1997-015-01
BPA 2019 Contract Number: 74017 REL 6

and

U.S. Fish and Wildlife Service
Lower Snake River Compensation Plan
1387 Vinnell Way
Boise, Idaho 83709

Cooperative Agreement for FY 2019: F16AC00029

2019

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 2018 (MY2018). These studies have been ongoing for the past 26 years and have contributed information to the Fish Passage Center's (FPC) Smolt Monitoring Program (SMP) for the past 24 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.

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 2017 through early July 2018 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 MY2018 to be 106,267 (91,491 – 124,795; 95% confidence interval) with 69,860 (56,429 – 86,591) emigrating as presmolts and 36,407 (31,797 – 42,371) emigrating as smolts. We estimated the minimum number of steelhead passing the trap to be 63,067 (54,338 – 73,881).

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 4/10/18 and 5/01/18, respectively). Hatchery Chinook Salmon arrived the latest of the Chinook Salmon emigrant groups with a median arrival date at LGR of 05/06/18. Emigration timing of natural and hatchery steelhead smolts at LGR was more similar (median arrival dates at LGR 05/14/18 and 05/09/18, 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 2018 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 0.35 (0.33 – 0.38); 95% CI), natural Chinook Salmon smolts was 0.71 (0.68 – 0.75), and hatchery Chinook Salmon smolt survival was 0.65 (0.58 – 0.74). 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 (0.79 – 0.85) and hatchery steelhead smolt survival was 0.94 (0.87 – 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 2018 allowed for estimates of smolt to adult return (SAR) rates from LGR to LGR for Imnaha River Chinook Salmon for brood years through 2013, and for Imnaha River steelhead migration years through 2016. 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 2018 was not an exception to this recent trend. The highest SAR for Chinook Salmon was natural smolts that were monitor mode PIT-tagged and returned as adults to LGR (0.79%). The highest SAR for steelhead was hatchery smolts that were monitor mode PIT-tagged and returned as adults to LGR (1.45%).

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 2018. 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 2,170 natural Chinook Salmon presmolts, 2,678 natural Chinook Salmon smolts, and 2,395 natural steelhead smolts were PIT-tagged and evaluated as part of the Fish Passage Center's Smolt Monitoring Program during MY2018. 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, Cobi Bisbee, David Bright, Jesse Elwell, Joseph McCormack, Jon Rombach and Neal Meshell. Ryan Kinzer provided technical support and advice for these studies and the report.

We also acknowledge the Oregon Department of Fish and Wildlife (ODFW) for PIT tagging under BPA program number 199602000 and for conducting the acclimation and releases of hatchery Chinook Salmon and steelhead smolts. Appreciation is also extended to Joseph Feldhaus and Mike Fletcher of ODFW for providing information on rearing and releases of hatchery fish. We extend our gratitude to the United States Forest Service for allowing us the use of the Thorn Creek guard station facilities, and Scott and Vicki McClaran of McClaran Ranch Inc. for access to their land for trapping purposes. The Fish Passage Center's Sergei Rasskazov, Chris McCarty, and Brandon Chockley provide software used in daily data collection, as well as assistance with server management and maintenance, and assistance with data management and analyses.

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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

The Nez Perce Tribe is a co-manager of Imnaha subbasin spring/summer Chinook Salmon (*Oncorhynchus tshawytscha*) and summer steelhead (*Oncorhynchus mykiss*). We coordinate with project partners to collect 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 and steelhead, both populations are listed as threatened under the Endangered Species Act (ESA). Along with our co-managers in the Imnaha subbasin, we have identified the need to collect information on life history, migration patterns, emigrant abundance, and reach specific smolt survival rates for both Chinook Salmon and steelhead (Ecovista 2004). This report summarizes monitoring conducted 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) 2018. This information is also used by the Federal Columbia River Power System (FCRPS) Biological Opinion (NMFS 2008). This study was conducted during the autumn of 2017 through the summer of 2018.

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 1999). 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 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 MY2018 trapping season covered in this report began in early October 2017 and ended in early July 2018 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 2018 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.

M&E Objective 2: Quantify and compare life-stage specific emigration timing of Imnaha River juvenile Chinook Salmon and steelhead from the Imnaha River trap through the lower Snake River hydrosystem.

M&E Objective 3: Quantify and compare life-stage specific survival of Imnaha River 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.

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

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

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 at lower elevations.

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).

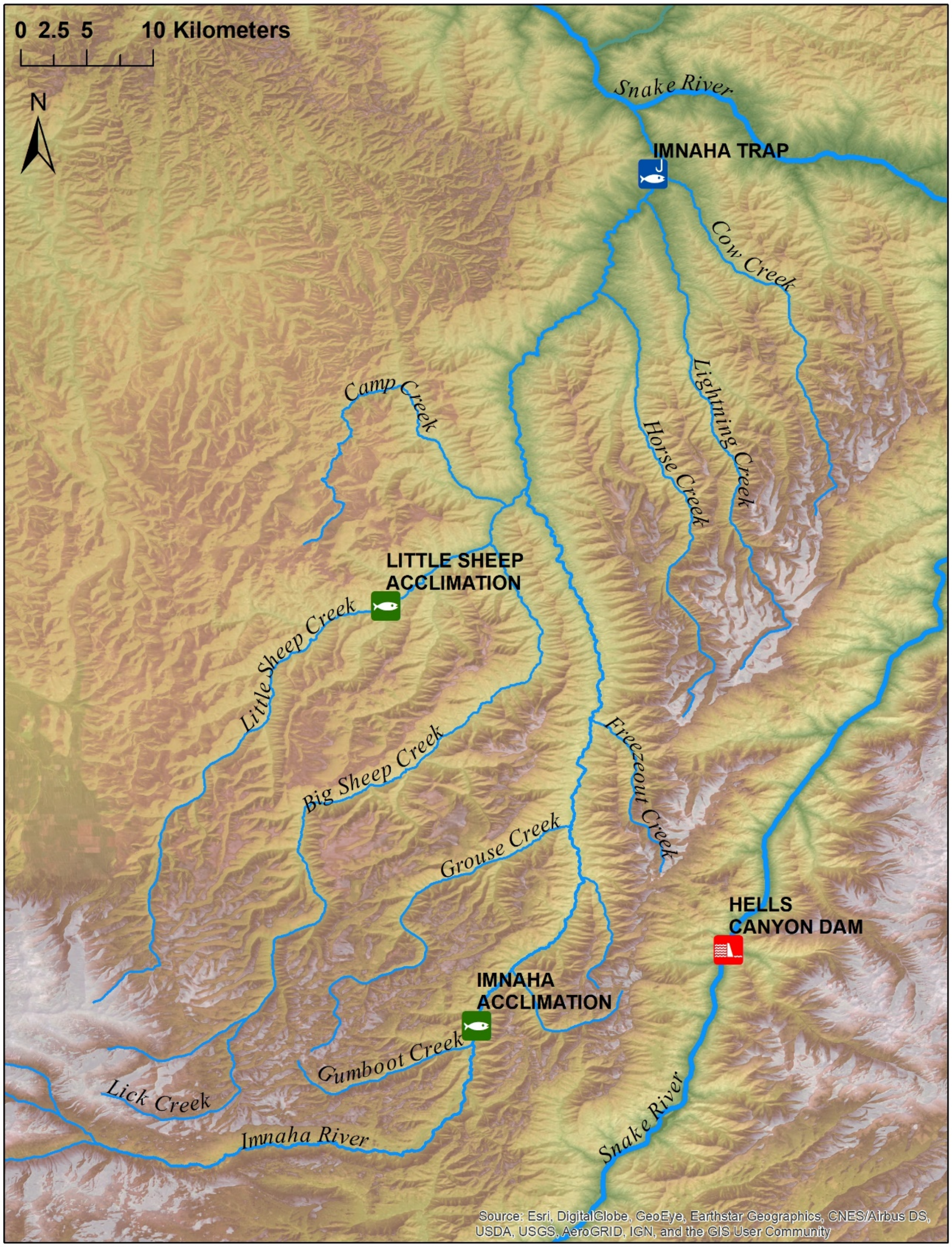

Figure 1. Map of the Imnaha River study area showing the location of the Imnaha River trap, the Imnaha River Chinook Salmon acclimation facility, and the Little Sheep Creek steelhead acclimation facility.

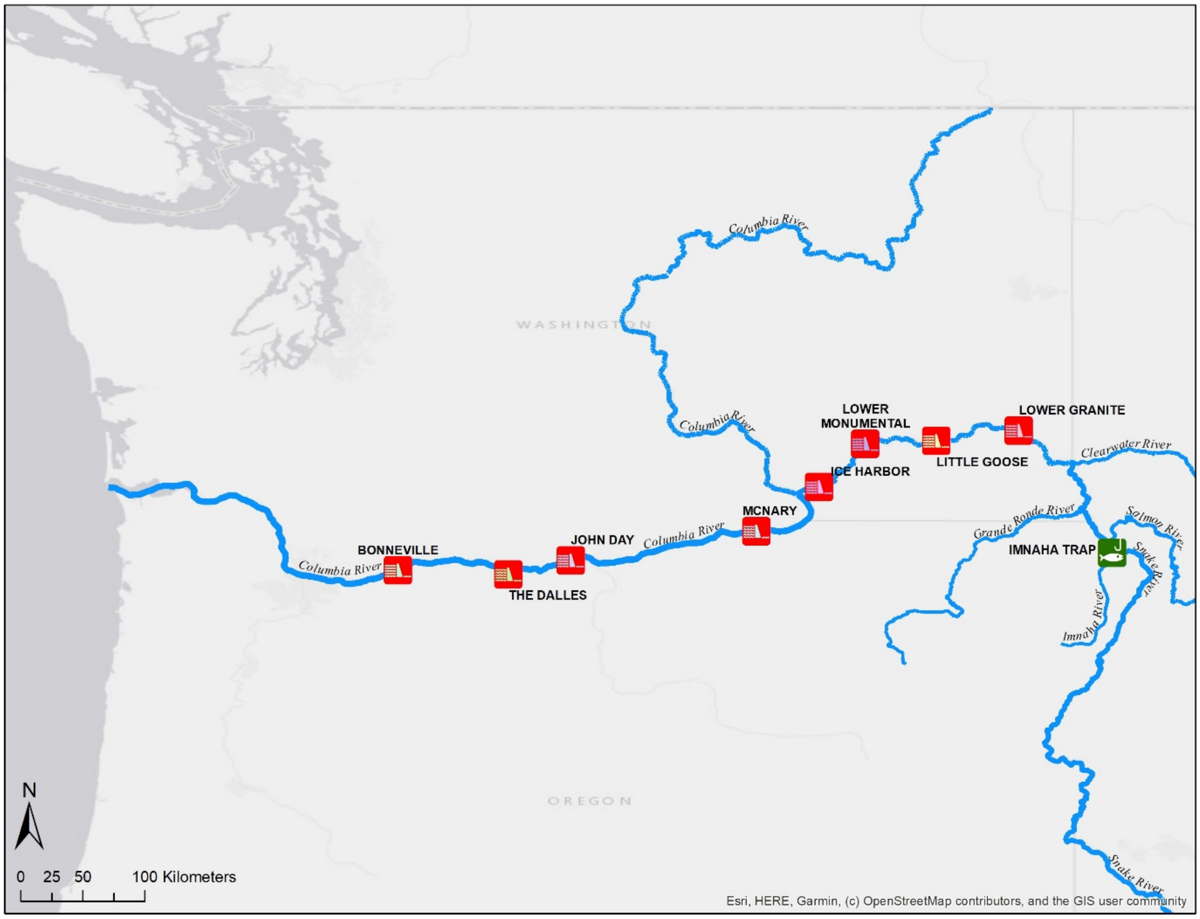

Figure 2. Map of the major dams on the lower Snake and Columbia rivers, the Imnaha River, and the Imnaha River trap.

Trapping and tagging

<u>Equipment description</u>

A rotary screw trap was used to capture emigrating juvenile Chinook Salmon and steelhead in the Imnaha River. For details on the basic operation and maintenance of rotary screw traps see: https://www.monitoringresources.org/Document/Method/Details/6608. The Imnaha River 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 four 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 and winter 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.

Equipment for processing fish was housed in the tent setup on the river bank adjacent to the trap 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.

<u>Fish capture and tagging</u>

Trapping for MY2018 began October 5, 2017 and ended July 13, 2018. The trap was operated continuously, seven days per week, throughout the sampling season, except during late June and early July when trapping occurred when staff were available. Additionally, trapping operations were intermittently terminated throughout the sampling season due to high flows, high stream temperatures, cattle crossings upriver, and ice events. The trap was checked and fish were processed daily.

Fish were removed from the trap following method: https://www.monitoringresources.org/Document/Method/Details/6632.

Fish were anesthetized following method: https://www.monitoringresources.org/Document/Method/Details/6633.

Fish were sampled and tagged following method: https://www.monitoringresources.org/Document/Method/Details/6634#Pitmanual. However, departures from the sampling and tagging protocol at the Imnaha River trap are as follows: (1) all target species are scanned for a PIT tag, weighed (nearest 0.1 g), measured for fork length (nearest mm), and checked for overall condition (https://www.monitoringresources.org/Document/Method/Details/3808); (2) all hatchery Chinook Salmon and steelhead smolts captured are scanned for a PIT tag; (3) those hatchery fish that have a PIT-tagged are weighed, measured for fork length, and checked for overall condition; and (4) ten additional untagged hatchery smolts of each species are weighed and measured for fork length. Natural Chinook Salmon and steelhead smolts and Bull Trout did not receive a PIT tag if they were considered to be in poor condition.

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. All newly PIT-tagged natural Chinook Salmon and steelhead were held in perforated recovery containers instream and released after dark. Daily trap efficiency was estimated by randomly selecting 50 newly tagged individuals of each species of natural Chinook Salmon and steelhead juveniles and releasing them after dark about one kilometer upstream of the trap. During summer conditions (i.e., low flow and warm 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.

Trap sub-sampling followed method:
https://www.monitoringresources.org/Document/Method/Details/6635.

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.

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 juveniles 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 smolts are released by LSRCP facilities managed by the Oregon Department of Fish and Wildlife in the spring. Hatchery Chinook Salmon smolts are released from the Imnaha Acclimation Facility and hatchery steelhead smolts are released from the Little Sheep Acclimation Facility. 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; $\alpha = 0.05$).

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, 10th percentile, median, 90th 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 April 24, 2018. Collections for transportation at McNary Dam were discontinued in 2013. It was assumed that fish arriving at LGR prior to April 24, 2018 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 2018 (http://www.fpc.org/documents/FPC_Annual_Reports.html).

Proportion of juveniles likely to be transported at Lower Granite Dam

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.

Life-stage and reach specific estimates of juvenile emigrant survival

Survival was 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 calculate 95% confidence intervals around the survival estimates. Data for PITPRO were obtained from PTAGIS (https://www.ptagis.org/).

Survival was estimated for hatchery Chinook Salmon and steelhead smolts from their point of release to the Imnaha River trap. Hatchery Chinook Salmon smolts were released in two groups, one group was volitionally released after a period of acclimation from the LSRCP Imnaha Acclimation Facility on the Imnaha River and the other group was directly released from the Imnaha River adult weir. Hatchery steelhead were volitionally released after a period of acclimation from the LSRCP Little Sheep Creek Acclimation Facility.

Survival was 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 were included in survival analysis due to sufficient numbers being captured and PIT tagged during the fall trapping period.

For estimates of juvenile survival through the entire Snake River and Columbia River hydrosystems 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 its 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:

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

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

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 = (weight/length^3)*100,000 (Anderson and Neumann 1996).

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 2013. Steelhead SAR rates were calculated for survival and monitor mode natural steelhead smolts PIT-tagged at the Imnaha River trap for migration years 2010 through 2015. The natural steelhead smolts PIT-tagged at 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.

Results and Discussion

Trapping and tagging

Trap operations

The Imnaha River smolt monitoring trapping season spanned 281 days in MY2018, from October 4, 2017 to July 13, 2018. There were a total of 27 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 maintenance and repair or staffing schedules.

Target catch

The catch of MY2018 natural Chinook Salmon totaled 8,442 fish including 4,726 presmolts trapped in the fall 2017 and 3,716 smolts trapped during spring and summer 2018. Six Chinook Salmon < 60 mm in length were caught in the spring of 2018 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 4,337 natural Chinook Salmon presmolts were tagged at the Imnaha River trap during fall 2017 and 3,633 smolts were tagged during the spring and summer of 2018. Thirteen (six recaptures in the fall and seven recaptures in the spring) belonged to the group of 1,000 natural Chinook Salmon juveniles that were PIT-tagged by the ODFW Early Life History Program during August and September of 2017.

The catch of MY2018 natural steelhead smolts totaled 6,027. In contrast to previous migration years, natural steelhead smolts were tagged in both the fall and the spring at the Imnaha River trap, 336 and 5,346 fish, respectively.

The Imnaha River trap captured or bypassed 37,584 hatchery Chinook Salmon smolts during the 2018 spring and summer trapping period; 4,395 were estimated as part of bypass procedures on April 4, 2018. Smolts were from an acclimated volitional release group (275,830 smolts) or a direct release group (214,680 smolts) released at the Imnaha Acclimation Facility; of which, 20,875 were PIT-tagged (Table 1) and 1,578 were interrogated at the Imnaha River trap.

Hatchery steelhead smolts from were volitionally released from the Little Sheep Acclimation Facility starting April 1, 2018; of the 251,209 smolts released 14,967 were PIT-tagged (Table 1). The Imnaha River trap captured or bypassed 21,770 smolts (Table 1); PIT-tagged individuals accounted for 1,282 hatchery steelhead smolts interrogated, and 832 smolts were estimated as part of bypass procedures on April 4, 2018.

Table 1. 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 2018. Data provided by the Oregon Department of Fish and Wildlife.

Species	Arrival Date at Acclimation Site	Number Released	Release Date(s)	PIT Tags Released	Release Site
Chinook Salmon	03/19/18	275,830	04/03/18 – 4/10/18	11,937	Imnaha Facility
Chinook Salmon	Direct Release	214,680	04/10/18	8,938	Imnaha River
Steelhead	03/06/18 – 03/09/18	251,209	04/01/18 – 04/30/18	14,967	Little Sheep Facility

Incidental catch

The incidental catch during MY2018 was 988 fish comprised of five families: Salmonidae, Centrarchidae, Catostomidae, Cyprinidae and Cottidae (Table 2). One juvenile Pacific Lamprey (*Lampetra tridentata*) in the family Petromyzontidae was caught during MY2018 (Table 3). Lamprey are considered "target species" by the Fish Passage Center.

Table 2. Incidental fish catch during the 2018 migration year. Juvenile bull trout identified as individuals <300 mm.

Family	Common Name (*Scientific name*)	Fall 2017	Spring 2018
Salmonidae	Adult Steelhead (*Oncorhynchus mykiss*)	-	19
	Rainbow Trout (*O. mykiss*)	43	3
	Mountain Whitefish (*Prosopium williamsoni*)	13	16
	Juvenile Bull Trout (*Salvelinus confluentus*)	18	4
	Adult Bull Trout (*S. confluentus*)	4	1
Centrarchidae	Smallmouth Bass (*Micropterus dolomieu*)	4	2
Catostomidae	Unidentified sucker (*Catostomus* sp.)	47	335
Cyprinidae	Chiselmouth (*Acrocheilus alutaceus*)	2	16
	Longnose Dace (*Rhinichthys cataractae*)	-	318
	Northern Pikeminnow (*Ptychocheilus oregonensis*)	18	83
	Redside Shiner (*Richardsonius balteatus*)	8	4
	Peamouth (*Mylocheilus caurinus*)	1	8
Cottidae	Unidentified sculpin (*Cottus* sp.)	4	17
Total Catch		162	826

Table 3. Pacific Lamprey (*Lampetra tridentate*) caught during migration year 2018.

Trap Date	Developmental Stage	Length (mm)	Weight (g)
4/21/2017	Macrophthalmia	170	7.7

<u>Trapping and tagging mortality</u>

Target species catch mortalities handled at the Imnaha River trap during the MY2018 trapping season included 57 natural and 20 hatchery Chinook Salmon emigrants and 132 natural and 220 hatchery steelhead emigrants (Appendix D). The majority of the mortality occurred as trapping mortality during a single trapping event in the spring when a large amount of debris lodged in the cone during a period of high flow and high emigrant density. Many of the emigrants lodged in the cone with the debris were not rescued in time to avoid numerous mortalities. Although, there was a high mortality event it accounted for a very low percent of the total target species captured (Appendix D). Other sources of mortality (i.e., handling, tagging, predation, and dead on arrival) were rare (Appendix D).

Seven incidental catch mortalities occurred at the Imnaha River trap during MY2018 trapping season. All of these occurred during the spring. Four sculpin sp. mortalities were attributed to trapping and two sculpin sp. mortalities were determined to be dead on arrival (DOA). One wild steelhead adult was also found in the trap box and determined to be DOA.

Performance measures

<u>Emigrant abundance at the Imnaha River trap during MY2018</u>

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. 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 MY2018 should be considered minimum estimates.

Natural Chinook Salmon and steelhead emigrant abundance

Mark-recapture at the Imnaha River trap estimated 69,860 (56,429 – 86,591) [estimate (95% confidence interval)] natural Chinook Salmon presmolts with a CV of 11.5%. Mean presmolt trap efficiency was 0.09 and ranged between 0.03 to 0.14 for the fall trapping season (Appendix A). The spring and summer population estimate for natural Chinook Salmon smolts was 36,407 (31,797 – 42,371) with a CV of 7.5%. Mean trap efficiency was 0.11 and ranged from 0.04 to 0.23 through the spring trapping season (Appendix A). The natural Chinook Salmon cohort (all captured Chinook Salmon emigrants) population estimate was 106,267 (91,491 – 124,795) with a CV of 8.4% (Appendix A). Presmolts and smolts comprised 65.7% and 34.3% of the natural Chinook Salmon cohort, respectively. The MY2018 cohort estimate was 9.3% more than the MY2017 cohort estimate. The population estimate for natural steelhead smolts was 63,067 (54,338 – 73,881) with a CV of 7.8%. Mean trap efficiency for natural steelhead was 0.09 and ranged from 0.05 to 0.20 (Appendix B).

Hatchery smolt emigrant abundance estimates at the Imnaha River trap

See post-release survival of hatchery smolts below.

<u>Imnaha River natural Chinook Salmon and steelhead production over time</u>

The Imnaha River trap has been operating since MY1992. However, trap efficiency trials have only been conducted since MY2007. This operational limitation restricted the estimates of Chinook Salmon and steelhead emigrants from the Imnaha River to migration years 2007 through 2018.

Natural Chinook Salmon production

The estimated number of natural Chinook Salmon emigrating from the Imnaha River has varied over time (Figure 7). Presmolt estimates have consistently ranged between 50,000 and 100,000 fish, except in MY2007 and MY2012 when estimates exceeded 100,000 fish (Figure 7 and Appendix C). Natural Chinook Salmon smolt population estimates range between 25,000 and

75,000 fish, and often contribute fewer individuals to the overall cohort estimate, especially in recent migration years (Figure 7 and Appendix C).

Natural Steelhead production

The Imnaha River natural steelhead population estimate for MY2018 included those fish tagged in the fall, unlike estimates produced in previous years, we had enough recaptures to allow us to estimate steelhead emigrant population from early October through late June (Appendix C). Additionally, it was the largest population estimate since estimates have been made starting with MY2007 (Figure 7). The addition of the fall and early spring tagged emigrants are contributing about 8,000 fish to the total population estimate; however, if these fish were removed from the estimate it would still suggest a strong cohort emigrating from the Imnaha River in MY2018 (Appendix C).

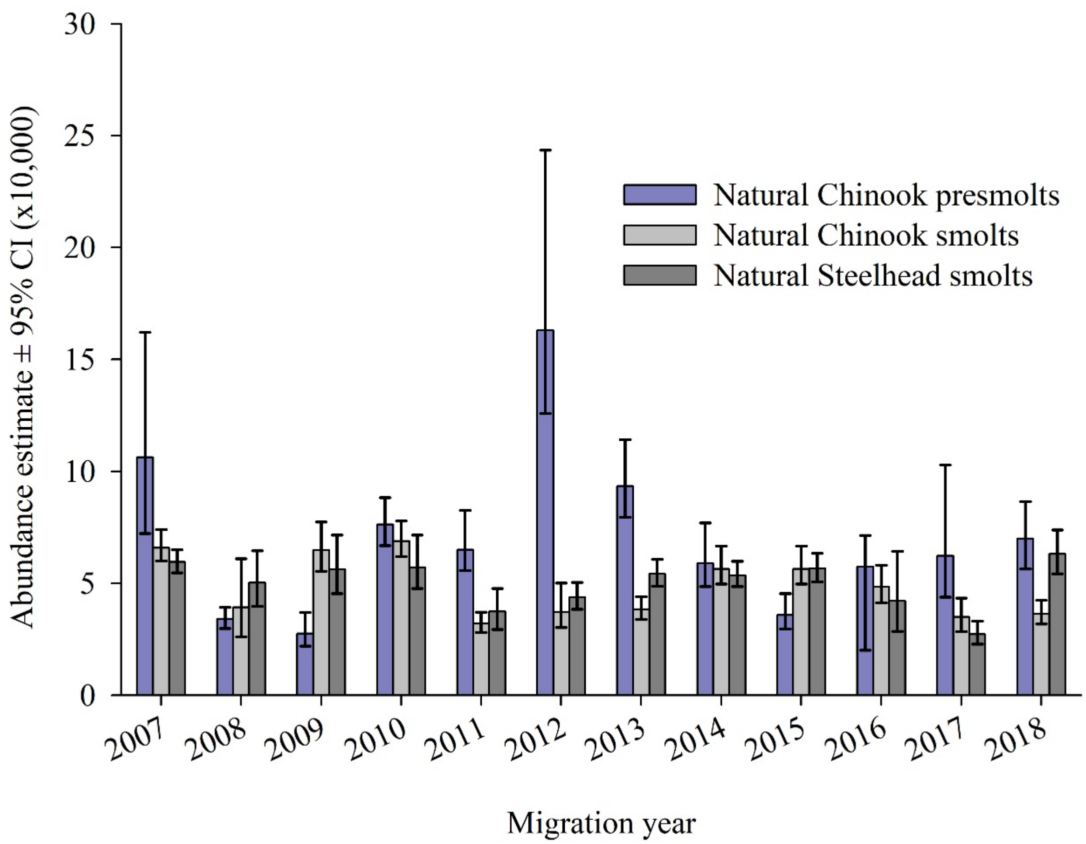

Figure 7. Natural Chinook Salmon presmolt and smolt and natural steelhead smolt population estimates and 95% confidence intervals (CI) for Imnaha River emigrants for migration years 2007-2018.

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. Although, natural Chinook Salmon and steelhead juveniles are captured at the Imnaha River trap in the fall, information on spring emigrants is presented below. Natural Chinook Salmon smolt emigration was highly protracted compared to hatchery Chinook Salmon smolts. Results of the two-sample K-S test suggests that emigration of natural and hatchery Chinook Salmon smolts was significantly different (D statistic = 0.722, $p < 0.001$, n = 3,712 natural smolts and 36,007 hatchery smolts) and maximum difference between emigration timing at the Imnaha River trap occurred on April 13, 2018 (Figure 8). The first natural smolts arrived at the Imnaha River trap on the first day of trapping on January 1, 2018 and the last smolt arrived on July 12, 2018 (Table 4). Conversely, hatchery Chinook Salmon smolts rapidly emigrated past the trap in a unimodal pulse of fish. The first hatchery Chinook Salmon smolt was captured April 5, 2018 and over 90% of the total catch had migrated past the Imnaha River trap by April 12, 2018 (Table 4). The last hatchery Chinook Salmon smolt was captured on May 22, 2018 (Table 4).

The pattern of natural and hatchery steelhead smolt emigration was more disparate than in some prior years with a large pulse of hatchery smolts emigrating just after release (Figure 8). Emigration of natural and hatchery steelhead smolts past the Imnaha River trap was significantly different (two-sample K-S test, D statistic = 0.231, $p = 0.006$, n = 5,687 natural smolts and 20,491 hatchery smolts). The maximum difference in hatchery and natural steelhead emigration timing occurred on April 19, 2018. The first natural steelhead smolt was captured at the trap January 5, 2018, median arrival occurred on May 9, 2018, and the last smolt was captured on June 26, 2018 (Table 4). Hatchery steelhead smolts were first captured at the Imnaha River trap on April 2, 2018, median arrival occurred on April 13, 2018, and the last smolt was captured July 13, 2018 on the last day of trapping for MY2018 (Table 4).

Table 4. 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	01/01/18	03/21/18	04/14/18	05/18/18	07/12/18
Hatchery Chinook smolts	04/05/18	04/05/18	04/08/18	04/12/18	05/22/18
Natural Steelhead smolts	01/05/18	04/24/18	05/09/18	05/22/18	06/26/18
Hatchery Steelhead smolts	04/02/18	04/04/18	04/13/18	05/15/18	07/13/18 [a]

[a] trapping ceased on 07/13/18

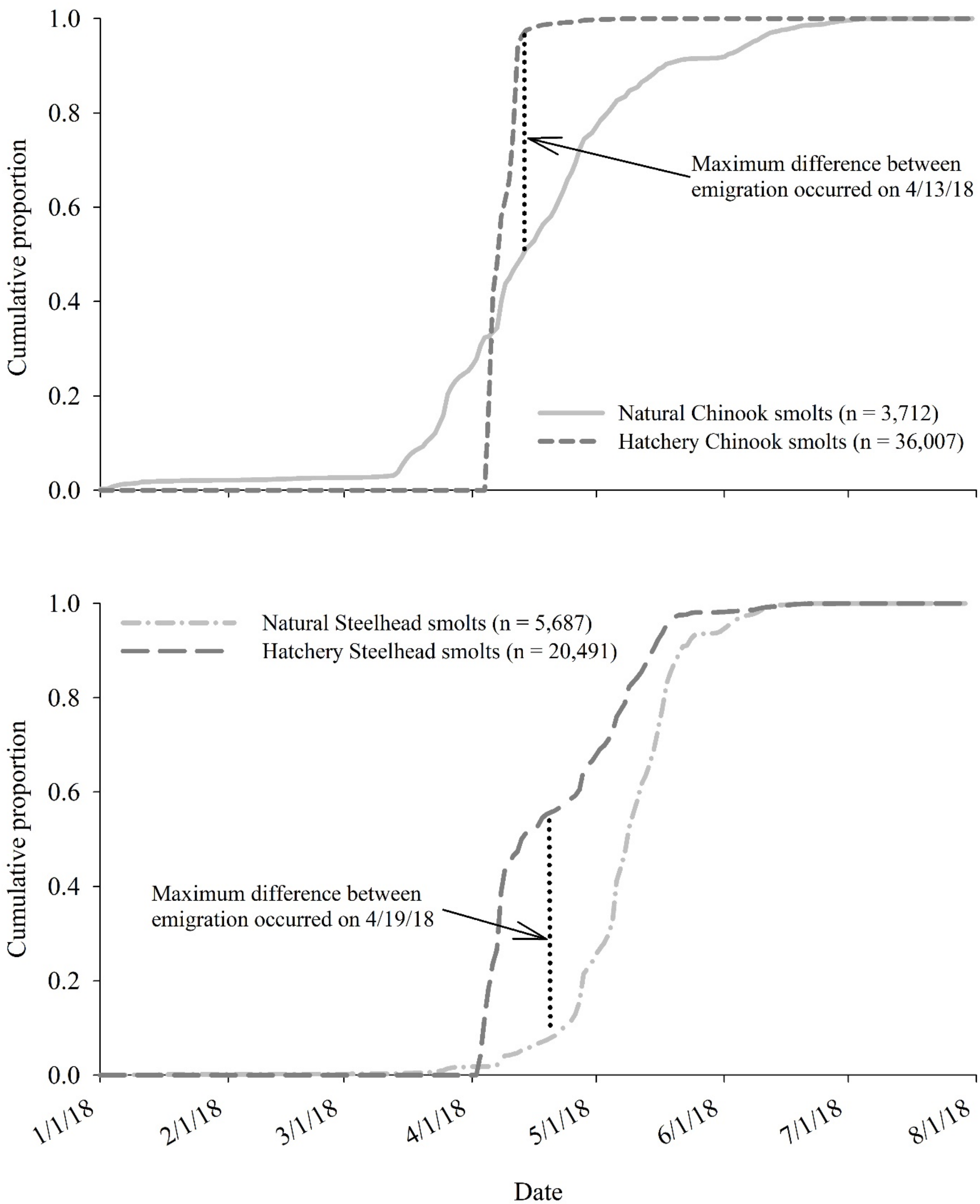

Figure 8. Cumulative proportion and passage date of natural and hatchery Chinook Salmon smolts (top panel) and steelhead smolts (bottom panel) at the Imnaha River trap.

Chinook Salmon arrival timing at Lower Granite Dam

Natural Chinook Salmon presmolts arrived at LGR earlier than natural Chinook Salmon smolts (Table 5; Figure 9), as indicated by PIT tag detections at LGR. 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 = 0.481, $p < 0.001$, n = 423 presmolts and 905 smolts) and maximum difference in emigration occurred on April 20, 2018 (Figure 9). When collections for smolt transportation began on April 24, 2018, 95.3% of presmolts had passed LGR, compared to 30.0% of smolts. Collection efficiency for natural Chinook Salmon smolts was estimated at 31%; resulting in an estimated 1.5% of presmolts and 21.7% of smolts emigrating from the Imnaha River being available for transportation at LGR (Table 6).

The cumulative proportion curves for natural and hatchery Chinook Salmon smolts arriving at LGR were significantly different (two-sample K-S test, D statistic = 0.351, $p < 0.001$, n = 905 natural smolts and 4531 hatchery smolts). Similar to the Imnaha River trap, the majority of hatchery Chinook Salmon smolts arrived at LGR within a couple weeks; conversely, the emigration period for natural Chinook Salmon smolts lasted about two months (Figure 9). The proportion of emigrating hatchery smolts surpassed the proportion of emigrating natural smolts on May 8, 2018 when 70.2% of natural smolts and 71.9% of hatchery smolts had passed LGR (Figure 9). Median arrival dates for natural and hatchery Chinook Salmon smolts at LGR were May 1, 2018 and May 6, 2018 respectively (Table 5). A greater proportion of natural smolts (30.0%) than hatchery smolts (4.6%) had passed LGR prior to the start of collection for transportation (April 24, 2018) and collection efficiencies were similar for natural smolts (31%) than hatchery smolts (29%; Table 6). The proportion of Imnaha River natural and hatchery Chinook Salmon smolts available to transport was 21.7% and 27.7%, respectively.

Steelhead arrival timing at Lower Granite Dam

Hatchery steelhead smolt arrival at LGR was slightly earlier overall but similar in pattern to that of natural steelhead smolt arrival (Figure 9) and the two groups likely experienced similar environmental conditions. However, a two-sample K-S test suggest a significant difference between the cumulative proportion curves for the two emigrant groups (D statistic = 0.313, $p < 0.001$, n = 1989 natural and 4196 hatchery smolts), and maximum difference in arrival occurred on May 12, 2018 (Figure 9). The first natural and hatchery steelhead smolts were observed at LGR April 1, 2018 and April 5, 2018, respectively (Table 5). Median arrival date for hatchery steelhead smolts occurred on May 9, 2018 with that last PIT tagged smolt arriving at LGR on July 9, 2018 (Table 5). Natural steelhead smolt median arrival at LGR occurred on May 14, 2018 with the last PIT tagged smolt arriving on June 18, 2018. Steelhead smolts were more available for transportation collection than natural Chinook Salmon presmolts and smolts due to their later emigration timing; 35.8% of natural steelhead smolts and 25.8% of hatchery steelhead smolts were likely transported at LGR during MY2018 (Table 6).

Table 5. 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	03/29/18	04/01/18	04/10/18	04/19/18	05/13/18
Natural Chinook smolts	03/30/18	04/12/18	05/01/18	05/18/18	06/28/18
Hatchery Chinook smolts	04/08/18	04/29/18	05/06/18	05/11/18	07/27/18
Natural Steelhead smolts	04/01/18	04/30/18	05/14/18	05/24/18	06/18/18
Hatchery Steelhead smolts	04/05/18	04/12/18	05/09/18	05/25/18	07/09/18

Table 6. Cumulative proportion of Imnaha River emigrants that had passed Lower Granite Dam before April 24, 2018 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	95.3	31.0	1.5
Natural Chinook smolts	30.0	31.0	21.7
Hatchery Chinook smolts	4.6	29.0	27.7
Natural Steelhead smolts	3.2	37.0	35.8
Hatchery Steelhead smolts	16.7	31.0	25.8

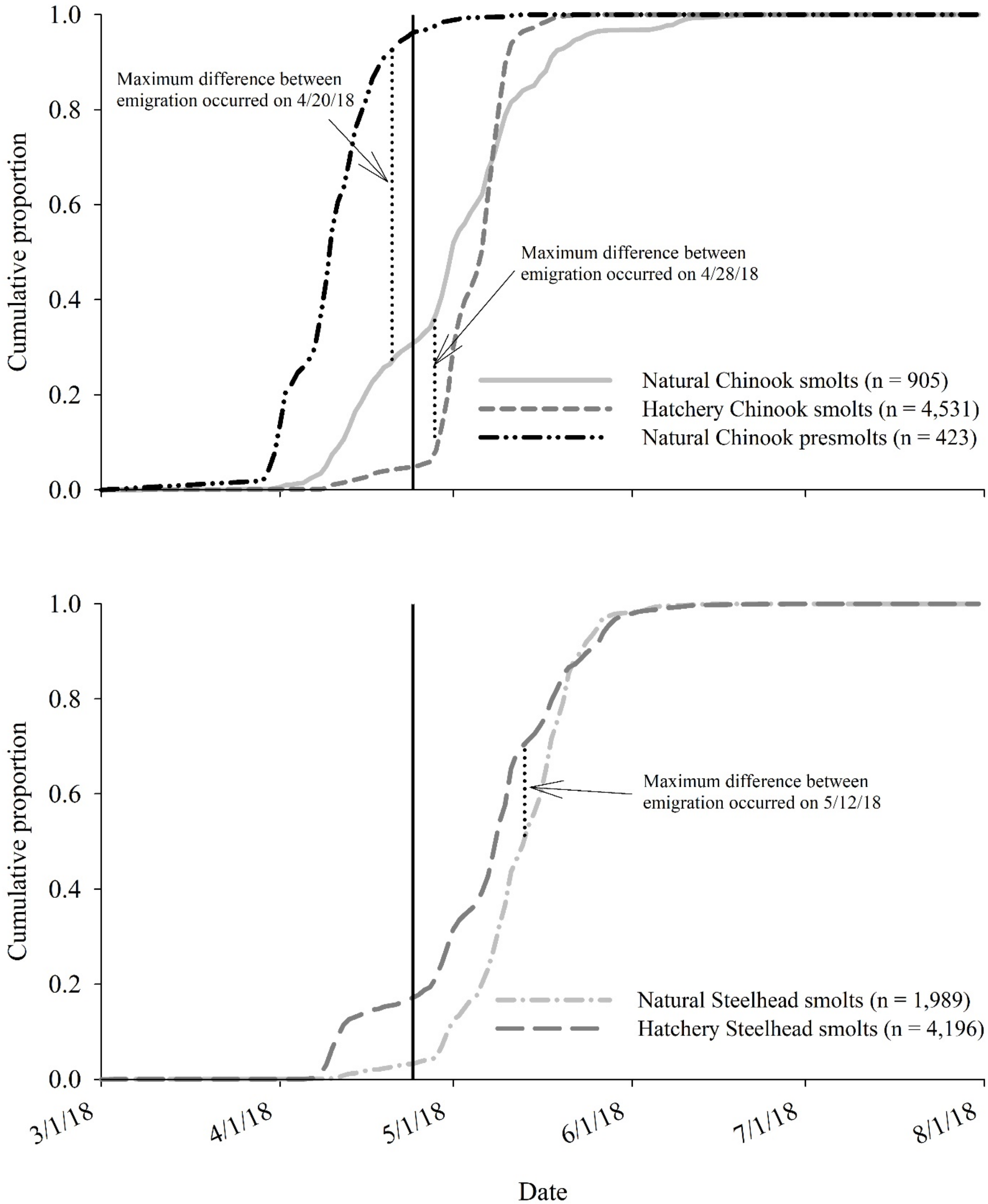

Figure 9. Cumulative proportion and passage date of natural Chinook Salmon presmolts and smolts and hatchery Chinook Salmon smolts at Lower Granite Dam (top panel), and natural and hatchery steelhead smolts at Lower Granite Dam (bottom panel). The solid vertical line represents the start of transportation collections at Lower Granite Dam.

Travel time from the Imnaha River trap to Lower Granite Dam

Emigrant travel time

Juvenile Chinook Salmon travel times from the Imnaha River trap to LGR were calculated for MY2018. Hatchery smolt travel times varied from 3 – 38 days and natural smolt travel times varied from 2 – 122 days (Table 7). During the limited seven-week period when hatchery smolts were observed at LGR, mean travel time steadily increased (except for a single individual the week of 05/20/2018) suggesting that hatchery Chinook Salmon smolt travel time might be more influenced by release date than environmental cues (Table 7 and Figure 10). Additionally, the majority of detections of hatchery Chinook Salmon smolts at LGR occurred during the weeks of 04/29/2018 and 05/06/2018 (Table 7). Conversely, natural Chinook Salmon smolt emigration lasted for fourteen weeks and mean travel time was fairly consistent the weeks of 04/08/2018 – 05/13/2018, when the majority of smolts were detected at LGR (Table 7 and Figure 10). During the latter weeks of emigration, natural Chinook Salmon smolt mean travel time declined as emigrant numbers declined (Table 7 and Figure 10).

Natural and hatchery steelhead smolts traveled the 143 km from the Imnaha River trap to LGR in as little as one day. Travel times for hatchery steelhead smolts ranged from 1 – 53 days, and 1 – 99 days for spring-tagged natural steelhead smolts (Table 8). Mean weekly travel times were seven days or fewer for spring-tagged natural steelhead smolts, and up to 25 days for hatchery steelhead smolts (Table 8 and Figure 11). The majority of spring-tagged natural steelhead smolts were detected at LGR from 04/29/2018 – 05/20/18; hatchery steelhead smolts followed a similar pattern (Table 8).

Fall-tagged natural Chinook Salmon and Steelhead travel times consistently exceeded 100 days (Tables 7 and 8 and Figure 12), which is expected given the time period when the fish were tagged and when smolt monitoring commences at LGR (i.e., begins in late March and continues through late October). It is assumed that fall-tagged Chinook Salmon presmolts rear below the Imnaha River trap but above LGR and begin their emigration to the ocean the following spring (e.g., Achord et al. 2012). Detections of PIT-tagged Chinook Salmon presmolts at LGR in the following spring support this assumption. Fall-tagged steelhead juveniles were also detected at LGR; however, steelhead have been documented as having a complex life history (Harbeck et al. 2016) and therefore preclude us from making similar assumptions about post-tagging migrations. The normal distribution of the weekly count of PIT tag detections suggests that smolt monitoring at LGR captured most of the emigration period for both Chinook Salmon and steelhead tagged in the fall at the Imnaha River trap (Tables 7 and 8). However, the beginning of the natural Chinook Salmon presmolt emigration may have been missed in MY2018 given the observation of 32 presmolts the first week of smolt monitoring at LGR (Table 7).

For a detailed analysis of how dam operations and environmental factors impact emigrant travel time through the hydrosystem and the lower Snake and Columbia rivers, see Chapter 3 of the CSS 2018 Annual Report (McCann et al. 2018).

Table 7. Week of detection at Lower Granite Dam (LGR), count of fish, mean travel time (days), and range travel time (days) from the Imnaha River trap to Lower Granite Dam for natural Chinook Salmon presmolts and smolts and hatchery Chinook Salmon smolts.

Week of detection	Natural Chinook presmolts			Natural Chinook smolts			Hatchery Chinook smolts		
	Count	Mean travel time	Travel time range	Count	Mean travel time	Travel time range	Count	Mean travel time	Travel time range
03/25/2018	32	149	100 - 167	3	22	8 - 49	-	-	-
04/01/2018	95	149	102 - 174	23	31	4 - 90	-	-	-
04/08/2018	194	157	110 - 181	122	16	3 - 98	13	4	3 - 8
04/15/2018	75	164	116 - 185	106	18	4 - 63	18	10	3 - 14
04/22/2018	17	166	143 - 183	80	17	4 - 42	17	19	14 - 23
04/29/2018	7	170	145 - 190	211	15	3 - 122	125	24	13 - 30
05/06/2018	2	203	198 - 207	204	13	2 - 54	142	29	3 - 35
05/13/2018	1	168	168 - 168	89	9	2 - 39	13	32	4 - 38
05/20/2018	-	-	-	35	10	2 - 40	1	5	5 - 5
05/27/2018	-	-	-	2	6	5 - 7	-	-	-
06/03/2018	-	-	-	17	5	3 - 7	-	-	-
06/10/2018	-	-	-	9	6	4 - 9	-	-	-
06/17/2018	-	-	-	3	9	7 - 12	-	-	-
06/24/2018	-	-	-	1	10	10 - 10	-	-	-

Table 8. Week of detection at Lower Granite Dam (LGR), count of fish, mean travel time (days), and range travel time (days) from the Imnaha River trap to Lower Granite Dam for natural steelhead smolts (fall and spring tagged) and hatchery steelhead smolts.

	Natural Steelhead smolts (fall tagged)			Natural Steelhead smolts (spring tagged)			Hatchery Steelhead smolts		
Week of detection	Count	Mean travel time	Travel time range	Count	Mean travel time	Travel time range	Count	Mean travel time	Travel time range
04/01/2018	-	-	-	1	5	5 - 5	-	-	-
04/08/2018	5	167	153 - 178	20	6	2 - 23	54	4	2 - 7
04/15/2018	2	182	182 - 182	28	7	2 - 28	9	9	5 - 14
04/22/2018	4	179	169 - 187	33	7	3 - 29	24	16	2 - 25
04/29/2018	16	176	146 - 199	238	6	2 - 48	61	20	3 - 31
05/06/2018	8	190	181 - 203	569	4	1 - 47	127	16	1 - 38
05/13/2018	1	189	189 - 189	574	4	2 - 99	68	10	1 - 44
05/20/2018	2	194	176 - 211	392	4	1 - 62	37	11	1 - 53
05/27/2018	-	-	-	70	5	2 - 21	12	25	1 - 53
06/03/2018	-	-	-	18	3	2 - 5	2	2	2 - 2
06/10/2018	-	-	-	6	3	2 - 4	2	16	2 - 29
06/17/2018	-	-	-	1	7	7 - 7	-	-	-

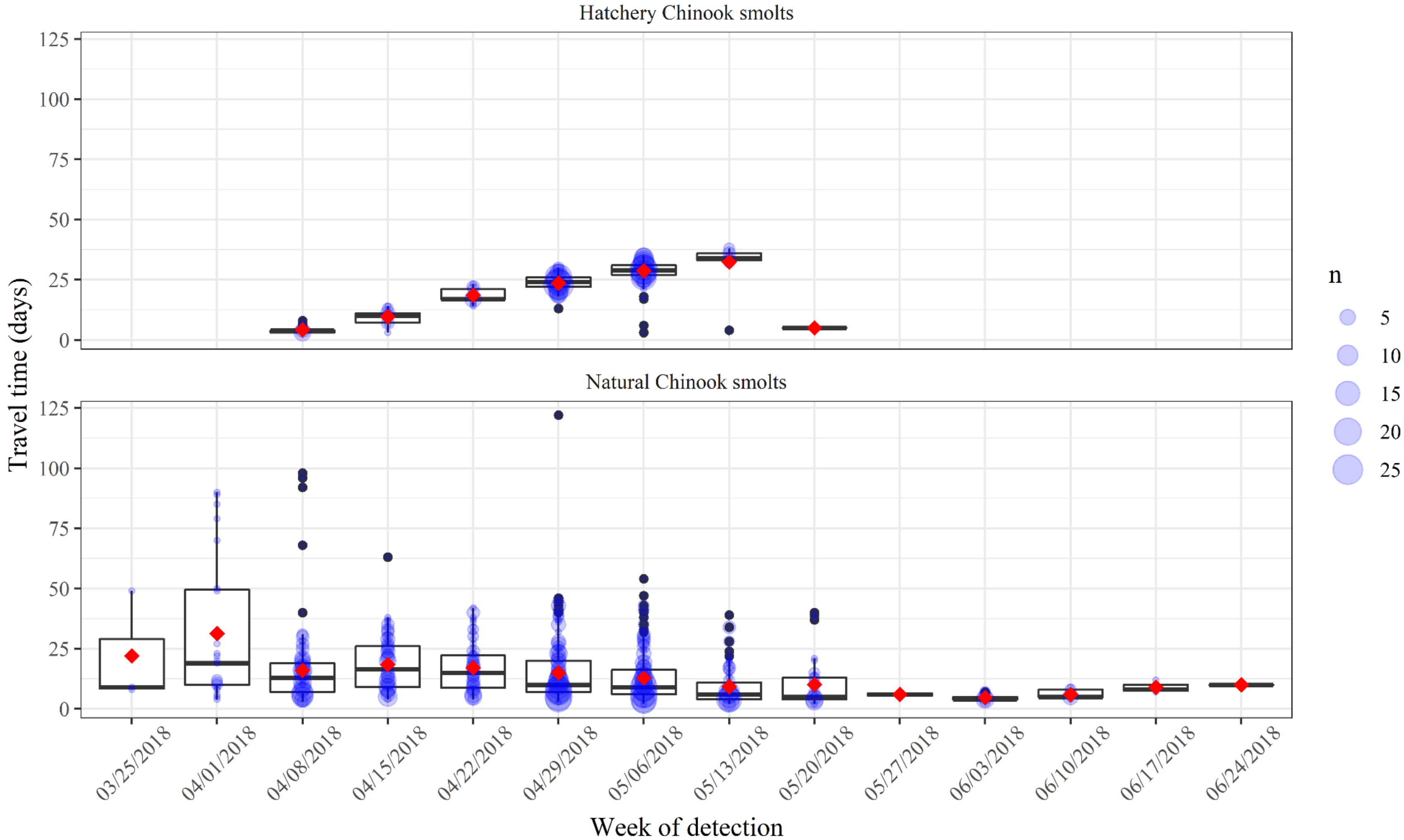

Figure 10. Travel time for smolts (blue circle size corresponds to the count [n] of smolts) from the Imnaha River trap to Lower Granite Dam for hatchery Chinook Salmon smolts (top panel) and natural Chinook Salmon smolts (bottom panel) summarized by week of detection at Lower Granite Dam. Mean travel time (red diamond) and box plots (25th percentile, median, and 75th percentile) of the weekly travel time data.

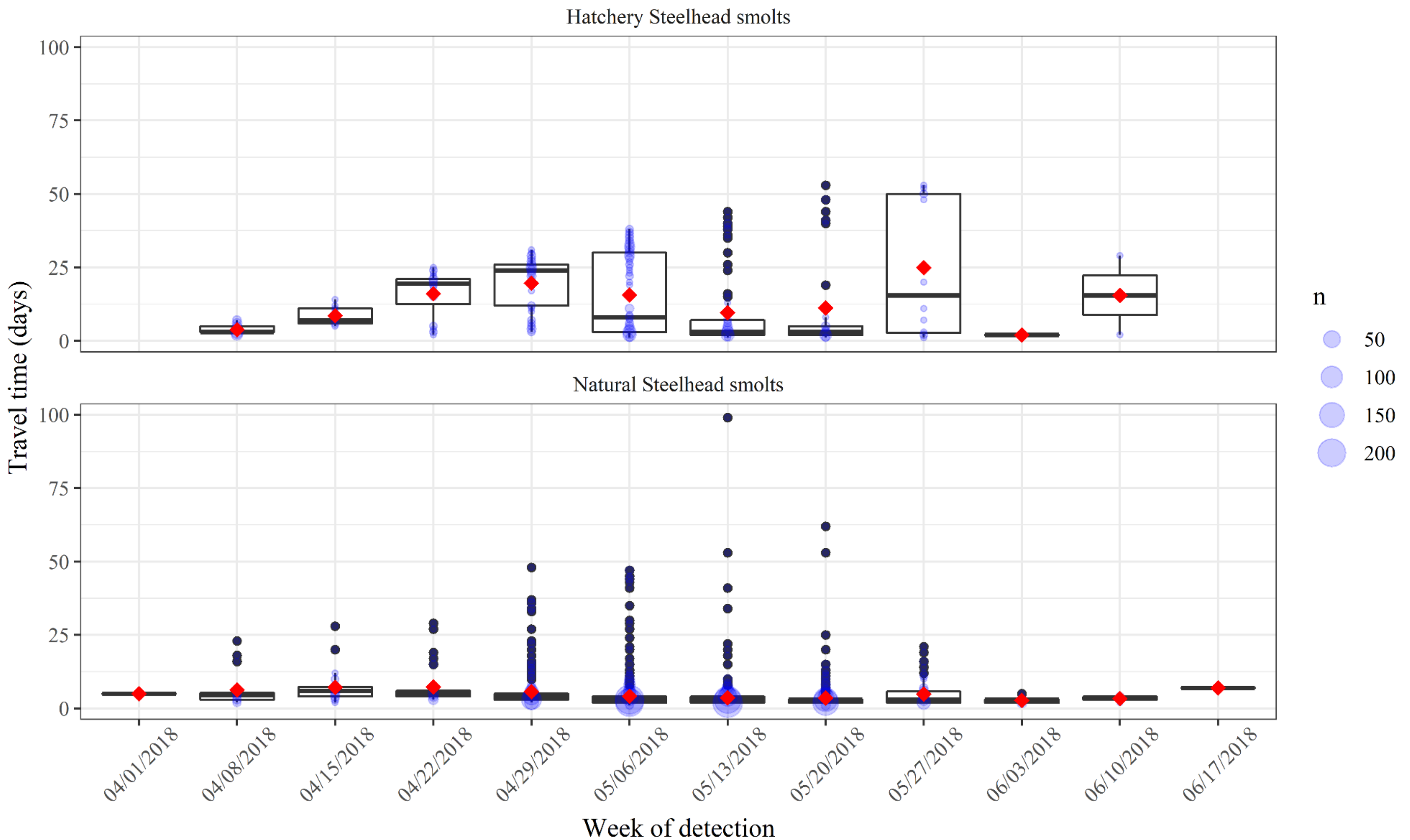

Figure 11. Travel time for smolts (blue circle size corresponds to the count [n] of smolts) from the Imnaha River trap to Lower Granite Dam for hatchery steelhead smolts (top panel) and natural steelhead smolts (bottom panel) summarized by week of detection at Lower Granite Dam. Mean travel time (red diamond) and box plots (25th percentile, median, and 75th percentile) of the weekly travel time data.

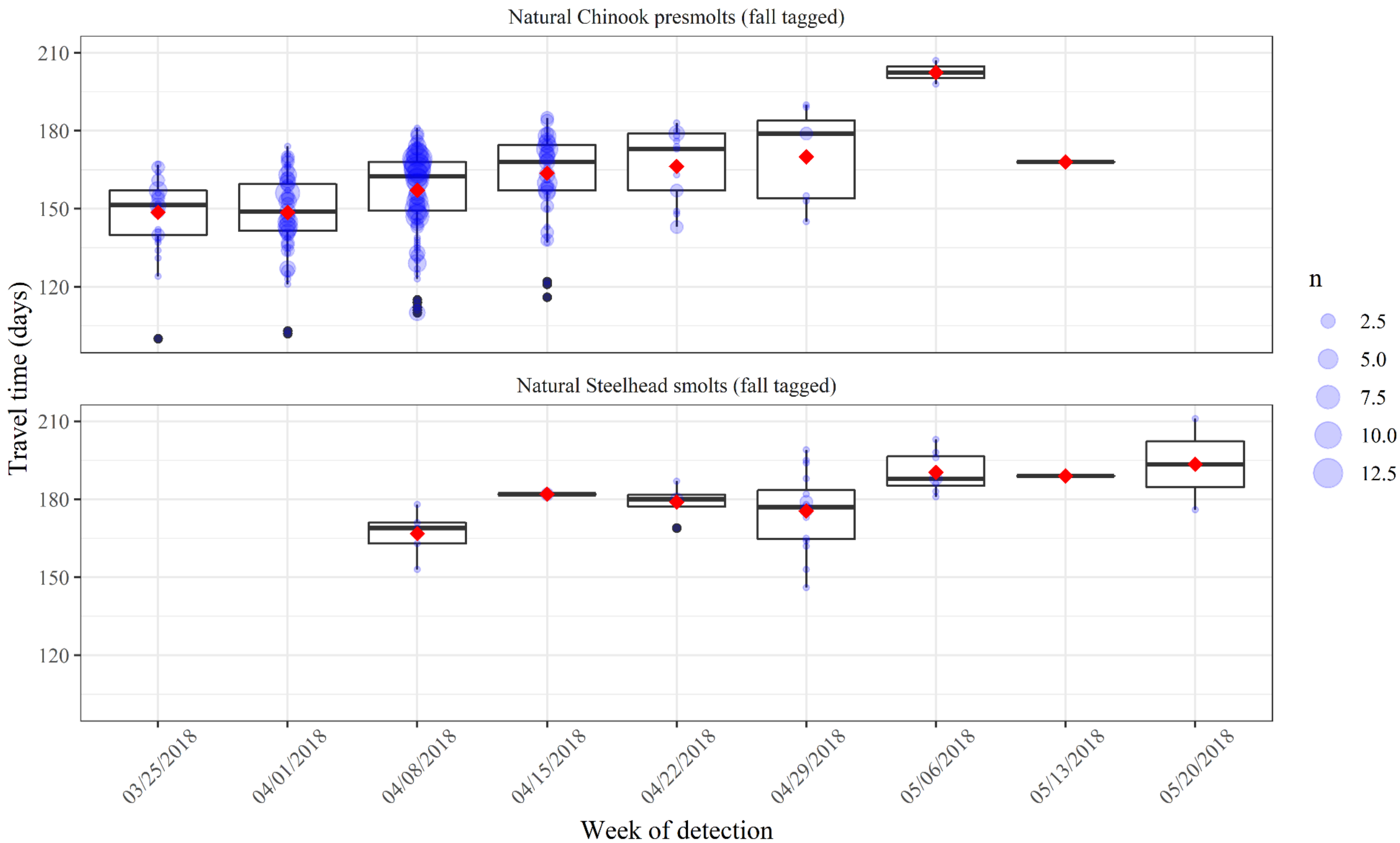

Figure 12. Travel time for smolts (blue circle size corresponds to the count [n] of smolts) from the Imnaha River trap to Lower Granite Dam for fall-tagged natural Chinook Salmon presmolts (top panel) and fall-tagged natural steelhead smolts (bottom panel) summarized by week of detection at Lower Granite Dam. Mean travel time (red diamond) and box plots (25^{th} percentile, median, and 75^{th} percentile) of the weekly travel time data.

Life-stage and reach specific estimates of juvenile emigrant survival

Post-release survival of hatchery smolts

Estimated survival rates for both species of hatchery smolts from release to the Imnaha River trap during MY2018 were higher than their respective mean survival estimates (Table 9). Steelhead survival exceeded 1.00 which inflates steelhead smolt equivalents beyond what was initially released at the acclimation facility (Tables 1 and 9). The error associated with estimating survival can result in an estimated survival rate greater than 1.0, especially when survival rates are high.

Table 9. Hatchery Chinook Salmon and steelhead smolt survival estimates and 95% confidence intervals (95% CI) from release to the Imnaha River trap, mean survival from 1994 – 2018 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 - 2018	Smolt equivalents (95% CI)
Chinook Salmon	0.99 (0.89 – 1.10)	0.91	483,594 (432,544 – 534,644)
Steelhead	1.05 (0.98 – 1.14)	0.84	263,769 (243,839 – 284,705)

Survival from Imnaha River trap to Lower Granite Dam

Natural Chinook Salmon survival from the Imnaha River trap to LGR was estimated for presmolts and smolts independently and collectively during MY2018. Estimated survival of presmolts was 0.35 (0.33 – 0.38) [mean (95% CI)] compared to 0.71 (0.68 – 0.75) for smolts. Estimated presmolt survival incorporates the over-winter survival of fish below the Imnaha River trap but above LGR; whereas, smolt survival is from the time tagging occurs on or after January 1 to when fish emigrate past LGR. The MY2018 natural Chinook Salmon cohort survival estimate from the Imnaha River trap to LGR was 0.52 (0.49 – 0.54). Survival of hatchery Chinook Salmon smolts from the Imnaha River trap to LGR was 20% higher than natural Chinook Salmon smolts (Table 10). Natural Chinook Salmon presmolt and smolt equivalent estimates at LGR were very similar during MY2018 (Table 10). Hatchery Chinook Salmon smolt equivalents was almost six times that of the natural Chinook Salmon cohort (Table 10).

Natural and hatchery steelhead smolt survival from the Imnaha River trap to LGR for MY2018 was estimated at 0.82 (0.79 – 0.85) and 0.94 (0.87 – 1.02), respectively (Table 10). Hatchery steelhead smolt equivalents was almost five times that of the natural steelhead smolts (Table 10).

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 adult returns, can be found in the Comparative Survival Study reports located at http://www.fpc.org/documents/CSS.html.

Decreasing survival as fish migrate downstream from LGR to MCN is expected for Chinook Salmon and steelhead emigrants. During MY2018, the decline in Chinook Salmon emigrant survival was considerably less than the decline in steelhead emigrant survival as fish migrated through the lower Snake River corridor (Table 10). However; the 95% confidence intervals associated with survival estimates for all emigrants at MCN are wider than those associated with survival estimates to LGR, suggesting fewer detections at MCN and increasing uncertainty around the point estimate. Additionally, the survival to MCN 95% confidence intervals often overlap with the survival to LGR 95% confidence intervals, so survival estimates should be interpreted in a holistic context.

Table 10. 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 presmolts	0.35 (0.33 – 0.38)	0.37 (0.29 – 0.46)	24,584 (18,783 – 30,385)
Natural Chinook smolts	0.71 (0.68 – 0.75)	0.53 (0.42 – 0.67)	25,885 (21,878 – 29,893)
Natural Chinook cohort	0.52 (0.49 – 0.54)	0.45 (0.38 – 0.55)	54,749 (45,419 – 64,078)
Hatchery Chinook smolts	0.65 (0.58 – 0.74)	0.66 (0.39 – 0.99)	313,756 (263,534 – 363,978)
Natural Steelhead smolts	0.82 (0.79 – 0.85)	0.54 (0.40 – 0.78)	51,614 (43,504 – 59,724)
Hatchery Steelhead smolts	0.94 (0.87 – 1.02)	0.69 (0.47 – 1.03)	247,279 (218,907 – 275,652)

Trends in juvenile survival for migration years 1993 through 2018

Post-release survival of hatchery smolts

The trend in hatchery smolt survival rates from release to the Imnaha River trap have been either steady or increasing over the years (Figure 13). Hatchery Chinook Salmon smolt mean survival from 1994 – 2018 is 0.91 ± 0.08 (mean ± standard deviation) and simple linear regression suggests that the trend is neither significantly increasing or decreasing ($p = 0.985$). Hatchery steelhead smolt mean survival from 1994 – 2018 is 0.84 ± 0.11 and simple linear regression suggests that the trend is significantly increasing ($p = 0.04$) with time.

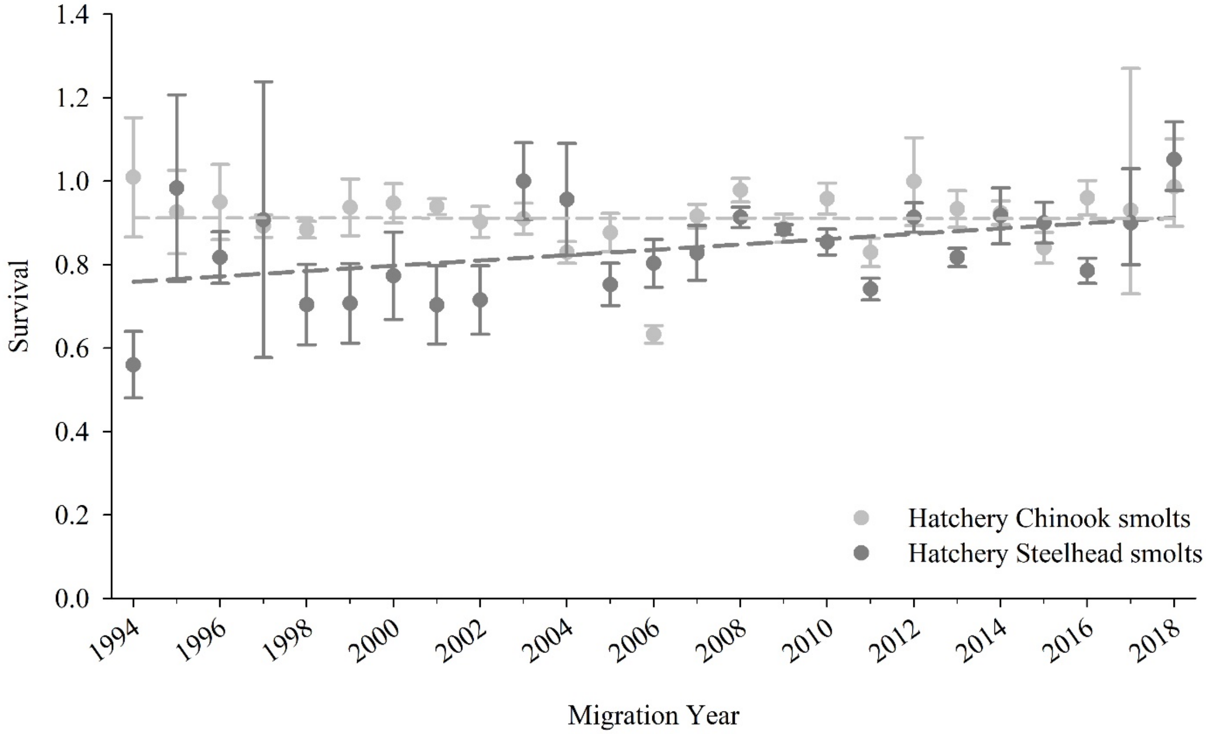

Figure 13. Hatchery Chinook Salmon and steelhead smolt survival estimates and 95% confidence intervals from release to the Imnaha River trap for migration years 1994 – 2018.

Survival from the Imnaha River trap to Lower Granite Dam

Chinook Salmon emigrant survival to Lower Granite Dam

Chinook Salmon survival from the Imnaha River trap to LGR was estimated for natural smolts (migration years 1993 – 2018), natural presmolts (migration years 1994 – 2018), and hatchery smolts (migration years 1994 – 2018). Natural Chinook Salmon smolt mean survival to LGR was 0.79 ± 0.06 for migration years 1993 – 2018 and ranged from 0.67 (0.65 – 0.69) to 0.91 (0.84 – 0.98) in migration years 2016 and 1995, respectively. Survival since migration year 2015 has been less than 0.80 and recently migration year 2016 had the lowest estimated survival to LGR on record (Figure 14). Simple linear regression suggested a significant ($p = 0.001$) negative trend in survival of natural Chinook Salmon smolts to LGR over time (Figure 14).

Natural Chinook Salmon presmolt mean survival to LGR was 0.33 ± 0.09 for migration years 1994 – 2018, and ranged from 0.17 (0.15 – 0.18) in 2006 to 0.61 (0.56 – 0.65) in 1998. Simple linear regression suggested a weak negative, non-significant ($p = 0.234$) trend in presmolt survival over time (Figure 14). As mentioned earlier, presmolt survival estimates from the Imnaha River trap to LGR incorporate over-winter survival of these fish below the trap but above LGR.

Hatchery Chinook Salmon smolt survival to LGR was generally lower than natural Chinook Salmon smolt survival. Hatchery Chinook Salmon smolt mean survival from the Imnaha River trap to LGR was 0.71 ± 0.05 for migration years 1994 – 2018 and ranged from 0.61 (0.57 – 0.65) to 0.80 (0.72 – 0.88) in migration years 2005 and 1997, respectively (Figure 14). Simple linear regression suggested a weak negative, non-significant (p = 0.226) trend in survival of hatchery Chinook Salmon smolts to LGR over time (Figure 14). Survival estimates for hatchery and natural smolts from the Imnaha River trap to LGR had a moderately strong, positive correlation (Pearson correlation coefficient = 0.67), which may suggest the two emigrant groups experience and are impacted similarly by environmental and anthropogenic conditions.

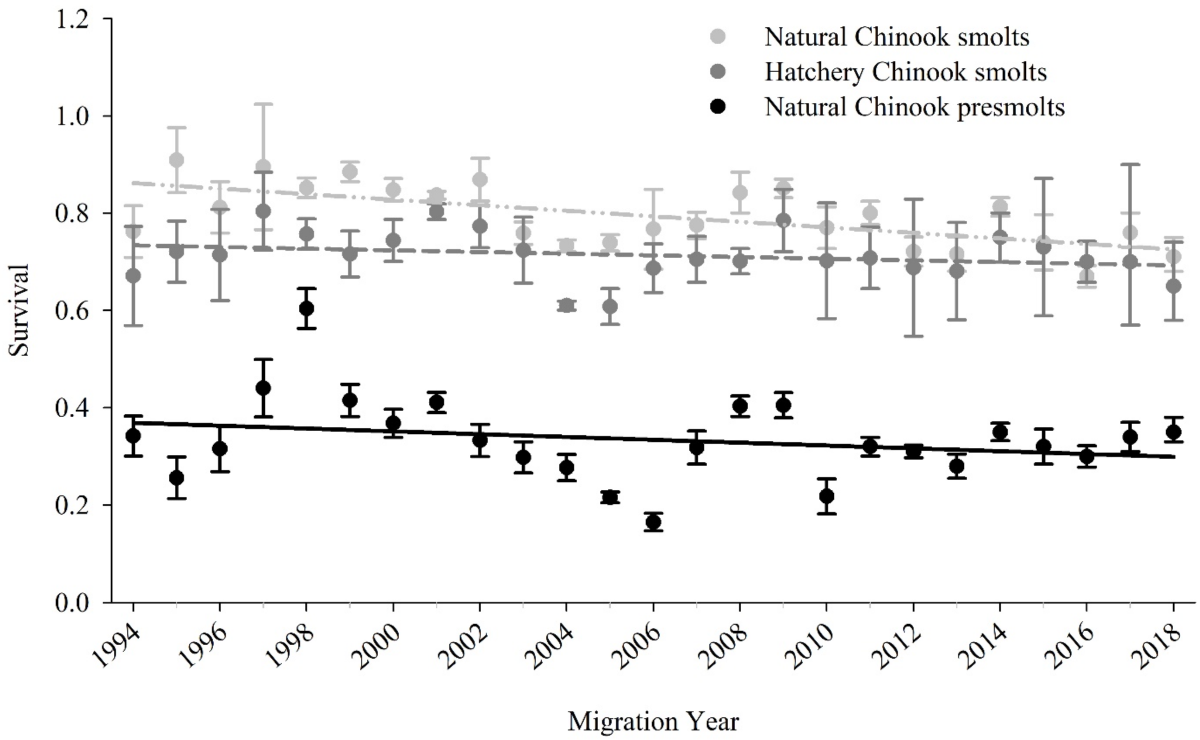

Figure 14. Survival estimates and 95% confidence intervals for natural and hatchery Chinook Salmon smolts from the Imnaha River trap to Lower Granite Dam during migration years 1994 – 2018. The dashed lines represent the line of best fit from a simple linear regression for each emigrant group.

Steelhead smolt survival to Lower Granite Dam

Steelhead smolt survival from the Imnaha River trap to LGR was estimated for natural and hatchery smolts (migration years 1995 – 2018). Natural steelhead smolt mean survival to LGR was 0.86 ± 0.05 for migration years 1995 – 2018 and ranged from 0.79 (0.74 – 0.83) to 1.00 (0.85 – 1.15) in migration years 2007 and 2013, respectively. Simple linear regression suggested a weak positive, but non-significant (p = 0.485) trend in survival over time for natural steelhead smolts (Figure 15). Survival was slightly higher over the last half of the record but with higher interannual variation than the first half of the record (Figure 15). Survival rates for migration years 2016 – 2018 have been very similar (Figure 15).

Mean survival from the Imnaha River trap to LGR for migration years 1995 – 2018 was similar for hatchery and natural steelhead smolts but survival varied considerably between the two emigrant groups within years (Figure 15). Hatchery steelhead smolt mean survival to LGR was 0.87 ± 0.07 for migration years 1995 – 2018 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 ($p = 0.001$) positive trend in survival over time for hatchery steelhead smolts (Figure 15). Survival of hatchery steelhead smolts in migration year 2018 was higher (0.94) than the overall average. Unlike Chinook Salmon smolts, there was no strong relationship between survival of natural and hatchery steelhead smolts (Pearson correlation coefficient = -0.13). Therefore, environmental and anthropogenic conditions may be impacting the two emigrant groups differently.

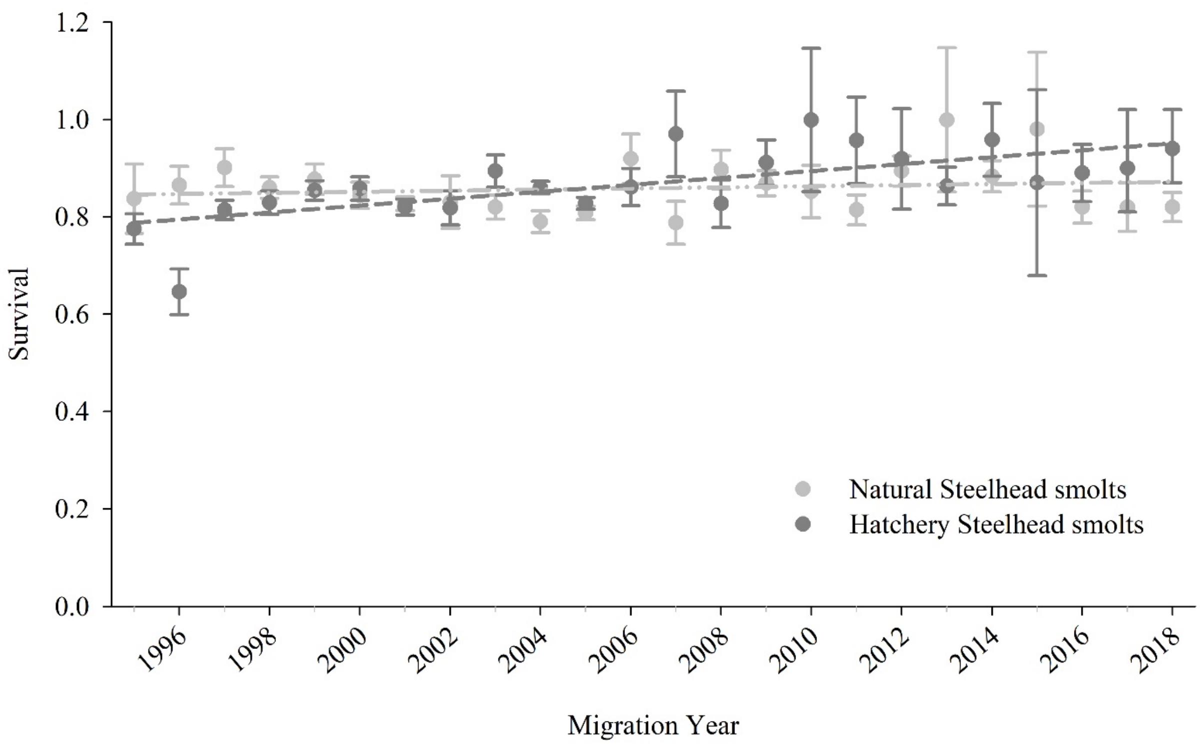

Figure 15. Survival estimates and 95% confidence intervals for natural and hatchery steelhead smolts from the Imnaha River trap to Lower Granite Dam during migration years 1995 – 2018. The dashed lines represent the line of best fit from a simple linear regression for each emigrant group.

Survival from the Imnaha River trap to McNary Dam

Chinook Salmon smolt survival to McNary Dam

Natural Chinook Salmon smolts had the highest mean survival from the Imnaha River trap to MCN of all the emigrant groups. Natural Chinook Salmon smolt mean survival was 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 16). Simple linear regression suggested no significant (p = 0.448) trend in survival over time for natural Chinook Salmon smolts (Figure 16). Migration year 2018 was the one of the lower survival rates estimated for natural Chinook Salmon smolts.

Hatchery Chinook Salmon smolt mean survival was 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 (p = 0.456) trend in survival over time for hatchery Chinook Salmon smolts (Figure 16). Migration year 2018 was one of the higher survival rates estimated for hatchery Chinook Salmon smolts over the years. Survival from the Imnaha River trap to MCN for natural and hatchery Chinook Salmon smolts had a moderately strong, negative correlation (Pearson correlation coefficient = -0.44).

Steelhead smolt survival to McNary Dam

Natural steelhead smolt mean survival from the Imnaha River trap to MCN was 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 (p = 0.147) trend in survival over time for natural steelhead smolts (Figure 16). Survival from the Imnaha River trap to MCN for migration year 2018 was below average.

Hatchery steelhead smolt mean survival from the Imnaha River trap to MCN was 0.63 ± 0.19 and ranged from 0.14 (0.10 – 0.18) to 0.89 (0.66 – 1.12) in 2001 and 2012, respectively (Figure 16). Simple linear regression suggested a significant positive (p = 0.004) trend in survival over time for hatchery steelhead smolts (Figure 16). Survival from the Imnaha River trap to MCN in migration year 2018 was above average. Survival from the Imnaha River trap to MCN for natural and hatchery steelhead smolts had a strong, positive correlation (Pearson correlation coefficient = 0.66).

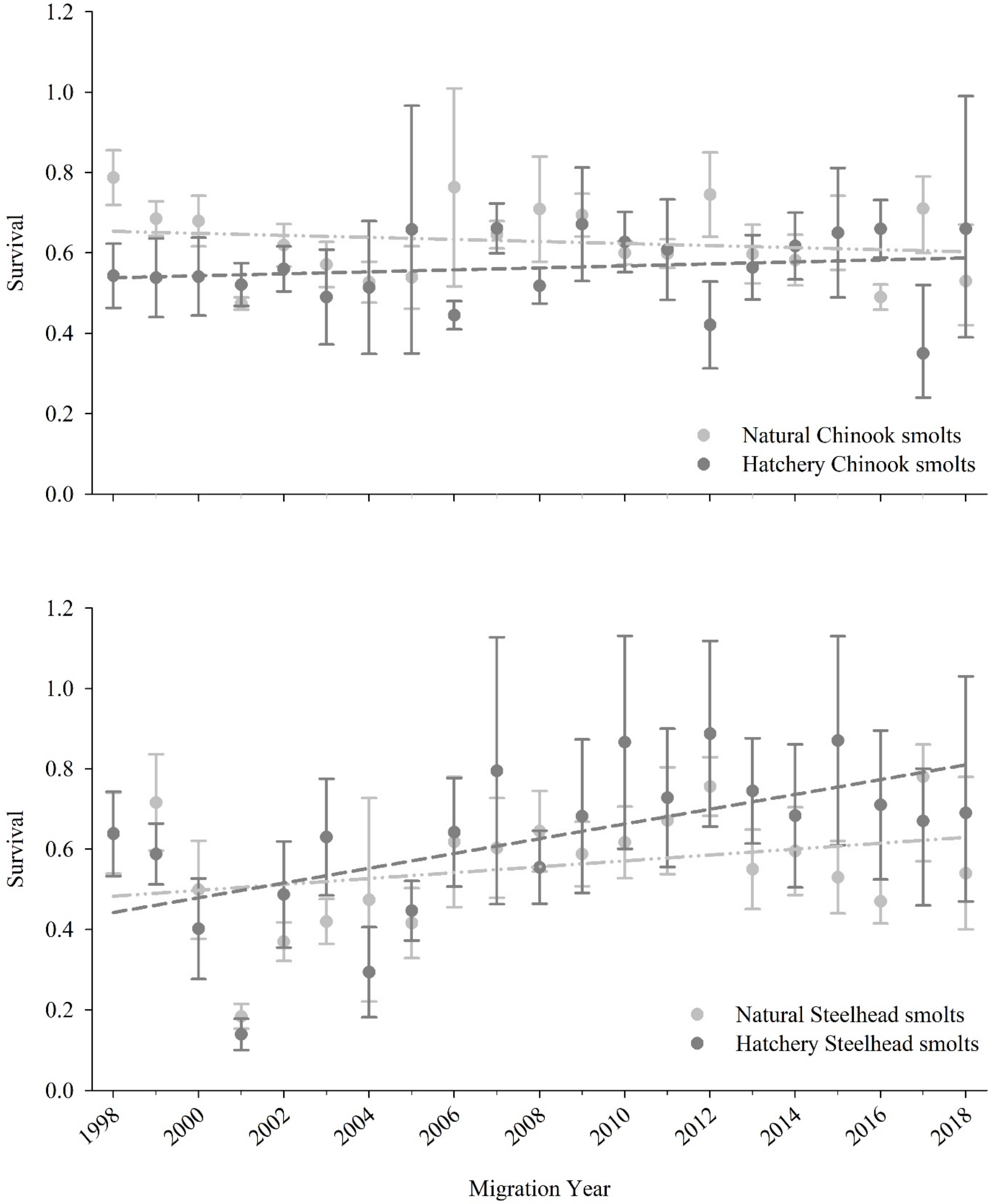

Figure 16. Survival estimates and 95% confidence intervals for natural and hatchery Chinook Salmon and steelhead smolts from the Imnaha River trap to McNary Dam during migration years 1998 – 2018. The dashed lines represent the line of best fit from a simple linear regression for each emigrant group.

Size and condition of juveniles at emigration

Mean fork length, weight, and condition varied by species and emigrant group. Natural Chinook Salmon presmolts, on average, were smaller and had a lower condition factor than natural and hatchery Chinook Salmon smolts (Table 11). Natural Chinook Salmon smolts had a smaller mean fork length and weight and lower mean condition factor than hatchery Chinook Salmon smolts (Table 11 and Figure 17), which has been the trend over the years. Similarly, natural steelhead smolts consistently had a smaller mean fork length and weight and lower mean condition factor than hatchery steelhead smolts (Table 11 and Figure 18).

Table 11. 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
	Sample size	4,349	3,696	1,712	5,699	1,897
Fork length (mm)	Mean	85.3	100.4	117.4	168.8	215.9
	Minimum	51.0	55.0	93.0	63.0	130.0
	Maximum	124.0	147.0	154.0	298.0	335.0
	Standard deviation	9.2	9.3	8.0	27.4	21.7
Weight (g)	Mean	6.8	11.3	19.2	52.1	106.2
	Minimum	1.4	1.9	9.2	2.2	25.5
	Maximum	19.4	33.9	52.7	281.1	382.6
	Standard deviation	2.1	3.3	4.08	23.7	33.0
Fulton condition factor	Mean	1.04	1.09	1.18	1.02	1.03
	Minimum	0.69	0.50	0.73	0.57	0.57
	Maximum	2.15	2.27	2.16	2.25	2.18
	Standard deviation	0.10	0.13	0.13	0.10	0.10

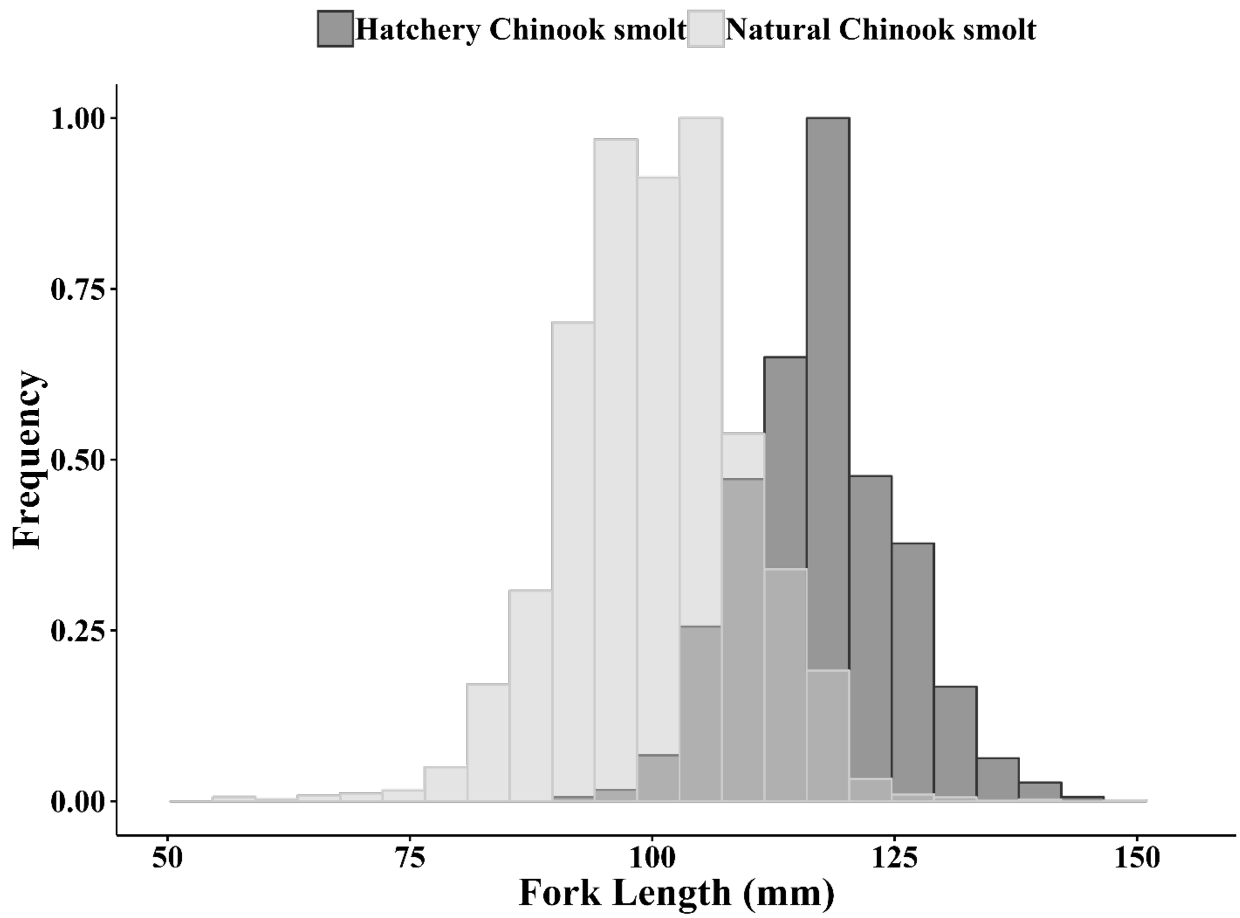

Figure 17. Fork length frequency distributions of natural and hatchery Chinook Salmon smolts captured at the Imnaha River trap during the spring trapping season.

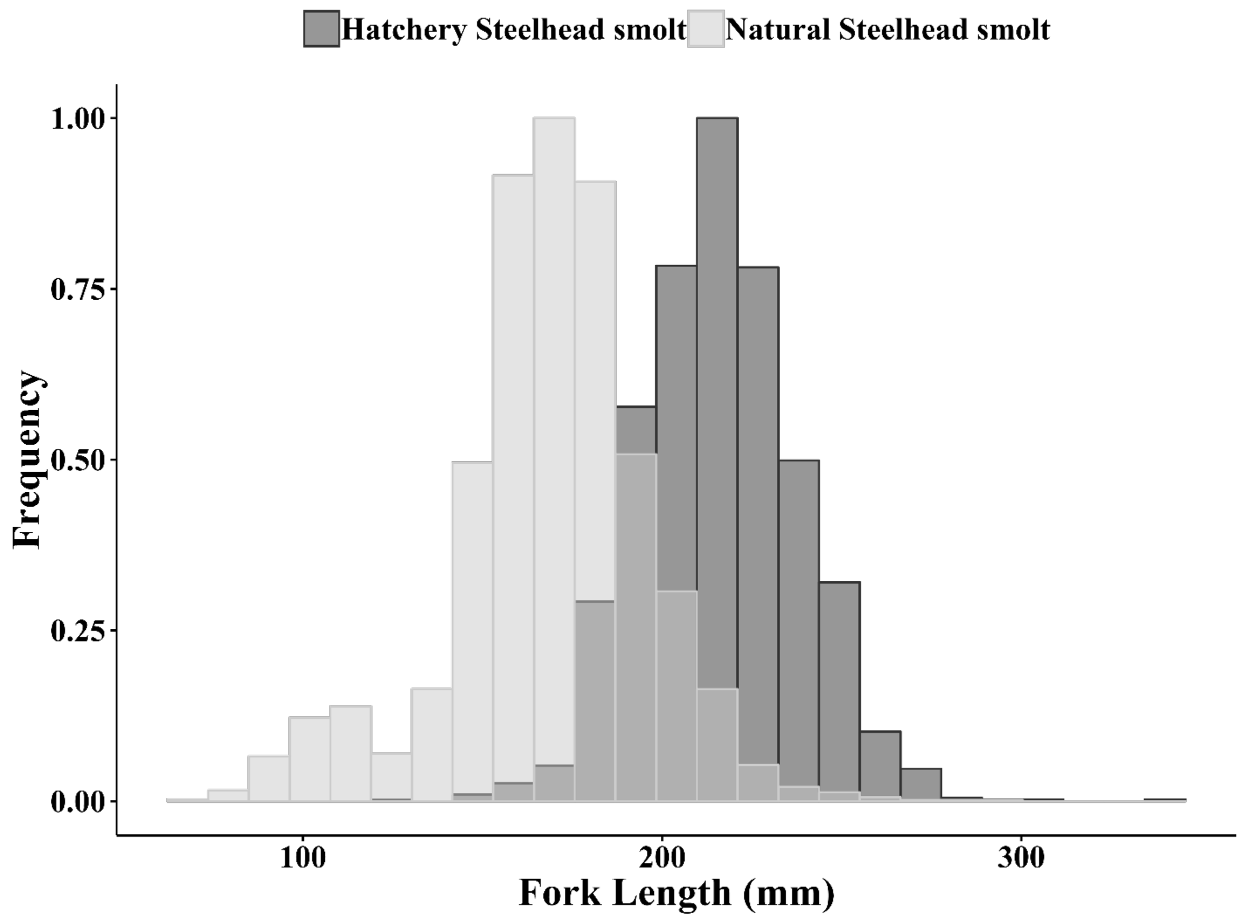

Figure 18. Fork length frequency distributions of natural and hatchery steelhead smolts captured at the Imnaha River trap during the spring trapping season.

Smolt to adult return rates

Smolt to adult return rates for Chinook Salmon

Adult returns in 2018 allowed for the estimation of smolt to adult return (SAR) rates to BY2013 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.

As with previous years, Imnaha River Chinook Salmon BY2013 adult returns to LGR remain well below the target (SAR 2% – 4%) set forth by the Northwest Power and Conservation Council, with <1% of adults returning for all emigrant groups and SbyC tag groups except for survival mode tagged natural Chinook Salmon presmolts (Tables 12 and 13). Mean SAR rates for monitor mode Chinook Salmon emigrant groups are slightly higher than survival mode Chinook Salmon emigrant groups (Tables 12 and 13). Among both SbyC tag mode groups, presmolts have the highest mean SAR (Tables 12 and 13). The data suggest that management actions at the dams associated with Chinook Salmon emigrants in the monitor mode tag group and presmolts, regardless of SbyC tag group, may be more likely to return to the Imnaha River to spawn as adults. Additionally, hatchery Chinook Salmon smolts (survival and monitor tags combined) returned at earlier ages than natural smolts and presmolts (Table 17). However, this analysis relies on PIT tag interrogations at hydrosystem facilities which results in small sample sizes (i.e., few or no adult PIT tag detections) during some years (e.g., Tables 12 and 13) reducing the amount of power we have to detect changes in SAR rates.

Smolt to adult return rates for steelhead

Natural steelhead smolts emigrate at variable ages; therefore, it was not possible to calculate 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. SAR rates 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 2018 completed the MY2016 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).

Steelhead SAR rates for MY2016 were higher than Chinook Salmon SAR rates; however, all steelhead emigrant groups and SbyC tag groups fell below the 2% target with survival mode natural steelhead SAR rates being the poorest at 0.47% (Table 15). Migration year 2016 SAR rates was an improvement for all groups over MY2015 SAR rates (Table 15). Hatchery steelhead tend to return at a younger age than natural steelhead (Table 16). For a detailed analysis and discussion of tributary to tributary steelhead SAR rates, see Harbeck et al. 2018.

Table 12. 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 – 2013.

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%
2013	881	319	1	--	1	--	0.31%
Mean							1.15%
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%
2013	1,568	302	6	0	5	1	1.99%
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%
2013	3,474	1,375	3	1	2	--	0.22%
Mean							1.01%

Table 13. 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 – 2013.

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	1,349	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%
2013	2,023	764	4	--	4	--	0.52%
Mean							1.86%
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%
2013	1,567	337	1	--	1	--	0.30%
Mean							2.21%
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%
2013	3,468	1,387	11	1	10	--	0.79%
Mean							1.22%

Table 14. The total returns at age (survival and monitor mode tags combined) for natural and hatchery Chinook Salmon from brood years 2006 – 2013.

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	183	98	80	5	53.6%	43.7%	2.7%
Natural Chinook presmolts	278	64	188	26	23.0%	67.6%	9.4%
Natural Chinook smolts	285	36	193	56	12.6%	67.7%	19.6%

Table 15. 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 – 2016.

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%
2015	2016	568	382	7	6	1	--	1.83%
Mean								1.70%
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%
2015	2016	690	481	7	6	1	--	1.45%
Mean								1.70%
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%
	2016	2,388	1,476	7	5	2	--	0.47%
Mean								1.47%
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%
	2016	2,392	1,435	19	15	4	--	1.32%
Mean								2.20%

Table 16. The total returns at age of all returning adults (monitor and survival tags combined) for natural and hatchery steelhead for migration years 2009 – 2016.

Emigrant group	Total Returns	Ocean Age I	Ocean Age II	Ocean Age III	Ocean Age I	Ocean Age II	Ocean Age III
Hatchery steelhead	160	105	55	--	65.6%	34.4%	0.0%
Natural steelhead	537	287	247	3	53.4%	46.0%	0.6%

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Appendices

Appendix A. 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 MY2018.

Trapping Period	Capture	TE Mark	Recap	TE	N	Lower CI	Upper CI	SE
10/06/17-10/17/17	441	240	27	0.11	3,796	2,651	5,378	708
10/18/17-10/26/17	1,485	430	37	0.09	16,843	12,491	22,952	2,658
10/27/17-10/29/17	483	150	43	0.29	1,658	1,276	2,175	223
10/30/17-11/05/17	604	256	25	0.10	5,970	4,134	8,588	1,166
11/06/17-11/09/17	354	167	23	0.14	2,478	1,726	3,801	530
11/10/17-11/19/17	842	476	16	0.03	23,626	14,910	38,980	6,229
11/20/17-12/21/17	514	451	14	0.03	15,489	9,594	26,167	4,477
Presmolt Total	4,723	2,170	185	0.09	69,860	56,429	86,591	8,006
Trapping Period	Capture	TE Mark	Recap	TE	N	Lower CI	Upper CI	SE
01/01/18-03/20/18	340	315	14	0.04	7,163	4,467	12,563	2,044
03/21/18-03/23/18	109	87	18	0.21	505	332	785	121
03/25/18-04/03/18	689	400	55	0.14	4,934	3,855	6,371	640
04/04/18-04/08/18	349	173	23	0.13	2,530	1,751	3,840	541
04/09/18-04/17/18	550	413	37	0.09	5,992	4,429	8,152	976
04/18/18-04/29/18	731	514	50	0.10	7,382	5,688	9,690	1042
04/30/18-05/05/18	259	214	27	0.13	1,989	1,378	2,963	404
05/06/18-05/15/18	261	178	18	0.10	2,459	1,611	3,760	579
05/16/18-05/21/18	101	78	7	0.09	997	498	1,955	414
05/22/18-06/05/18	94	81	9	0.11	771	410	1,661	324
06/06/18-06/12/18	122	120	15	0.13	923	563	1,609	257
06/13/18-06/17/18	35	43	10	0.23	140	76	264	48
06/18/18-07/12/18	79	62	7	0.11	622	325	1,324	259
Smolt Total	3,719	2,678	290	0.11	36,407	31,797	42,371	2,718
Chinook Cohort Total	8,442	4,848	475	0.10	106,267	91,491	124,795	8,949

Appendix B. 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 MY2018.

Trapping Period	Capture	TE Mark	Recap	TE	N	Lower CI	Upper CI	SE
10/09/17-11/03/17	134	123	7	0.06	2,077	1,096	4,795	926
11/04/17-11/11/17	126	106	13	0.12	963	576	1,697	290
11/12/17-04/08/18	269	213	10	0.05	5,233	2,824	9,416	1,739
04/09/18-04/18/18	210	230	31	0.14	1,516	1,093	2,204	288
04/19/18-04/24/18	217	180	10	0.06	3,571	2,047	6,557	1,196
04/25/18-04/28/18	603	188	17	0.09	6,332	4,100	9,966	1,492
04/29/18-05/09/18	1,766	354	39	0.11	15,673	12,002	21,630	2,471
05/10/18-05/17/18	1,413	303	30	0.10	13,857	10,055	19,805	2,547
05/18/18-05/31/18	948	345	32	0.09	9,940	7,204	13,951	1,762
06/01/18-06/06/18	190	191	17	0.09	2,027	1,275	3,422	540
06/07/18-06/09/18	41	40	8	0.20	187	101	349	76
06/10/18-06/26/18	110	122	7	0.06	1,691	840	3,413	794
Smolt Total	6,027	2,395	221	0.09	63,067	54,338	73,881	4,942

Appendix C. Population estimates and 95% confidence intervals (CI) for natural Chinook Salmon and steelhead emigrating from the Imnaha River for migration years 2007 - 2018.

	Natural Chinook Salmon					Natural Steelhead		
Migration year	Presmolt estimate	Smolt estimate	Cohort estimate	Cohort lower 95% CI	Cohort upper 95% CI	Smolt 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
2018	69,860	36,407	106,267	91,491	124,795	63,067	54,338	73,881
Mean	70,927	49,328	120,747	102,332	147,517	50,104	42,386	60,485
SD	38,952	13,671	38,244	31,638	53,944	10,450	10,653	11,675
CV	54.9	27.7	31.7	30.9	36.6	20.9	25.1	19.3

Appendix D. 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 2018.

Fall 2017

	Chinook				Steelhead			
	Natural		Hatchery		Natural		Hatchery	
Source of Mortality	N	Total Trapped (%)	N	Total Trapped (%)	N	Total Trapped (%)	N	Total Trapped (%)
Trapping	3	0.06	0	0.00	0	0.00	0	0.00
Handling	0	0.00	0	0.00	0	0.00	0	0.00
Tagging	0	0.00	0	0.00	0	0.00	0	0.00
Predation	1	0.02	0	0.00	0	0.00	0	0.00
DOA	0	0.00	0	0.00	0	0.00	0	0.00
Total	4	0.08	0	0.00	0	0.00	0	0.00

Spring 2018

	Chinook				Steelhead			
	Natural		Hatchery		Natural		Hatchery	
Source of Mortality	N	Total Trapped (%)	N	Total Trapped (%)	N	Total Trapped (%)	N	Total Trapped (%)
Trapping	45	1.12	16	0.04	124	2.10	219	1.01
Handling	1	0.02	2	0.01	1	0.02	0	0.00
Tagging	6	0.15	0	0.00	3	0.05	0	0.00
Predation	1	0.02	0	0.00	3	0.05	0	0.00
DOA	0	0.00	2	0.01	1	0.02	1	0.00
Total	53	1.32	20	0.05	132	2.24	220	1.01