BPA instituted new reporting requirements in 2012. This report was not submitted to BPA.
This report is the Grande Ronde Salmonid Early Life History Project annual data report for Migratory Year 2016.

INVESTIGATIONS INTO THE EARLY LIFE HISTORY OF NATURALLY PRODUCED SPRING CHINOOK SALMON AND SUMMER STEELHEAD IN THE GRANDE RONDE RIVER SUBBASIN

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Prepared by:

Alan B. Garner
Bradley C. Power
Joshua W. Dowdy
Gregory A. McMichael
Tyler J. Warner
Emily Branigan
Owen C. Davis
Scott D. Favrot
Brian C. Jonasson
James R. Ruzycki

Oregon Department of Fish and Wildlife
La Grande, OR

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ABSTRACT

This study was designed to document and describe status and life history strategies of spring Chinook salmon and summer steelhead in Grande Ronde River Subbasin. We determined migration timing, abundance and life-stage survival rates for juvenile spring Chinook salmon *Oncorhynchus tshawytscha* and summer steelhead *O. mykiss* at five trap locations during migratory year 2016 (MY16) from 1 July 2015 through 30 June 2016. Similar to previous years, spring Chinook salmon and steelhead exhibited fall and spring movements from natal rearing areas, but did not begin smolt migration through the Snake and main stem Columbia River hydrosystem until spring 2016. In this report, we provide estimates of migrant abundance and migration timing for each study stream, and survival and migration timing to Lower Granite Dam. We also document aquatic habitat conditions using water temperature and discharge at five trap locations within the subbasin.

CONTENTS

Page

CONTENTS (continued)

Page

TABLES

Number Page

FIGURES

Number Page

FIGURES (continued)

APPENDIX TABLES

APPENDIX TABLES (continued)

EXECUTIVE SUMMARY

Objectives

Document in-basin migration patterns and estimate abundance of spring Chinook salmon juveniles in Catherine Creek and the Lostine, middle Grande Ronde, Minam, and upper Grande Ronde rivers.

Determine overwinter mortality and relative success of fall (early) and spring (late) migrant life history strategies for spring Chinook salmon from tributary populations in Catherine Creek and the Lostine and upper Grande Ronde rivers, and relative success of fall (early) and spring (late) migrant life history strategies for spring Chinook salmon from Minam River.

Estimate and compare smolt survival probabilities at main stem Columbia and Snake river dams for migrants from five natural populations of spring Chinook salmon in the Grande Ronde and Imnaha river subbasins.

Document annual migration patterns for spring Chinook salmon juveniles from five natural populations in Grande Ronde and Imnaha river subbasins: Catherine Creek and Imnaha, Lostine, Minam, and upper Grande Ronde rivers.

Document patterns of movement and estimate abundance of juvenile steelhead from populations in Catherine Creek and the Lostine, middle Grande Ronde, Minam, and upper Grande Ronde rivers.

Estimate and compare survival probabilities to main stem Columbia and Snake River dams for summer steelhead from five populations: Catherine Creek and the Lostine, middle Grande Ronde, Minam, and upper Grande Ronde rivers.

Describe aquatic habitat conditions, using water temperature and discharge, in Catherine Creek and the Lostine, middle Grande Ronde, Minam, and upper Grande Ronde rivers.

Accomplishments

Generally, we accomplished all of our objectives for MY 2016.

Findings

Spring Chinook Salmon

We determined migration timing and abundance of juvenile spring Chinook salmon *Oncorhynchus tshawytscha* using rotary screw traps at five locations in the Grande Ronde River Subbasin from 8 September 2015 through 21 June 2016. Based on migration timing and abundance, two distinct life history strategies were identified for juvenile spring Chinook salmon. 'Early' migrants emigrated from upper rearing areas from 8 September 2015 to 28 January 2016 with a peak during fall. 'Late' migrants emigrated from upper rearing areas from 29 January 2015 to 21 June 2016 with a peak during spring. At Catherine Creek trap, we estimated 26,818 juvenile spring Chinook salmon migrated from upper rearing areas with 85% leaving as early migrants. At Lostine River trap, we estimated 57,275 juvenile spring Chinook salmon migrated from upper rearing areas with 85% leaving as early migrants. At middle Grande Ronde River trap, we estimated 30,600 juvenile spring Chinook salmon migrated from upper rearing areas. At Minam River trap, we estimated 66,846 juvenile spring Chinook salmon migrated from upper rearing areas with 68% leaving as early migrants. At upper Grande Ronde River trap, we estimated 22,353 juvenile spring Chinook salmon migrated from upper rearing areas with 29% leaving as early migrants.

Juvenile spring Chinook salmon, that were PIT-tagged in natal rearing areas of Catherine Creek and Imnaha, Lostine, Minam, and upper Grande Ronde rivers during summer 2015, were detected at Lower Granite Dam between 28 March and 11 June 2016. Median dates of arrival at Lower Granite Dam for upper Catherine Creek, Imnaha, Lostine, Minam, and upper Grande Ronde rivers were significantly different during MY 2016 (Kruskal–Wallis, $P < 0.05$). Median dates of arrival for upper Catherine Creek, Imnaha, Lostine, and Minam rivers were significantly different from the upper Grande Ronde River in MY 2016 (Dunn test, $P < 0.05$). Median arrival dates, at Lower Granite Dam, of juvenile spring Chinook salmon from all study streams, ranged from 13 April to 20 May. Survival probabilities to Lower Granite Dam, for parr tagged during summer 2015, were 0.032 for upper Catherine Creek, 0.131 for Imnaha, 0.081 for Lostine, 0.124 for Minam, and 0.076 for upper Grande Ronde river populations. Survival probabilities fall within ranges previously reported for all populations. Insufficient dam detections precluded estimating survival probability of lower Catherine Creek summer tagged spring Chinook salmon.

Chinook salmon tagged at the traps were detected at Lower Granite Dam between 26 March and 11 June 2016. Although there was overlap in arrival dates, median arrival dates for early migrants were before that of late migrants for Catherine Creek and Lostine, Minam, and upper Grande Ronde rivers. Early migrant survival probabilities to Lower Granite Dam ranged from 0.060 to 0.188, while late migrants ranged from 0.183 to 0.516. Survival probabilities fall within ranges previously observed for all populations. Catherine Creek and Lostine River juvenile spring Chinook salmon, which overwintered downstream from trap sites (early migrants), survival probabilities were not significantly different than those that overwintered upstream (late migrants) (Maximum Likelihood

Ratio test, $P < 0.05$). Upper Grande Ronde River juvenile spring Chinook salmon, which overwintered downstream from trap sites (early migrants), survival probability was significantly higher than those that overwintered upstream (late migrants) (Maximum Likelihood Ratio test, $P<0.001$)

Summer Steelhead

We determined migration timing and abundance of juvenile steelhead (*O. mykiss)* using rotary screw traps at five locations in the Grande Ronde River Subbasin during MY 2016. Based on migration timing and abundance, early and late migration patterns were identified, similar to those for spring Chinook salmon. For MY 2016, we estimated 15,998 steelhead migrants emigrated from upper rearing areas in Catherine Creek with 41% migrating as early migrants. We estimated 16,331 steelhead emigrated from Lostine River, with 67% migrating as early migrants. At middle Grande Ronde River trap, we estimated 48,239 steelhead emigrated from upper rearing areas. We estimated 56,532 steelhead emigrated from Minam River with 32% migrating as early migrants. We estimated 6,033 steelhead migrants emigrated from upper rearing areas of upper Grande Ronde River with 15% migrating as early migrants. Upper Grande Ronde River spring trap season ended prematurely, thereby missing a portion of late migrants.

Steelhead collected at trap sites during MY 2016 were comprised of five age groups. Early migrants ranged from 0 to 3 years of age and late migrants ranged from 1 to 4 years of age. Smolts detected at Snake and lower Columbia river dams ranged from 1 to 4 years of age with age-2 fish comprising the highest percentage of emigrants.

Juvenile steelhead PIT-tagged at screw traps on Catherine Creek and Lostine, middle Grande Ronde, Minam, and upper Grande Ronde Rivers were detected at Lower Granite Dam from 31 March to 15 June. Early and late migrant median arrival dates ranged from 23 April to 11 May and 7 May to 12 May, respectively.

Probabilities of surviving and migrating in the first year to Lower Granite Dam for early migrating steelhead ranged from 0.096 (upper Grande Ronde River) to 0.248 (Minam River). Probabilities of surviving and migrating in the first year to Lower Granite Dam for late migrants, greater than 100 mm, ranged from 0.200 (Catherine Creek) to 0.598 (Minam River). Beginning spring 2015, no fish less than 100 mm fork length were tagged. Therefore, we will no longer estimate probability of migrating and surviving for steelhead less than 100 mm.

Stream Condition

Daily mean water temperatures typically fell within DEQ standards, at all five trap locations, during the period 2014 BY spring Chinook salmon were in the Grande Ronde River Subbasin (1 August 2014–30 June 2016). The 2014 BY encountered daily mean water temperatures in excess of DEQ standard of 17.8°C for 55 of 700 d in Catherine Creek and 0 of 518 d in Lostine, 146 of 700 d in middle Grande Ronde, 79 of 691 d in Minam, and 55 of 700 d in upper Grande Ronde rivers. Temperatures preferred by juvenile Chinook salmon (10–15.6°C) occurred 140 of 700 d in Catherine Creek and 172 of 518 d in Lostine, 149 of 700 d in middle Grande Ronde, 115 of 691 d in Minam, and 143 of 700 d in upper Grande Ronde rivers. These optimal temperatures tended to occur May through October, but varied by river. Water temperatures considered lethal to Chinook salmon (>25° C) occurred 13 of 700 d in middle Grande Ronde River. With the exception of the middle Grande Ronde River, moving mean of maximum daily water temperature showed that temperatures below the limit for healthy growth (4.4°C) occurred more often than temperatures above that limit (18.9°C).

Stream discharge for Catherine Creek and Lostine and upper Grande Ronde rivers remained relatively low and stable from August through March. Middle Grande Ronde and Minam rivers experienced greater and more variable discharge. Spring run-off typically occurred from April through July with peak flows occurring during late April to early June for Catherine Creek, Lostine, middle Grande Ronde, Minam, and upper Grande Ronde rivers.

Management Implications and Recommendations

Rearing of juvenile spring Chinook salmon and summer steelhead in Grande Ronde River Subbasin is not confined to adult spawning reaches. A portion of juvenile spring Chinook salmon and steelhead from each study stream distribute from natal rearing areas to overwinter in downstream reaches before emigrating as smolts the following spring or later. These movements indicate that lower reaches function as migration corridors and overwinter rearing reaches, and indicate a need for holistic management and habitat protection, rather than exclusively focusing on spawning and natal rearing reaches. Migration timing and Lower Granite Dam arrival dates continue to vary between years and populations; therefore, hydrosystem management that maximizes survival throughout the migratory period of Snake River spring/summer Chinook salmon and steelhead smolts is needed.

INTRODUCTION

Grande Ronde River originates in the Blue Mountains of northeast Oregon and flows 334 km to its confluence with Snake River near Rogersburg, Washington. Grande Ronde River Subbasin is divided into three watershed areas: the upper Grande Ronde River Watershed, the lower Grande Ronde River Watershed, and the Wallowa River Watershed. Upper Grande Ronde River Watershed includes Grande Ronde River and tributaries from headwaters to the confluence with Wallowa River. Lower Grande Ronde River Watershed includes Grande Ronde River and tributaries, excluding Wallowa River, from Wallowa River to the confluence with Snake River. Wallowa River Watershed includes Wallowa River and tributaries, including Lostine and Minam rivers, from headwaters to its confluence with Grande Ronde River.

Historically, Grande Ronde River Subbasin supported an abundance of salmonids including spring, summer, and fall Chinook salmon, sockeye salmon, coho salmon and summer steelhead (ODFW 1990). During the past century, numerous factors have led to a reduction in salmonid stocks such that the only viable populations remaining are spring Chinook salmon and summer steelhead. Snake River spring/summer Chinook salmon, including Grande Ronde River spring Chinook salmon, were listed as threatened under the Endangered Species Act (ESA) in 1992. Snake River steelhead, including Grande Ronde River summer steelhead, were listed as threatened under the ESA in 1997. Six spring Chinook salmon populations have been identified in the subbasin (TRT 2003): Wenaha River; Wallowa–Lostine River (includes Wallowa River, Lostine River, Bear Creek and Hurricane Creek); Minam River; Catherine Creek (includes Catherine and Indian creeks); Upper Grande Ronde River (includes the upper Grande Ronde River and Sheep Creek); and Lookingglass Creek, of which the endemic spring Chinook salmon population is considered extinct. Four summer steelhead populations have been identified in the subbasin (TRT 2003): Lower Grande Ronde River (includes the main stem Grande Ronde River and all tributaries, except Joseph Creek, upstream to the confluence of Wallowa River); Joseph Creek; Wallowa River (includes Minam and Lostine rivers); and Upper Grande Ronde River (includes main stem upper Grande Ronde River, Lookingglass Creek, Catherine Creek, Indian Creek, and tributaries).

Anadromous fish production in the subbasin is primarily limited by two factors (Nowak 2004). Adult escapement of salmon and steelhead is limited by out-of-subbasin issues, such as juvenile and adult passage problems at Columbia and Snake River dams and out-of-subbasin overharvest (Nowak 2004). Carrying capacity has been reduced within the subbasin by land management activities which have contributed to riparian and instream habitat degradation. Impacts to fish and aquatic habitat includes water withdrawal for irrigation, urban development, livestock overgrazing, mining, channelization, low stream flows, poor water quality, mountain pine beetle damage, logging activity, and road construction (Nowak 2004). Many of these impacts have been reduced in recent years as management practices become more sensitive to fish and aquatic habitats, but effects of past management remain (Nowak 2004).

Development of sound recovery strategies for these salmon stocks requires knowledge of stock-specific life history strategies and critical habitats for spawning, rearing, and downstream migration (Snake River Recovery Team 1993; NWPPC 1992; ODFW 1990). This project is acquiring knowledge of juvenile migration patterns, smolt production, and rates of survival. This project collects data to obtain life stage specific survival estimates (parr-to-smolt), and includes an evaluation of importance and frequency at which alternative life history strategies are demonstrated by spring Chinook salmon populations in northeast Oregon.

Spring Chinook salmon and summer steelhead smolt migration from Grande Ronde River Subbasin occurs during spring. Data from Lookingglass Creek (Burck 1993), Catherine Creek, upper Grande Ronde River and Lostine River (Keefe et al. 1994, 1995; Jonasson et al. 1997, Van Dyke et al. 2001) indicate a substantial number of juveniles move out of upper rearing areas during fall and overwinter downstream within Grande Ronde River Subbasin. The proportion, of total migrant population, these early migrants represent, and subsequent survival to Snake and Columbia river dams varies among years and streams.

Juvenile Chinook salmon that leave upper rearing areas of Catherine Creek and upper Grande Ronde River during fall overwinter in Grande Ronde Valley. Much of the habitat in Grande Ronde River, flowing through Grande Ronde Valley, is degraded. Stream conditions in Grande Ronde River below the city of La Grande consist of both meandering and channeled reaches, which run through agricultural land. Riparian vegetation in this area is sparse, and provides minimal shade and instream cover. These reaches are heavily silted due to the underlying geology of the Grande Ronde Valley and extensive erosion associated with agricultural, forest management practices, and mining activities. It is reasonable to suggest that salmon overwintering in degraded habitat may be subject to increased mortality due to limited function of degraded habitat to buffer against environmental extremes. Fall migration from upper rearing areas in Catherine Creek constitutes a substantial portion of juvenile production (Jonasson et al. 2006); therefore, Grande Ronde Valley winter rearing habitat quantity and quality may be important factors limiting Grande Ronde River spring Chinook salmon smolt production.

Juvenile steelhead that leave upper rearing areas during fall and spring may continue rearing within the subbasin for an extended period of time (6 months to several years) before resuming smolt migration during spring. Therefore, rearing habitat is not limited to areas where steelhead spawn.

Numerous enhancement activities have been undertaken to recover spring Chinook salmon populations in Grande Ronde River Subbasin. Supplementation programs have been initiated by Oregon Department of Fish and Wildlife, the Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe using endemic broodstock from Catherine Creek and Lostine and upper Grande Ronde rivers. Information collected by this project will serve as the foundation for assessing effectiveness of these programs to increase natural production of spring Chinook salmon in the Grande Ronde River Subbasin.

SPRING CHINOOK SALMON INVESTIGATIONS

Methods

For the purpose of this report, we assume all juvenile spring Chinook salmon captured in traps were downstream “migrants”. A migratory year (MY) in the Grande Ronde River Subbasin begins on 1 July, which is the earliest calendar date juvenile spring Chinook salmon are expected to begin their migration to the ocean. The migratory year ends on 30 June the following calendar year. The term “brood year” (BY) refers to the calendar year eggs were fertilized. All spring Chinook salmon referred to in this report were naturally produced unless noted otherwise.

In-Basin Migration Timing and Abundance

We determined in-basin migration timing and abundance of juvenile spring Chinook salmon in Catherine Creek and Lostine, middle Grande Ronde, Minam, and upper Grande Ronde rivers by operating rotary screw traps during MY 2016. Spring Chinook salmon in each study stream exhibit two migratory life history patterns. Early migrants leave upper rearing areas during fall to overwinter downstream before continuing seaward migration during spring. Late migrants exhibit another life history strategy whereby they overwinter in upper rearing areas prior to initiating seaward spring migration. Designations of early and late migration periods were based on capture rate trends at trap sites. A common period of diminished capture rate occurs at all four tributary trap sites during winter and was used to separate fish into early and late migration periods. We determined migration timing and abundance for both of these periods.

In Grande Ronde River Subbasin, we sampled at five rotary screw locations (Figure 1). In the Upper Grande Ronde River Watershed, one rotary screw trap was located downstream of spawning and upper rearing areas in upper Grande Ronde River near the town of Starkey at rkm 299, and a second trap was located in Catherine Creek downstream of spawning and upper rearing areas near the town of Union at rkm 32. A third trap site was located on middle Grande Ronde River downstream of spawning and all rearing areas near the town of Elgin at rkm 160. In Wallowa River Watershed, one rotary screw trap was located below the majority of spawning and upper rearing areas on Lostine River near the town of Lostine at rkm 3, and a second trap was employed on Minam River below spawning and rearing areas at rkm 0. Although intent was to operate traps continuously through the year, there were times when a trap could not be operated due to high or low flows or freezing conditions. There were also instances when traps were not operating due to excessive debris and mechanical breakdowns. No attempt was made to adjust population estimates for periods when traps were not operated. For this reason, estimates represent a minimum number of migrants.

Sampling and Marking: Rotary screw traps were equipped with live-boxes that safely held hundreds of juvenile spring Chinook salmon trapped over 24–72 h periods. Traps were generally checked daily, but were checked as infrequently as every third day when few fish were captured per day and environmental conditions were not severe. All juvenile spring Chinook salmon captured in traps were removed for enumeration and scanned for PIT tags. Before scanning and marking, fish were anesthetized in an aerated solution of tricaine methanesulfonate (40–50 mg/L; MS-222). PIT tags were injected manually with a modified hypodermic syringe as described by Prentice et al. (1986, 1990) and Matthews et al. (1990, 1992) for fish with fork length (FL) greater than 54 mm. Syringes were disinfected for 10 min in 70% isopropyl alcohol and allowed to dry between each use. A portable tagging station that consisted of a computer, PIT tag reader, measuring board, and electronic balance was used to record tag code, fork length (±1 mm), and weight (±0.1 g) of tagged fish. Fork lengths (mm) and weights (g) were measured from at least 100 juvenile spring Chinook salmon weekly. All fish were handled and marked at stream temperatures of 16°C or less and released within 24 h of being tagged. River height was recorded daily from permanent staff gages and water temperatures were recorded hourly at each trap location using temperature loggers or with hand held thermometers when traps were checked.

Migrant abundance was estimated by conducting weekly trap efficiency tests throughout the migratory year at each trap site. Fry and precocious spring Chinook salmon were not included in migrant abundance estimates. Trap efficiency was determined by releasing a known number of marked fish above each trap and enumerating recaptures. Immature parr that exceeded 54 mm in FL were either caudal fin-clipped or PIT-tagged, whereas fish less than 55 mm in FL were marked with a caudal fin clip only. On days when a trap stopped operating, number of recaptured fish and number of marked fish released the previous day were subtracted from weekly totals. Trap efficiency was estimated by

$$\hat{E}_j = R_j / M_j \, , \qquad (1)$$

where $\hat{E}_j$ is estimated trap efficiency for week *j*, R_j is number of marked fish recaptured during week *j*, and M_j is number of marked fish released upstream during week *j*.

Weekly abundance of migrants that passed each trap site was estimated by

$$\hat{N}_j = U_j / \hat{E}_j \, , \qquad (2)$$

where $\hat{N}_j$ is estimated number of fish migrating past the trap for week *j* , U_j is total number of unmarked fish captured that week, and $\hat{E}_j$ is the estimated trap efficiency for week *j*. Total migrant abundance was estimated as the sum of weekly abundance estimates.

Variance of each weekly $\hat{N}$ was estimated by the one-sample bootstrap method (Efron and Tibshirani 1986; Thedinga et al. 1994; as implemented in R function beta version 1.0, Petersen, JT, Oregon Cooperative Fish and Wildlife Research Unit, unpublished) with 1,000 iterations. Preliminary analysis indicated that when less than 10 fish were recaptured in a week, bootstrap variance estimates were greatly expanded. For this reason, consecutive weeks were combined when there were fewer than 10 recaptures until total recaptures were greater or equal to 10 fish. This combined trap efficiency estimate was used in the bootstrap procedure to estimate variance of weekly population estimates. Each bootstrap iteration calculated weekly $\hat{N}_j^*$ from equations (1 and 2) drawing Rj^* and U_j^* from the binomial distribution, where asterisks denote bootstrap values. Variance of $\hat{N}_j^*$ was calculated from 1,000 iterations. Weekly variance estimates were summed to obtain an estimated variance for total migrant abundance. Confidence intervals for total migrant abundance were calculated by

$$95\%\ CI = 1.96\sqrt{V}\ , \qquad (3)$$

where V is estimated total variance determined from bootstrap.

Catherine Creek and Lostine and upper Grande Ronde river traps were located below hatchery spring Chinook salmon release sites. Magnitude of hatchery spring Chinook salmon releases into these streams during spring required modifications to methods used for estimating migrant abundance of wild spring Chinook salmon. During low hatchery spring Chinook salmon catch periods, traps were operated continuously as described above. During high hatchery catch periods, traps were operated systematically for a 1 to 4 h interval using systematic two-stage sampling. Systematic sampling reduced handling and overcrowding induced stress, and avoided labor-intensive 24 h trap monitoring.

Systematic sampling required estimating proportion of total daily catch captured during each sampling interval. This proportion was estimated by fishing the trap over several 24 h periods prior to systematic sampling. Number of fish trapped during the 1 to 4 h sampling interval and number in the remaining interval within each 24 h period were counted. Proportion of total daily catch captured during the sampling interval (*i*) was estimated by

$$\hat{P}_i = S_i / C\ , \qquad (4)$$

where $\hat{P}_i$ is estimated proportion of total daily catch for sampling interval *i*, S_i is total number of fish caught during sampling interval *i*, and C is total number of fish caught throughout the 24 h sampling periods.

Estimates of trap efficiency could not be obtained during systematic sampling, so trap efficiency was calculated using mark–recapture numbers from 3 to 5 d before and after the systematic sampling period. Abundance of wild juvenile spring Chinook salmon at each trap during systematic sampling was estimated by

$$\hat{N}_s = \left(U_i / \hat{P}_i\right) / \hat{E}\ , \qquad (5)$$

where $\hat{N}_s$ is estimated number of fish migrating past the trap during systematic sampling, U_i is total number of fish captured during interval *i*, $\hat{P}_i$ is proportion of daily catch from equation (4), and $\hat{E}$ is estimated trap efficiency. Total migration abundance estimates for Catherine Creek and Lostine and upper Grande Ronde river traps were calculated by summing continuous and systematic sampling estimates.

Variance for $\hat{N}_s$ at each trap during systematic sampling was estimated by one-sample bootstrap method (Efron and Tibshirani 1986; Thedinga et al. 1994; as implemented in R function beta version 1.0, Petersen, J. T., Oregon Cooperative Fish and Wildlife Research Unit, unpublished) with 1,000 iterations. Each bootstrap iteration calculated $\hat{N}_s$ from equations (1, 4, and 5) obtaining R and S_i from the binomial distribution and U_i from the Poisson distribution. Variance of total migrant abundance was determined by summing variance from continuous and systematic sampling estimates.

Migration Timing and Survival to Lower Granite Dam

Detections of PIT tagged fish at Lower Granite Dam (i.e., first Snake River dam encountered) were used to estimate migration timing, while survival probabilities to Lower Granite Dam were estimated using detections of PIT tagged fish at Snake and Columbia river dams and Estuary Towed Array site. Both estimates were calculated for summer, fall, winter, and spring tag groups.

Summer tag groups consisted of age-0 parr tagged during July and August 2015 in upstream rearing areas. Summer tag groups are comprised of fish that emigrated from upper rearing areas either as early or late migrants, and consequently overwintered either in lower or upper rearing areas, respectively, before continuing downstream migration. Therefore, summer tag groups represented migration timing and survival for the entire population.

Summer tag group fish were captured using snorkeling and seining methods; whereby, 2 to 3 snorkelers forced parr downstream into a seine positioned perpendicular to flow. Captured fish were held in aerated, 19-L buckets and transferred periodically to live cages anchored in shaded areas of the stream following tagging. Our goal was to PIT-tag 1,000 parr from upper Catherine Creek, lower Catherine Creek, and Imnaha, Lostine, Minam, and upper Grande Ronde rivers.

Fall tag groups represented early migrants that emigrated from upstream rearing areas during fall and overwintered downstream from screw traps. For consistency with previous years, fish tagged at trap sites from 1 September 2015 through 28 January 2016 were designated as early migrants. Early migrants were captured, tagged, and released at screw traps on Catherine Creek and Lostine, Minam, and upper Grande Ronde rivers. The goal was to PIT-tag 600 fish at upper Grande Ronde river trap, 1,100 fish at Catherine Creek and Minam river traps, and 1,200 fish at Lostine river trap throughout the early migration period.

Winter and spring tag groups represented late migrants that overwintered as parr upstream from screw traps and emigrated during spring. Winter tag groups were tagged earlier in upper rearing areas (December 2015) than spring tag groups, which were tagged as migrants (29 January–30 June 2016) at rotary screw traps. Therefore, winter tag groups experienced overwinter mortality post-tagging, while spring tag groups did not. Winter tag group fish were caught, tagged, and released a minimum of 8 km upstream from trap sites to minimize the chance they would pass trap sites while making localized winter movements. Fish were sampled using dip nets while snorkeling at night. For winter tag groups, the goal was to PIT-tag 600 fish from Catherine Creek and Lostine and upper Grande Ronde rivers.

Spring tag group fish (i.e., late migrants) were captured, tagged, and released at screw traps on Catherine Creek and Lostine, Minam, middle Grande Ronde, and upper Grande Ronde river traps. The goal was to PIT-tag 800 fish at middle Grande Ronde river trap, 1,100 fish at Catherine Creek and Minam River traps, and 1,200 fish at Lostine River and upper Grande Ronde River traps throughout the late migration period.

During MY 2016, all captured fish were scanned for PIT tags at all screw traps. Additionally, PIT tag interrogation systems were used in juvenile bypass systems at seven of eight Snake and Columbia river dams to monitor fish passage. All recaptured fish were identified by original tag group, insuring independence of tag groups for analysis. MY 2016 detection information was obtained from juvenile PIT tag interrogation sites at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, and Bonneville dams, and the Estuary Towed Array.

Calculations: *Migration Timing:* Timing of migration past Lower Granite Dam was estimated for each tag group by expanding total daily numbers of PIT tag detections relative to proportion of river outflow and spill. This procedure was necessary because some fish may have passed undetected over the spillway and amount of spill varies daily. Proportion of fish passed over the spillway was assumed to be directly related to proportion of flow spilled. This assumption conforms to data obtained using non-species-specific hydroacoustic methods (Kuehl 1986). No temporal variation in proportion of fish diverted from turbine intakes into the bypass system and proportion of fish passed through surface bypass collector was also assumed. These assumptions were made in light of evidence to the contrary (Giorgi et al. 1988, Swan et al. 1986, Johnson et al. 1997), because data required to account for such variation were unavailable. Extent to which results may be biased would depend on overall rates of fish passage via bypass system and surface bypass collector, and variation of daily passage rates via these routes during emigration. Number of fish in a particular tag group migrating past Lower Granite Dam by day ($\hat{N}_d$) was estimated by multiplying number of tagged fish that were detected each day by a daily expansion factor calculated using Lower Granite Dam forebay water flow data obtained from U.S. Army Corps of Engineers at the DART website (www.cbr.washington.edu/dart/river.html):

$$\hat{N}_d = D_d \times \frac{O_d + L_d}{O_d}, \quad (6)$$

where D_d is number of PIT tagged fish from a tag group detected at Lower Granite Dam on day *d*, O_d is outflow (kcfs) measured at Lower Granite Dam forebay on day *d*, and L_d is spill at Lower Granite dam (kcfs) on day *d*. Each daily estimate was rounded to the nearest integer. Daily estimates were summed weekly to obtain weekly migration timing estimates for each tag group. First and last arrival dates were reported for each tag group. Median arrival date of each tag group was determined from daily estimates.

Late migrants were tagged while fish were actively emigrating seaward during spring, while PIT tagged early migrants overwinter prior to resuming seaward migration during spring. Simulated chi-square tests using number of PIT tag releases and estimated number of migrants for each week have shown that these two variables are independent, while both trap efficiency estimates and annual peaks in movement vary (i.e., random). Therefore, spring tag group median arrival dates may be biased by distribution of PIT tag releases. In an attempt to alleviate this bias, winter tag groups were used to represent late migrants when comparing migration timing differences with those of early migrants. Travel times for spring tag groups, to reach Lower Granite Dam from screw traps, were summarized for each location.

Survival Probabilities: Probability of survival to Lower Granite Dam for fish in each tag group was calculated using the Cormack–Jolly–Seber model in program SURPH 3.5.2 (Lady et al. 2001). This method takes into account detection probability when calculating probability of survival.

Overwinter Survival: Winter and spring tag group survival probabilities were used to indirectly estimate overwinter survival ($\hat{S}_{s,overwinter}$) for late migrants in upstream rearing areas of Catherine Creek and Lostine and upper Grande Ronde rivers:

$$\hat{S}_{s,overwinter} = \frac{\hat{S}_{s,winter}}{\hat{S}_{s,spring}} \qquad (7)$$

where $\hat{S}_{s,winter}$ is survival probability to Lower Granite Dam for the winter tag group from stream *s, and* $\hat{S}_{s,spring}$ is survival probability to Lower Granite Dam for the spring tag group from stream *s*.

Smolt Equivalents: Smolt equivalents are defined as an estimated number of smolts from a population that successfully emigrate from a specified area (Hesse et al. 2006). We used early and late migrant abundance estimates (*see* **In-Basin Migration Timing and Abundance**) and subsequent survival probabilities to Lower Granite Dam (*see* **Migration Timing and Survival to Lower Granite Dam; *Calculations; Survival probabilities*)** to estimate number of smolt equivalents leaving their respective tributary in spring ($\hat{Q}_{s,tributary}$):

$$\hat{Q}_{s,tributary} = \left(\hat{N}_{s,early} \times \frac{\hat{S}_{s,early}}{\hat{S}_{s,late}}\right) + \left(\hat{N}_{s,late}\right), \qquad (8)$$

and number of smolt equivalents reaching Lower Granite Dam ($\hat{Q}_{s,LGD}$):

$$\hat{Q}_{s,LGD} = \left(\hat{N}_{s,early} \times \hat{S}_{s,early}\right) + \left(\hat{N}_{s,late} \times \hat{S}_{s,late}\right), \qquad (9)$$

where $\hat{N}_{s,early}, \hat{N}_{s,late}$ are estimated number of early and late migrants, respectively, from stream *s*, and $\hat{S}_{s,early}, \hat{S}_{s,late}$ are estimated survival probabilities to Lower Granite Dam for early and late migrants, respectively, from stream *s*.

Population Characteristics and Comparisons: Summer tag groups include various life history patterns displayed by a population and provides information about population overall survival and timing past dams. We PIT-tagged parr from Catherine Creek and Imnaha, Lostine, Minam, and upper Grande Ronde river populations during summers 2015 and 2016 to monitor and compare smolt migration timing to Lower Granite Dam and survival probabilities from tagging to Lower Granite Dam. Fish tagged during summer 2016 will be analyzed with the 2017 migratory year in next year's report. Tagging was conducted during late summer (Table 1) so that fish would be large enough to tag (FL $\geq$ 55 mm). Sampling and tagging primarily occurred in spawning reaches utilized during the previous year.

Migration Timing: Population migration timing data were compared using the Kruskal–Wallis one-way ANOVA on dates of arrival, expressed as day of the year for expanded total daily PIT tag detections (see expansion explanation in **Migration Timing and Survival to Lower Granite Dam: *Calculations*: *Migration Timing***). When significant differences were found, Dunn's pairwise multiple comparison procedure was used ($\alpha = 0.05$) to compare arrival dates among populations.

Comparison of Life History Strategies within Populations: Tests were performed to determine if early or late migrant life history strategies were associated with differences in migration timing and survival to Lower Granite Dam.

Migration Timing: Timing of migration past Lower Granite Dam was compared between fall (early migrants) and winter (late migrants) Catherine Creek and Lostine and upper Grande Ronde river tag groups to identify possible differences in migration timing. Comparisons were made using the Mann–Whitney rank sum test on arrival dates. Spillway flow (and the passage of undetected PIT tagged fish at the dam) was taken into account when expanding daily detections (see expansion explanation in **Migration Timing and Survival to Lower Granite Dam: *Calculations*: *Migration Timing***). A winter tag group was not available for Minam River.

Survival Probabilities: Fish emigrating from upstream rearing areas (early migrants) overwintered in different stream reaches than fish that remained upstream (late migrants), possibly subjecting groups to different environmental conditions. Selecting different overwintering areas may have implications on overwinter survival. For each stream, relative success of early and late migrants was evaluated by using the Maximum Likelihood Ratio Test to test a null hypothesis that survival probabilities of fall (early migrants) and winter tag groups (late migrants) were similar. Any difference in survival probabilities between these groups was assumed to be due to differential survival in upstream (winter tag group) and downstream (fall tag group) overwintering stream reaches. However, since the fall group was tagged before the winter group, a lower survival estimate for the fall tag group could be due to elapsed time rather than a difference in overwintering conditions.

Results and Discussion

In-Basin Migration Timing and Abundance

Catherine Creek: The trap fished for 169 d between 10 September 2015 and 21 June 2016 (Table 2). A distinct early and late migration was exhibited by juvenile spring Chinook salmon at this trap site (Figure 2). Median emigration date for early migrants passing the trap was 29 October 2015, and median emigration date for late migrants was 10 March 2016 (Appendix Table A-1). Both dates are within the ranges of median emigration dates reported for this study.

We estimated a minimum of 26,818 ± 2,886 juvenile spring Chinook salmon emigrated from Catherine Creek upper rearing areas during MY 2016. This migrant estimate was within ranges previously reported during this study (Appendix Table A-1). Based on total minimum estimate, 85% (22,743 ± 2,809) migrated early and 15% (4,075 ± 664) migrated late. Typically, emigration from Catherine Creek upper rearing areas occurs during the early migration period.

Lostine River: The trap fished for 204 d between 8 September 2015 and 7 June 2016 (Table 2). Distinct early and late migrations were evident at this trap site (Figure 2). Systematic subsampling comprised 8 of 113 d the trap was fished during the late migration period, and 111 juvenile Chinook salmon were caught during this period. Median emigration date for early migrants was 22 October 2015, and 31 March 2015 for late migrants (Appendix Table A-1). Both dates fall within ranges previously reported for this study.

We estimated a minimum of 57,275 ± 8,210 juvenile spring Chinook salmon emigrated from Lostine River during MY 2016 (Appendix Table A-1). Based on the minimum estimate, 85% (48,509 ± 8,166) of juvenile spring Chinook salmon migrated early, while 15% (8,766 ±849) migrated late (Appendix Table A-1).

Middle Grande Ronde River: The trap fished for 82 d between 26 February 2016 and 3 June 2016 (Table 2). Late migrant median date was 28 April 2016 (Figure 2). We estimated a minimum of 30,600 ± 3,288 juvenile spring Chinook salmon emigrated from upper rearing areas (Appendix Table A-1).

Minam River: The trap fished for 158 d between 9 September 2015 and 8 June 2016 (Table 2). Distinct early and late migrations were evident (Figure 2). Early migrant median emigration date was 29 October 2015, while late migrant median date was 24 March 2016 (Appendix Table A-1). Both dates fall within ranges previously reported during this study.

We estimated a minimum of 66,846 ± 6,978 juvenile spring Chinook salmon emigrated from Minam River during MY 2016. Based on the minimum estimate, 68% (45,379 ± 5,988) of juvenile spring Chinook salmon migrated early and 32% (21,467 ± 3,582) migrated late.

Upper Grande Ronde River: The trap fished for 79 d between 17 September 2015 and 9 April 2016 (Table 2). Spring trap season ended prematurely on 9 April 2016, thereby missing a portion of the late migrants. Distinct early and late migration was exhibited by juvenile spring Chinook salmon at this trap site (Figure 2). Median emigration date for early migrants was 29 October 2015, and 3 March 2016 for late migrants (Appendix Table A-1). Early migrant median emigration falls within ranges previously reported during this study.

We estimated a minimum of 22,353 ± 2,261 juvenile spring Chinook salmon emigrated from upper Grande Ronde River during MY 2016. Based on the minimum estimate, 29% (6,423 ± 352) of juvenile spring Chinook salmon migrated early and 71% (15,930 ± 2,234) migrated late.

Size of Migrants: A comparison of mean lengths and weights of juvenile spring Chinook salmon captured in traps as early and late migrants and in upper rearing areas during winter, and those PIT-tagged and released are given in Tables 3 and 4. Length frequency distributions of juvenile spring Chinook salmon caught in all traps by migration period are shown in Figure 3. Weekly mean lengths of emigrants generally increased over time at each trap (Figure 4).

Migration Timing and Survival to Lower Granite Dam

Population Comparisons: During August and September 2015, Chinook salmon parr were PIT-tagged and released in upper summer rearing areas of Catherine Creek and Imnaha, Lostine, Minam, and upper Grande Ronde rivers (Table 1).

Migration Timing: Spring Chinook salmon parr PIT-tagged from upper Catherine Creek and Imnaha, Lostine, Minam, and upper Grande Ronde rivers during summer 2016 were detected at Lower Granite Dam from 28 March to 11 June 2016 (Appendix Table A-2). Period of detection at Lower Granite Dam among the five populations ranged from 37 d (Lostine River) to 75 d (Minam River). Median dates of arrival ranged from 21 April to 20 May (Figure 5). Median dates of arrival at Lower Granite Dam for upper Catherine Creek, Imnaha, Lostine, Minam, and upper Grande Ronde rivers were significantly different during MY 2016 (Kruskal–Wallis, $P < 0.05$). Dunn's multiple comparison tests revealed that median dates of arrival for upper Catherine Creek, Imnaha, Lostine, and Minam rivers were significantly different from the upper Grande Ronde River during MY 2016 (Dunn test, $P < 0.05$), while all other multiple comparison tests were not significantly different (Dunn test, $P > 0.05$). Median arrival dates for Imnaha, Lostine, Minam, and upper Grande Ronde rivers summer tag groups fell into previously reported ranges during this multiyear study.

Survival Probabilities: Survival probabilities to Lower Granite Dam for parr tagged during summer 2015 were 0.032 for upper Catherine Creek, 0.131 for Imnaha, 0.081 for Lostine, 0.124 for Minam, and 0.076 for upper Grande Ronde river populations (Table 5). Survival probabilities during MY 2016 fell within ranges previously reported compared to previous years (Appendix Table A-3). Insufficient detections precluded survival probability estimation for lower Catherine Creek summer tagged parr.

Comparison of Early Life History Strategies: Juvenile spring Chinook salmon were PIT-tagged at screw traps on Catherine Creek and Lostine, Minam, middle Grande Ronde, and upper Grande Ronde rivers. Parr were also tagged upstream of screw traps on Catherine Creek and Lostine and upper Grande Ronde rivers during winter. Total number of Chinook salmon parr PIT-tagged for each study stream, per season, is provided in Table 6.

Migration Timing: Median arrival dates at Lower Granite Dam for Catherine Creek fall, winter, and spring tag groups were 27 April, 22 April, and 7 May 2016, respectively (Figure 6). Median arrival dates at Lower Granite Dam for Lostine River fall, winter, and spring tag groups were 14 April, 7 May, and 5 May 2016, respectively (Figure 7). Median arrival date for middle Grande Ronde River spring tag group was 5 May 2016 (Figure 8). Median arrival dates at Lower Granite Dam for Minam River fall and spring tag groups were 13 April and 7 May 2016, respectively (Figure 9). Median arrival dates at Lower Granite Dam for upper Grande Ronde River fall, winter, and spring tag groups were 8 May, 12 May, and 10 May 2016, respectively (Figure 10). Median arrival date of the Minam River spring group was the earliest observed during this multiyear study. Median arrival dates from all other populations were within ranges previously reported (Appendix Table A-2).

Similar to past years, early migrants (fall tag group) reached Lower Granite Dam earlier than late migrants (winter tag group) for the Lostine River (Mann–Whitney rank-sum test, $P \leq 0.001$). There was no detectable difference in median arrival date between Catherine Creek and Upper Grande Ronde River early and late migrants ($P = 0.381$ and 0.092, respectively). There was no winter tag group for Minam River to compare with early migrants.

Travel time for Catherine Creek late migrants, from screw trap to Lower Granite Dam, ranged from 21 to 82 d with a median of 51 d (n =3). Travel time for Lostine River late migrants ranged from 5 to 88 d with a median of 30 d (n = 31). Travel time for middle Grande Ronde River late migrants ranged from 3 to 63 d with a median of 10 d (n = 61). Travel time for Minam River late migrants ranged from 6 to 70 d with a median of 38 d (n = 69). Travel time for upper Grande Ronde River late migrants ranged from 22 to 90 d with a median of 56 d (n = 29). Median travel times during MY 2016 were within previously observed ranges for all populations (Appendix Table A-4).

Survival Probabilities: Catherine Creek fall, winter, and spring tag group survival probabilities to Lower Granite Dam were 0.060, 0.077 and 0.183, respectively. Survival probabilities for Lostine River fall, winter, and spring tag groups were 0.188, 0.199, and 0.516, respectively. Probability of survival for the middle Grande Ronde River spring tag group was 0.572. Survival probabilities for Minam River fall and spring tag groups were 0.185 and 0.464, respectively. Upper Grande Ronde River fall, winter, and spring tag group survival probabilities to Lower Granite Dam were 0.120, 0.048, and 0.232, respectively. Survival probabilities, similar to past years, were generally higher for spring tag groups, likely because these fish were not subject to overwinter mortality that summer, fall, and winter tag groups experienced (Table 6).

Overwinter survival of BY 2014 fish in upper rearing areas of Catherine Creek was 42%, and was similar to those previously observed during this multiyear study (Appendix Table A-5). During MY 2016, overwinter survival between fish that overwintered upstream and those downstream of Catherine Creek trap was not significantly different (Maximum Likelihood Ratio test, $P = 0.313$). Higher survival rates were observed for fish overwintering downstream of the Catherine Creek trap in MY 1997, 2000-2001, 2007, 2009, and 2012 (Appendix Table A-6); however, overwinter survival has generally been similar between upstream and downstream overwintering fish (13 of 20 years).

Overwinter survival of BY 2014 fish in upper rearing areas of Lostine River was 39%, and was similar to those previously observed during this multiyear study (Appendix Table A-5). During MY 2016, overwinter survival between fish that overwintered upstream and those downstream of Lostine River trap was not significantly different (Maximum Likelihood Ratio test, $P = 0.880$). For Lostine River, we have generally observed equivalent overwinter survival rates between upstream and downstream overwintering areas (13 of 18 years), while significantly higher survival rates for downstream rearing fish were estimated the remainder of the time (Appendix Table A-6).

Overwinter survival of BY 2013 fish in upper rearing areas of upper Grande Ronde River was 23%, and was generally similar to those previously observed during this multiyear study (Appendix Table A-5). During MY 2016, difference in survival between fish that overwintered upstream and those downstream from upper Grande Ronde River trap was significant (Maximum Likelihood Ratio test, $P = 0.001$). We previously observed higher survival rates for fish overwintering downstream from the trap during MY 1995, 1998-2000, 2007, 2010-2014, and 2016 (Appendix Table A-6). Upstream overwintering conferred better survival in MY 2004-2005. Survival rates were equivalent between overwintering areas for MY 1994, 2006, 2008, and 2015 (Appendix Table A-6).

Smolt Equivalents: We estimated 11,532 smolt equivalents emigrated from Catherine Creek rearing areas during spring of MY 2016, and 2,110 successfully emigrated to Lower Granite Dam (Appendix Table A-7). Both estimates are within previously reported estimates of smolt equivalent estimates from MY 1997-2016. (Appendix Table A-7). Highest estimates occurred during MY 2012, when an estimated 44,703 smolt equivalents emigrated from Catherine Creek rearing areas, and an estimated 13,500 successfully reached Lower Granite Dam. Lowest estimates occurred during MY 1997, when an estimated 3,974 smolt equivalents emigrated from Catherine Creek rearing areas, and an estimated 1,641 successfully reached Lower Granite Dam.

We estimated 26,440 smolt equivalents emigrated from Lostine River rearing areas during spring of MY 2016, and 13,643 successfully emigrated to Lower Granite Dam (Appendix Table A-7). Both estimates are within previously reported estimates of smolt equivalent estimates from MY 1997-2016. Highest smolt equivalent estimates occurred during MY 2012, when an estimated 65,167 smolt equivalents emigrated from Lostine River rearing areas, and an estimated 35,842 successfully reached Lower Granite Dam. Lowest smolt equivalent estimates occurred during MY 1997, when an estimated 3,203 smolt equivalents emigrated from Lostine River rearing areas, and an estimated 2,463 successfully reached Lower Granite Dam. Access to Lostine River trap site was denied during MY 2004, precluding estimates of migrant abundance, survival to Lower Granite Dam, and smolt equivalents.

We estimated 39,560 smolt equivalents emigrated from Minam River rearing areas during spring MY 2016, of which 18,356 successfully emigrated to Lower Granite Dam (Appendix Table A-7); both estimates are within previously reported estimates of smolt equivalents from the Minam River during MY 2001-2016. Highest estimates occurred during MY 2010, when an estimated 134,149 smolt equivalents emigrated from Minam River rearing areas during spring, and an estimated 85,318 successfully emigrated to Lower Granite Dam (Appendix Table A-7).

We estimated 19,252 smolt equivalents emigrated from upper Grande Ronde River rearing areas during spring MY 2016, of which 4,467 successfully emigrated to Lower Granite Dam (Appendix Table A-7). Both estimates are within previously reported estimates of smolt equivalent estimates from MY 1994-2016. Spring trap season ended prematurely, thereby missing a portion of the late migrants. For years in which estimates were available, lowest spring smolt equivalent estimates from rearing reaches of upper Grande Ronde River and at Lower Granite Dam occurred during MY 2003 (4,198 and 1,666, respectively). Highest spring smolt equivalent estimates from upper Grande Ronde River rearing reaches occurred during MY 2012 (46,616), and the highest smolt equivalent estimates at Lower Granite Dam occurred during MY 1995 (21,732). As a result of insufficient sample size and subsequent incomplete survival estimates for one or both migrant groups, smolt equivalents were not estimated for MY 1996, 1997, 2001, and 2009 (Appendix Table A-7).

SUMMER STEELHEAD INVESTIGATIONS

Methods

In Grande Ronde River Subbasin, most juvenile steelhead populations coexist with rainbow trout populations and only steelhead smolts and mature adults can be visually differentiated from resident rainbow trout. For this reason, all *Oncorhynchus mykiss* are referred to as steelhead in this report, even though some of these fish are likely resident rainbow trout. Screw traps and mark/recapture techniques were used to study movement of juvenile steelhead downstream from spawning and upper rearing reaches in Catherine Creek and Lostine, Minam, and upper Grande Ronde rivers. We assumed all juvenile steelhead captured at trap sites were emigrating and not conducting localized movement. Violation of this assumption would result in positively biased population estimates.

In-Basin Migration Timing and Abundance

Summer steelhead migration timing and abundance for Catherine Creek and Lostine, Minam, and upper Grande Ronde rivers were determined by operating rotary screw traps annually. As with spring Chinook salmon, summer steelhead exhibit two life history strategies in Grande Ronde River Subbasin (Van Dyke et al. 2001). Identical methods described for spring Chinook salmon data collection and analysis were used for steelhead (*see* **SPRING CHINOOK SALMON INVESTIGATIONS; Methods; In-Basin Migration Timing and Abundance**).

Fork length (mm) and weight (g) were measured from randomly-selected steelhead weekly throughout the migratory year. Methods described for spring Chinook salmon were used to sample and mark steelhead (*see* **SPRING CHINOOK SALMON INVESTIGATIONS; Methods; In-Basin Migration Timing and Abundance; *Sampling and Marking***). Beginning in MY 15, steelhead less than 100 mm fork length were not tagged during spring because historically fish from this size range have been detected at Snake or Columbia River dams predominantly during subsequent years. In addition, scale samples were taken from a subsample of steelhead (10 fish/10 mm FL group) during both migration periods. Descriptive statistics and an age–length key were employed to describe age structure of early and late migrants collected at each trap site.

Migration Timing and Survival to Lower Granite Dam

Migration Timing: Detections of PIT tagged steelhead at Lower Granite Dam were used to estimate migration timing using methods described for spring Chinook salmon (see **SPRING CHINOOK SALMON INVESTIGATIONS; Methods; Migration Timing and Survival to Lower Granite Dam**). Summer tag groups represent steelhead occupying upstream spawning and rearing reaches of Catherine Creek during the beginning of a migratory year (July) and have not been collected since 2006. Fall tag groups represent early migrant summer steelhead that relocate downstream of screw trap sites between 1 September 2015 and 28 January 2016. Spring tag groups represent fish that migrate downstream of trap sites between 29 January and 30 June 2016 (late migrants). At Catherine Creek, Lostine, Minam, and upper Grande Ronde rivers sites during MY 2016, our goal was to PIT-tag 600 steelhead during fall and spring to assess migration timing of early and late migrants. At middle Grande Ronde River trap site, our goal was to PIT-tag 800 steelhead during spring to assess migration timing of late migrants.

Survival Probabilities: We monitored PIT tagged steelhead migration behavior using methods described for spring Chinook salmon (*see* **SPRING CHINOOK SALMON INVESTIGATIONS; Methods; Migration Timing and Survival to Lower Granite Dam**) for the tag groups described above. Groups of PIT tagged juvenile steelhead represent an undetermined combination of resident rainbow trout and steelhead. Therefore, survival probabilities calculated from these groups incorporate an unknown probability of an individual selecting the resident life history. Steelhead tagged during each migratory year of this multiyear study have been detected at dams across more than one migratory year (Reischauer et al. 2003); however, calculating a survival estimate across multiple migration years violates assumptions of the Cormack-Jolly-Seber model. For this study, only detections during migration year of tagging (2016) were used to calculate probability of surviving and migrating to Lower Granite Dam. Survival probabilities were calculated using program SURPH 3.5.2 (Lady et al. 2001).

Length and Age Characterization of Smolt Detections: We compared steelhead length at tagging, grouped by dam detection history, to investigate relationships between size, migration patterns, and survival. Fork lengths of all steelhead tagged during fall 2015 were compared to fork lengths of those subsequently detected at dams in 2016 using the Mann–Whitney rank-sum test. Fork lengths of all steelhead tagged during fall 2014 were compared to that of those subsequently detected in 2015 and 2016 using a Kruskal–Wallis one-way ANOVA on ranks. Dunn's multiple comparison test was performed when the Kruskal–Wallis test rejected the null hypothesis that all tag groups were the same. In addition, fork lengths of steelhead tagged during spring 2016 were compared to that of those subsequently detected at dams during spring 2016 using a Mann–Whitney rank-sum test. Age structure of steelhead PIT-tagged at the traps and subset detected at the dams during spring 2016 was characterized. Only steelhead of known age, at time of tagging, were used for this analysis.

Results and Discussion

In-Basin Migration Timing and Abundance

Catherine Creek: The trap fished for 169 d between 10 September 2015 and 21 June 2016 (Table 7). Distinct early and late migrations were exhibited by juvenile steelhead at this trap site (Figure 11). Median emigration date for early migrants was 29 October 2015, while median emigration date for late migrants was 29 April 2016. Both median migration dates were within ranges previously reported for this study (Appendix Table B-1).

We estimated a minimum of 15,998 ± (95% CI, 1,484) juvenile steelhead migrated from upper rearing areas during MY 2016. Based on total minimum abundance estimate, 41% (6,605 ± 880) migrated early and 59% (9,393 ± 1,195) migrated late. MY 2016 proportion of juvenile steelhead emigrating from upper rearing areas as late migrants (59%) is within those proportions previously reported during this study (Appendix Table B-1).

Lostine River: The trap fished for 204 d between 8 September 2015 and 7 June 2016 (Table 7). Systematic subsampling comprised 8 of 113 d the trap was fished during the late migration period. Distinct early and late migrations were evident at this trap site (Figure 11). Median emigration date for early migrants was 1 October 2015, and median emigration date for late migrants was 7 April 2016. Median migration dates for early and late migrants were within ranges previously reported during this study (Appendix Table B-1).

We estimated a minimum of 16,331 ± 2,553 juvenile steelhead emigrated during MY 2016. Based on total minimum abundance estimate, 67% (10,939 ± 1,530) of juvenile steelhead migrated early and 33% (5,392 ± 2,043) migrated late. MY 2016 proportion of juvenile steelhead emigrating from upper rearing areas as late migrants (33%) is within those proportions previously reported during 1997-2016 (Appendix Table B-1).

Middle Grande Ronde River: The trap fished for 82 d between 26 February 2016 and 3 June 2016 (Table 7). Late migrant median migration date was 28 April 2016 (Figure 11). We estimated a minimum of 48,239 ± 5,542 late migrants (Appendix Table A-1).

Minam River: The trap fished for 158 d between 9 September 2015 and 8 June 2016 (Table 7). Distinct early and late migrations were evident at this trap site (Figure 11). Median emigration date for early migrants was 17 September 2015, and median emigration date for late migrants was 7 April 2016. Early migrant median migration date was within ranges previously reported during this study (Appendix Table B-1). Late migrant median migration date was the earliest observed during this study.

We estimated a minimum of 56,532 ± 15,668 juvenile steelhead emigrated during MY 2016. Based on total minimum abundance estimate, 32% (18,360 ± 3,606) migrated early and 68% (38,172 ± 15,247) migrated late. Proportion of juvenile steelhead emigrating as late migrants, during MY 2016, is within those proportions previously reported during 1997-2016 (Appendix Table B-1).

Upper Grande Ronde River: The trap fished for 79 d between 17 September 2015 and 9 April 2016 (Table 7). Distinct early and late migrations were evident at this trap site (Figure 11). Median emigration date for early migrants was 29 October 2015, and median emigration date for late migrants was 31 March 2016. Early migrant median migration date was within ranges previously reported during this study (Appendix Table B-1). Spring trap season ended prematurely on 9 April 2016, thereby missing a portion of the late migrants.

We estimated a minimum of 6,033 ± 946 juvenile steelhead emigrated from upper rearing areas of upper Grande Ronde River during MY 2016, which is within estimates from previous migration years (Appendix Table B-1). Based on total minimum abundance estimate, 15% (906 ± 138) were early migrants and 85% (5,127 ± 936) were late migrants. Predominant late migration of juvenile steelhead in upper Grande Ronde River is consistent for all migration years studied to date (Appendix Table B-1).

Age of Migrants at Traps: Summer steelhead collected at trap sites during MY 2016 comprised five age-groups. Early migrants ranged from 0 to 3 years of age, while late migrants ranged from 1 to 4 years of age (Table 8). Majority of Lostine River early migrants were age 0 (37.6%) and age 1 (37.6%), while majority of Catherine Creek (51.6%) and upper Grande Ronde River (63.8%) early migrants were age 1, and majority of Minam River (75.5%) early migrants were age 0. Majority of Catherine Creek (81.9%), Lostine River (55.5%), and Minam River (46.1%) late migrants were age 1, while majority of middle Grande Ronde River (61.3%) and upper Grande Ronde River (51.5%) late migrants were age 2 (Table 8).

Migration Timing and Survival to Lower Granite Dam

Total number of steelhead tagged in each tag group for each study stream is provided in Appendix Table B-2.

Migration Timing: Median arrival dates at Lower Granite Dam for Catherine Creek fall and spring tag groups were 23 April and 12 May, respectively (Figure 12). Median arrival dates for Lostine River fall and spring tag groups were 9 May and 9 May, respectively (Figure 13). Median arrival dates for the middle Grande Ronde River spring tag group was 8 May (Figure 14). Median arrival dates for Minam River fall and spring tag groups were 9 May and 7 May (Figure 15). Median arrival dates for the upper Grande Ronde River spring tag group was 11 May and 8 May, respectively (Figure 16).

Spring tag group travel time from screw trap to Lower Granite Dam, for all four study streams, are presented in Table 9. Travel time to Lower Granite Dam for the Catherine Creek spring tag group ranged from 7 to 68 d with a median of 22 d. Travel time to Lower Granite Dam for the Lostine River spring tag group ranged from 4 to 43 d with a median of 16 d. Travel time to Lower Granite Dam for the middle Grande Ronde River spring tag group ranged from 3 to 71 d with a median of 11 d. Travel time to Lower Granite Dam for the Minam River spring tag group ranged from 4 to 70 d with a median of 20 d. Travel time to Lower Granite Dam for the upper Grande Ronde River spring tag group ranged from 6 to 80 d with a median of 36 d.

Survival Probabilities: Probability of surviving and migrating, during migration year of tagging, to Lower Granite Dam for steelhead tagged in fall 2015 ranged from 0.096 to 0.248 for upper Grande Ronde River and Minam River, respectively (Table 10). Probabilities of migration and survival, for larger steelhead (FL ≥ 100 mm) tagged during spring 2016, ranged from 0.200 to 0.598 for all five populations studied (Table 10). Generally, probabilities of migration and survival, during spring 2016, were similar for three of the five populations studied compared to previous years (Appendix Table B-3). The probability of migration and survival for Lostine River steelhead (FL ≥ 100mm) tagged in spring 2016 was the lowest compared to previous years.

Length and Age Characterization of Smolt Detections: Of all early migrating steelhead tagged at Catherine Creek and upper Grande Ronde river traps during fall 2015, predominantly larger individuals were detected at dams during 2016 (Mann–Whitney, $P < 0.05$, Figure 17), with no significant difference observed for Lostine and Minam river steelhead. Of all early migrating steelhead tagged from Catherine Creek and Lostine, Minam, and upper Grande Ronde rivers during fall 2014, predominately smaller individuals tended to be detected at dams during 2016 (Kruskal–Wallis, $P < 0.05$, Figure 18). MY 2016 spring tag groups exhibited a pattern of larger individuals being detected at dams during spring (Mann–Whitney, $P < 0.05$, Figure 19). Fork length summaries, at time of tagging, for steelhead tag groups and those detected at dams are provided in Appendix Tables B-4, B-5 and B-6. While median differences between original tag groups and those detected at dams could be a result of smaller fish experiencing greater size-dependent mortality, there is evidence that small fish delay seaward migration until subsequent migratory years (Appendix Tables B-4, B-5, and B-6).

Of 219 early migrating age-0 fish tagged during MY16, zero were observed at dams the following spring, while 39 of 293 age-1, 28 of 207 age-2, and 1 of 11 age-3 fish tagged during MY16 were observed at dams the following spring. As in past years, age-2 smolts (age-1 early migrants) made up the highest weighted percentage of all MY16 observations (Table 11). Generally, late migrant smolts primarily consisted of age 1 to 4 years during 2016, with the majority consisting of age-1 and age-2 fish. Peven et al. (1994) found that steelhead smolts from mid-Columbia River ranged in age from 1 to 7 years with most occurring as age-2 and age-3 fish. Even though the proportion of steelhead smolts within age-groups has been shown to vary considerably between migratory years (Ward and Slaney 1988), results from all years of this study indicate that the majority of steelhead originating from the subbasin smolt as age-2 fish.

STREAM CONDITION INVESTIGATIONS

Methods

Stream Temperature and Flow

An assessment of stream condition was conducted for all four study streams. General stream condition sampling was based on protocols described by The Oregon Plan for Salmon and Watersheds (OPSW 1999) and stream flow data provided by the United States Geologic Survey (USGS) and Oregon Water Resources Department (OWRD) La Grande District Watermaster. Stream temperature and discharge was characterized for all four study streams constrained by in-basin life history of BY 2014 juvenile spring Chinook salmon, which ranged from 1 August 2014 (spawning) to 30 June 2016 (the end of MY 2016).

Mean daily temperature was produced using hourly 24 h data recorded to the nearest 0.1°C using a stationary temperature logger located at each trap site. Descriptive statistics were used to characterize water temperature in each study stream with standards of optimal and lethal temperature ranges for juvenile Chinook salmon (OPSW 1999). Cumulative effects of prolonged exposure to high water temperature were characterized using a seven-day moving mean of daily maximum, and were calculated by averaging daily maximum temperature and maximum temperatures for the preceding and following three days ($n = 7$). Water temperature data were compared to Department of Environmental Quality (DEQ) standards to evaluate seasonal water temperature variation and subsequent relationships to early life history stages of spring Chinook salmon and summer steelhead.

Stream discharge was obtained from Catherine Creek (USGS station 13320000; rkm 38.6; 266.8 km^2 drainage area), Lostine River (USGS station 13330300; rkm 1.6; 237.5 km^2), Minam River (USGS station 13331500; rkm 0.4; 619.0 km^2), and upper Grande Ronde River (USGS station 13317850; rkm 321.9; 101.0 km^2) gaging stations that measured discharge in cubic feet per second (cfs) every 15 minutes. In addition, stream discharge was estimated for middle Grande Ronde River (rkm 160.0) by summing stream discharge from Catherine Creek (USGS station 13320000; rkm 38.6) and upper Grande Ronde River (USGS station 13318960; 216.5 rkm). Average daily discharge was converted to cubic meters per second (nearest 0.0001, m^3/s). Generally, each gage station was situated near the downstream margin of summer rearing distribution, except the upper Grande Ronde River gage which was approximately 25 km upstream of the summer rearing distribution.

Results and Discussion

Stream Temperature and Flow

Catherine Creek: Water temperatures, during in-basin occupancy of BY 2014 Chinook salmon, ranged from 0.0°C to 25.9°C. Daily mean water temperature exceeded

DEQ standard of 17.8°C for 13 d (2 August 2014–19 August 2014) during spawning, 40 d (26 June 2015–27 August 2015) during parr rearing and early migration, and 2 d (29 June 2016 – 30 June 2016) during late migration. Water temperatures were within the range preferred by juvenile Chinook salmon (10–15.6°C; OPSW 1999) for 40 d (21 August 2014–12 October 2014) during spawning and incubation, 9 d (23 May 2015 – 31 May 2015) during emergence, 66 d (1 June 2015–20 October 2015) during parr rearing and early migration, and 25 d (29 May 2016–26 June 2016) during late migration. DEQ lethal limit of 25°C was not exceeded during 700 d temperature was logged. The seven-day moving mean of maximum temperature revealed that water temperatures below the range expected to support healthy growth (4.4–18.9°C; OPSW 1999) were encountered for a longer duration than those that exceeded the healthy growth water temperature range (Figure 20). Moving mean temperatures were less than 4.4°C on 89 d (11 November 2014–28 February 2015) during incubation, 5 d (1 March 2015 – 5 March 2015) during emergence, and 88 d (17 November 2015–2 February 2016) during early and late migration. Moving mean temperatures exceeded 18.9°C for 28 d (1 August 2014–30 August 2014) during spawning, 72 d (18 June 2015–28 August 2015) during parr rearing and early migration, and 5 d (26 June 2016 -30 June 2016) during late migration.

Average daily discharge during in-basin life history of the 2014 cohort ranged from 0.5 to 15.9 m^3/s (Figure 21). Discharge was greater than 2.0 m^3/s from late November 2014 through mid-June 2015, during incubation, emergence, and parr rearing, and early December 2015 through late-June 2016, during early and late migration, excluding 10 d in December 2014 and early January 2015. Annual peak flows occurred on 10 February 2015 and 22 April 2016, at 8.83 m^3/s and 15.86 m^3/s, respectively. Discharge was generally less than 2.0 m^3/s from August 2014 through mid-November 2014, during spawning and incubation, mid-June 2015 through mid-February 2016, during parr rearing, early migration, and late migration. In addition to typical spring freshets, stream discharge exceeded 2.0 m^3/s for 5 d in early December 2015.

Lostine River: Water temperatures, during the majority of in-basin occupancy of BY 2014 Chinook salmon, ranged from 0.1°C to 20.3°C. We were unable to characterize a 28 d period (1 January 2016–28 January 2016) during early migration, as well as a 154 d period (29 January 2016 - 30 June 2016) during late migration. However, daily mean water temperature did not exceed the DEQ standard of 17.8°C during 518 d temperature was logged. Water temperatures were within the range preferred by juvenile Chinook salmon (10–15.6°C; OPSW 1999) for 63 d (1 August 2014–13 October 2014) during spawning and incubation, and 109 d (6 June 2015–31 October 2015) during parr rearing and early migration. The seven-day moving mean of maximum temperature revealed that water temperatures below the range expected to support healthy growth (4.4–18.9°C; OPSW 1999) were encountered for a longer duration than those that exceeded the healthy growth water temperature range (Figure 20). Moving mean temperatures were less than 4.4°C for 75 d (12 November 2014–24 February 2015) during incubation, and 38 d (20 November 2015–28 December 2015) during early migration. Moving mean temperatures exceeded 18.9°C for 20 d (29 June 2015 – 3 August 2015) during parr rearing and early migration.

Average daily discharge during in-basin life history of the 2014 cohort ranged from 0.2 to 31.2 m^3/s (Figure 21). Discharge was greater than 7.5 m^3/s from mid-May through mid-June 2015, during emergence and parr rearing, and mid-April through late-June 2016, during late migration, excluding 10 d in mid-April and early May 2016. Annual peak flows occurred on 2 June 2015 and 6 June 2016, at 29.17 m^3/s and 31.15 m^3/s, respectively. Discharge was less than 7.5 m^3/s from August 2014 through mid-May 2015, during spawning, incubation, and emergence, and from mid-June 2015 through early-April 2016, during parr rearing, early migration and late migration. In addition to typical spring freshets, stream discharge exceeded 7.5 m^3/s for 1 d in late November 2014.

Middle Grande Ronde River: Water temperatures, during the majority of in-basin occupancy of BY 2014 Chinook salmon, ranged from 0.0°C to 31.5°C. Daily mean water temperature exceeded the DEQ standard of 17.8°C for 35 d (1 August 2014–24 September 2014) during spawning and incubation, 2 d (30 May 2015 – 31 May 2015) during emergence, 92 d (1 June 2015-13 September 2015) during parr rearing and early migration, and 17 d (4 June 2016-30 June 2016) during late migration. Water temperatures were within the range preferred by juvenile Chinook salmon (10–15.6°C; OPSW 1999) for 30 d (2 September 2014–26 October 2014) during incubation, 36 d 17 April 2015–25 May 2015) during emergence, 41 d (4 September 2015–1 November 2015) during early migration, and 42 d (8 April 2016–19 June 2016) during late migration. DEQ lethal limit of 25°C was exceeded for 13 d (26 June 2015 – 8 July 2015) during parr rearing and early migration. The seven-day moving mean of maximum temperature revealed that water temperatures below the range expected to support healthy growth (4.4–18.9°C; OPSW 1999) were encountered for a shorter duration than those that exceeded the healthy growth water temperature range (Figure 20). Moving mean temperatures were less than 4.4°C for 78 d (12 November 2014–4 February 2015) during incubation, and 83 d (19 November 2015–9 February 2016) during early and late migration. Moving mean temperatures exceeded 18.9°C for 57 d (1 August 2014–26 September 2014) during spawning and incubation, 1 d (31 May 2015) during emergence, 111 d (1 June 2015–25 September 2015) during parr rearing and early migration, and 27 d (31 May 2016–30 June 2016) during late migration.

Average daily discharge during in-basin life history of the 2014 cohort ranged from 0.9 to 101.7 m^3/s (Figure 21). Discharge was typically greater than 12.0 m^3/s from mid-December 2014 through early June 2015, during incubation, emergence, and parr rearing, and from mid-February through late-May 2016 during late migration, with exception of 6 d in late December through early January 2015, 1 d in mid-January 2015, 12 d in March 2015, and 33 d in April through May 2015. Annual peak flows occurred on 10 February 2015 and 15 February 2016, and were 53.01 m^3/s and 101.71 m^3/s, respectively. Discharge was less than 12.0 m^3/s from August through mid-December 2014, during spawning and incubation, from early-June 2015 through mid-February 2016, during parr rearing ,early migration and late migration, and from late May through late June 2016 during late migration. In addition to typical spring freshets, stream discharge exceeded 12.0 m^3/s for 1 d in late November 2014.

Minam River: Water temperatures, during a majority of in-basin occupancy of BY 2014 Chinook salmon, ranged from 0.0°C to 26.7°C. We were unable to characterize a 9 d period (9 January 2016–17 January 2016) during early migration. Daily mean water temperature exceeded the DEQ standard of 17.8°C for 19 d (2 August 2014–29 August 2014) during spawning, and 60 d (26 June 2015–28 August 2015) during parr rearing and early migration. Water temperatures were within the range preferred by juvenile Chinook salmon (10–15.6°C; OPSW 1999) for 35 d (24 August 2014–13 October 2014) during spawning and incubation, for 3 d (29 May 2015 – 31 May 2015) during emergence, 63 d (1 June 2015–20 October 2015) during parr rearing and early migration, and 14 d (4 June 2016–27 June 2016) during late migration. DEQ lethal limit of 25°C was not exceeded during 691 d temperature was logged. The seven-day moving mean of maximum temperature revealed water temperatures below the range expected to support healthy growth (4.4–18.9°C; OPSW 1999) were encountered for a longer duration than those that exceeded the healthy growth water temperature range (Figure 20). Moving mean temperatures were less than 4.4°C for 88 d (11 November 2014–27 February 2015) during incubation, 2 d (1 March 2015 – 2 March 2015) during emergence, and 67 d (18 November 2015–7 February 2016) during early and late migration. Moving mean temperatures exceeded 18.9°C for 43 d (1 August 2014–23 September 2014) during spawning and incubation, and 76 d (22 June 2015–13 September 2015) during parr rearing and early migration.

Average daily discharge during in-basin life history of the 2014 cohort ranged from 1.1 to 65.4 m^3/s (Figure 21). Discharge was greater than 9.0 m^3/s from late November 2014 through June 2015, during incubation, emergence, and parr rearing, and from mid-February through late June 2016, during late migration, with the exception of 19 d in December 2014 through January 2015, and 4 d in late February 2016. Annual peak flows occurred on 24 May 2015 and 8 May 2016, and were 45.87 m^3/s and 65.41 m^3/s, respectively. Discharge was generally less than 9.0 m^3/s from August through late November 2014, during spawning and incubation, and late June 2015 through mid-February 2016, during parr rearing, early migrationand late migration. In addition to typical spring freshets, stream discharge exceeded 9.0 m^3/s for 3 d in early December 2015, and 1 d in early January 2016.

Upper Grande Ronde River: Water temperatures, during in-basin occupancy of BY 2014 Chinook salmon, ranged from 0.1°C to 27.2°C. Daily mean water temperature exceeded the DEQ standard of 17.8°C for 13 d (1 August 2014–19 August 2014) during spawning, 34 d (8 June 2015–14 August 2015) during parr rearing and early migration, and 8 d (5 June 2016 – 30 June 2016) during late migration. Water temperatures were within the range preferred by juvenile Chinook salmon (10–15.6°C; OPSW 1999) for 40 d (21 August 2014–8 October 2014) during spawning and incubation, 22 d (22 April 2015 - 31 May 2015) during emergence, 50 d (1 June 2015–20 October 2015) during parr rearing and early migration, and 31 d (4 May 2016–25 June 2016) during late migration. DEQ lethal limit of 25°C was not exceeded during 700 d temperature was logged. The seven-day moving mean of maximum temperature revealed water temperatures below the range expected to support healthy growth (4.4–18.9°C; OPSW 1999) were encountered for a longer duration than those that exceeded the healthy growth water temperature range (Figure 20). Moving mean temperatures were less than 4.4°C for 105 d (10 November 2014–28 February 2015) during incubation, 6 d (1 March 2015 – 6 March 2015) during emergence, and 109 d (8 November 2015–26 February 2016) during early and late migration. Moving mean temperatures exceeded 18.9°C for 30 d (1 August 2014–30 August 2014) during spawning, 82 d (7 June 2015–27 August 2015) during parr rearing and early migration, and 16 d (3 June 2016 – 30 June 2016) during late migration.

Average daily discharge during in-basin life history of the 2014 cohort ranged from 0.2 to 4.3 m^3/s (Figure 21). Discharge was greater than 1.0 m^3/s from mid-March through June 2015, during emergence and parr rearing, and from early April through early June 2016, during late migration, excluding 2 d in late March, and 11 d in mid-April 2015. Annual peak flows occurred on 16 May 2015 and 6 May 2016, and were 3.06 m^3/s and 4.33 m^3/s, respectively. Discharge was less than 1.0 m^3/s from August 2014 through mid-March 2015, during spawning, incubation, and emergence, and from mid-June 2015 through early April 2016, during parr rearing, early migration and late migration. In addition to typical spring freshets, stream discharge exceeded 1.0 m^3/s for 1 d in late November 2014, 1 d in early January 2015, 2 d in mid-February 2015, and 4 d in mid-June 2016.

FUTURE DIRECTIONS

We will continue this early life history study of spring Chinook salmon and summer steelhead in Catherine Creek and Imnaha, Lostine, middle Grande Ronde, Minam, and upper Grande Ronde rivers. This project will continue to provide key metrics to monitor and evaluate success of restoration efforts for spring Chinook salmon and steelhead in Grande Ronde River Subbasin.

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Table 1. Dates of tagging and number of spring Chinook salmon parr PIT-tagged in various northeast Oregon streams during summer 2015 and 2016.

Migration year and stream	Tagging Dates	Number PIT-tagged	Distance to Lower Granite Dam (km)
2016 (*Summer 2015)*			
Upper Catherine Creek	20 Jul–22 Jul	1,000	371–383
Lower Catherine Creek	14 Jul–16 Jul	999	356–359
Imnaha River	29 Jul, 10–12 Aug	999	221–233
Lostine River	23–24 Jul, 27–28 Jul	997	271–308
Minam River	17 Aug–20 Aug	994	276–290
Upper Grande Ronde	24 Aug–26 Aug	999	418–428
2017 (*Summer 2016)*			
Upper Catherine Creek	18 Jul, 25–27 Jul	996	371–383
Lower Catherine Creek	18 Jul–21 Jul	998	356–359
Imnaha River	3 Aug, 8–9 Aug	999	221–233
Lostine River	21 July, 28 July, 1–2 Aug	999	271–308
Minam River	15 Aug–18 Aug	994	276–290
Upper Grande Ronde	22 Aug–23 Aug	996	418–428

Table 2. Juvenile spring Chinook salmon catch at five general trap locations in Grande Ronde River Subbasin during MY 2016. Early migration period starts 1 July 2015 and ends 28 January 2016. Late migration period starts 29 January and ends 30 June 2016. The period a trap operated was used to identify total number of days fished, with percentage in parentheses, during each migration period.

Trap site	Migration period	Sampling period	Days fished	Trap catch
Catherine Creek	Early	10 Sep 15–18 Nov 15	69 (99)	11,584
	Late	26 Feb 16–21 Jun 16	100 (85)	526
Lostine River	Early	8 Sep 15–28 Jan 16	91 (64)	6,577
	Late	29 Jan 15–7 Jun 16	105 (80)[a]	1,486[a]
			8 (6)[b]	111[b]
Middle Grande Ronde River	Late	26 Feb 16–3 Jun 16	82 (83)	1,728
Minam River	Early	9 Sep 15–21 Nov 15	72 (97)	16,519
	Late	3 Mar 16–8 Jun 16	86 (86)	1,758
Upper Grande Ronde River	Early	17 Sep 15–18 Nov 15	38 (63)	4,172
	Late	27 Feb 16–9 Apr 16	41 (95)	5,171

[a] Continuous 24 h trapping
[b] Sub-sampling with 1 to 4 h trapping.

Table 3. Fork lengths of juvenile spring Chinook salmon collected from study streams during MY 2016. Summer, early and late migrants were captured with rotary screw traps. Summer and winter tag group fish were captured using netting techniques upstream from rotary screw traps. Min = minimum, Max = maximum.

	Lengths (mm) of fish collected					Lengths (mm) of fish tagged and released				
Stream and tag group	*n*	Mean	SE	Min	Max	*n*	Mean	SE	Min	Max
Catherine Creek										
Summer (upper)	1,098	64.35	0.23	46	99	997	65.45	0.21	55	86
Summer (lower)	1,037	66.64	0.20	46	89	998	67.19	0.19	55	89
Early migrants	1,220	73.27	0.26	49	125	699	72.48	0.31	55	104
Winter	578	80.74	0.34	55	104	570	80.77	0.34	55	104
Late migrants	476	82.64	0.33	60	105	462	82.56	0.33	60	103
Lostine River										
Summer	997	66.72	0.30	55	100	997	66.72	0.30	55	100
Early migrants	1,546	85.43	0.26	53	127	1,198	85.76	0.28	57	127
Winter	612	77.45	0.27	60	102	598	77.47	0.27	60	102
Late migrants	1,229	90.34	0.25	53	135	891	90.41	0.28	63	128
Middle Grande Ronde River										
Late Migrants	1,327	97.66	0.28	68	135	796	93.43	0.31	68	116
Minam River										
Summer	994	66.91	0.24	55	94	994	66.91	0.24	55	94
Early migrants	1,515	77.56	0.27	48	120	1,089	77.98	0.31	55	112
Late migrants	864	85.22	0.30	63	132	746	85.17	0.32	66	132
Upper Grande Ronde River										
Summer	1,175	60.42	0.18	44	94	997	61.64	0.17	55	84
Early migrants	932	71.28	0.20	53	89	699	71.48	0.23	55	89
Winter	381	70.50	0.37	56	95	331	70.85	0.41	56	95
Late migrants	920	77.97	0.23	58	101	600	78.13	0.29	58	95
Imnaha River										
Summer	999	65.89	0.24	55	92	999	65.89	0.24	55	92

Table 4. Weights of juvenile spring Chinook salmon collected from study streams during MY 2016. Early and late migrants were captured with a rotary screw trap on each study stream. Summer and winter tag group fish were captured using netting techniques upstream from rotary screw traps. Min = minimum, Max = maximum.

	Weights (g) of fish collected					Weights (g) of fish tagged and released				
Stream and group	*n*	Mean	SE	Min	Max	*n*	Mean	SE	Min	Max
Catherine Creek										
Summer (upper)	1,000	3.26	0.04	1.6	12.7	997	3.24	0.03	1.6	7.5
Summer (lower)	999	3.70	0.03	1.9	9.4	998	3.70	0.03	1.9	9.4
Early migrants	1,217	4.30	0.05	1.1	15.5	699	4.16	0.05	1.7	9.7
Winter	578	5.50	0.07	1.5	11.5	570	5.50	0.07	1.5	11.5
Late migrants	476	6.06	0.08	2.3	15.1	462	6.04	0.08	2.3	12.8
Lostine River										
Summer	996	3.53	0.06	1.1	11.8	996	3.53	0.06	1.1	11.8
Early migrants	1,546	6.95	0.07	1.6	24.2	1,198	7.00	0.07	1.7	21.8
Winter	612	4.80	0.05	2.1	10.7	598	4.81	0.05	2.1	10.7
Late migrants	1,229	8.00	0.07	1.5	24.5	891	8.00	0.08	3.0	21.7
Middle Grande Ronde River										
Late Migrants	1,327	10.00	0.09	2.8	23.7	796	8.51	0.09	2.8	16.4
Minam River										
Summer	987	3.42	0.04	1.4	10.3	987	3.42	0.04	1.4	10.3
Early migrants	1,515	5.05	0.06	1.2	16.4	1,089	5.09	0.06	1.6	14.1
Late migrants	864	6.62	0.08	2.4	26.6	746	6.63	0.09	2.6	26.6
Upper Grande Ronde River										
Summer	1,004	2.71	0.03	1.6	10.3	997	2.69	0.02	1.6	6.8
Early migrants	912	3.68	0.03	1.2	6.7	699	3.72	0.03	1.6	6.7
Winter	381	3.68	0.06	1.8	8.0	331	3.74	0.07	1.8	8.0
Late migrants	920	4.62	0.04	1.7	9.6	600	4.68	0.05	1.7	8.2
Imnaha River										
Summer	999	3.28	0.04	1.5	9.4	999	3.28	0.04	1.5	9.4

Table 5. Survival probability to Lower Granite Dam of juvenile spring Chinook salmon tagged during summer 2014 and detected at Columbia and Snake river dams during 2016.

Stream	Number PIT-tagged and released	Survival probability (95% CI)
Upper Catherine Creek	997	0.032 (0.020–0.053)
Lower Catherine Creek	998	(a)
Imnaha River	999	0.131 (0.106–0.162)
Lostine River	997	0.081 (0.062–0.107)
Minam River	994	0.124 (0.101–0.153)
Upper Grande Ronde River	997	0.076 (0.056–0.107)

[a] Data were insufficient to calculate a survival probability.

Table 6. Juvenile spring Chinook salmon survival probability by location and tag group from time of tagging to Lower Granite Dam. Spring Chinook salmon were tagged from fall 2015 to spring 2016 and detected at dams during 2016.

Stream and tag group	Number PIT-tagged and released	Survival probability (95% CI)
Catherine Creek		
Fall (trap)	699	0.060 (0.043–0.083)
Winter (above trap)	570	0.077 (0.055–0.106)
Spring (trap)	462	0.183 (0.129–0.289)
Lostine River		
Fall (trap)	1,198	0.188 (0.161–0.220)
Winter (above trap)	598	0.199 (0.160–0.251)
Spring (trap)	891	0.516 (0.472–0.565)
Middle Grande Ronde River		
Spring (trap)	796	0.572 (0.524–0.624)
Minam River		
Fall (trap)	1,090	0.185 (0.158–0.217)
Spring (trap)	747	0.464 (0.421–0.511)
Upper Grande Ronde River		
Fall (trap)	699	0.120 (0.090–0.163)
Winter (above trap)	331	0.048 (0.026–0.095)
Spring (trap)	600	0.232 (0.192–0.283)

Table 7. Juvenile steelhead catch at five general trap locations in Grande Ronde River Subbasin during MY 2016. Early migration period starts 1 July 2015 and ends 28 January 2016. Late migration period starts 29 January and ends 30 June 2016. The period a trap operated was used to identify total number of days fished, with percentage in parentheses, during each migration period.

Trap site	Migration period	Sampling period	Days fished	Trap catch
Catherine Creek	Early	10 Sep 15–18 Nov 15	69 (99)	1,756
	Late	26 Feb 16–21 Jun 16	100 (85)	1,058
Lostine River	Early	8 Sep 15–28 Jan 16	91 (64)	726
	Late	29 Jan 15–7 Jun 16	105 (80)[a]	226[a]
			8 (6)[b]	13[b]
Middle Grande Ronde River	Late	26 Feb 16–3 Jun 16	82 (83)	2,075
Minam River	Early	9 Sep 15–21 Nov 15	72 (97)	3,144
	Late	3 Mar 16–8 Jun 16	86 (86)	787
Upper Grande Ronde River	Early	17 Sep 15–18 Nov 15	38 (63)	381
	Late	27 Feb 16–9 Apr 16	41 (95)	1,086

[a] Continuous 24 h trapping.
[b] Sub-sampling with 1 to 4 h trapping.

Table 8. Age structure of early and late steelhead migrants collected at trap sites during MY 2016. The same four cohorts were represented in each migration period, but ages increased by one year from early migrants to late migrants (e.g., age-0 early migrants were same cohort as age-1 late migrants). Age structure was based on frequency distribution of sampled lengths and allocated using an age–length key. Means were weighted by migrant abundance at trap sites.

	Percent				
Emigrant type and trap site	Age-0	Age-1	Age-2	Age-3	Age-4
Early					
Catherine Creek	37.2	51.6	11.0	0.3	0.0
Lostine River	37.6	37.6	24.6	0.2	0.0
Minam River	75.5	11.3	12.4	0.8	0.0
Upper Grande Ronde River	16.9	63.8	17.8	1.5	0.0
Mean	47.2	36.6	15.7	0.6	0.0
CV (%)	51.9	61.7	39.4	110.1	0.0
Late					
Catherine Creek	0.0	81.9	17.2	0.9	0.0
Lostine River	0.0	55.5	37.0	7.6	0.0
Minam River	0.0	46.1	27.6	25.1	1.3
Upper Grande Ronde River	0.0	29.3	51.5	19.2	0.0
Mean	0.0	55.4	31.4	12.8	0.3
CV (%)	0.0	39.7	46.4	85.5	196.5
Early and Late[a]					
Middle Grande Ronde River	0.0	22.7	61.3	15.6	0.3

[a] Middle Grande Ronde River trap was located downstream from Catherine Creek and upper Grande Ronde River overwinter rearing reaches resulting in early and late emigrants being sampled simultaneously during spring emigration.

Table 9. Travel time to Lower Granite Dam of wild steelhead PIT-tagged at screw traps during spring 2016 and subsequently arriving at Lower Granite Dam (LGD) during spring 2016.

Stream	Distance to LGD (km)	Number detected	Travel time (d) Median	Min	Max
Catherine Creek	362	9	22	7	68
Lostine River	274	16	16	4	43
Middle Grande Ronde River	258	166	11	3	71
Minam River	245	92	20	4	70
Upper Grande Ronde River	397	58	36	6	80

Table 10. Probability of surviving and migrating, in the first year to Lower Granite Dam, for steelhead PIT-tagged at screw traps on Catherine Creek and Lostine, middle Grande Ronde, Minam, and upper Grande Ronde rivers during fall 2015 and spring 2016 (MY 2016). Catherine Creek and upper Grande Ronde River early migrants overwinter upstream of middle Grande Ronde River trap site, so no fall tag group was available for that site.

Season and location tagged	Number tagged	Number detected	Probability of surviving and migrating in the first year (95% CI)
Fall			
Catherine Creek	454	53	0.154 (0.112–0.224)
Lostine River	361	63	0.227 (0.168–0.334)
Minam River	159	30	0.248 (0.164–0.413)
Upper Grande Ronde River	248	21	0.096 (0.059–0.178)
Spring (FL ≥ 100 mm)			
Catherine Creek	192	20	0.200 (0.101–0.399)
Lostine River	107	29	0.317 (0.218–0.479)
Middle Grande Ronde River	787	324	0.595 (0.519–0.696)
Minam River	332	158	0.598 (0.513–0.708)
Upper Grande Ronde River	499	118	0.312 (0.251–0.399)

Table 11. PIT tagged early migrating steelhead sampled by screw trap in the Grande Ronde Basin, and subset subsequently detected at Snake and Columbia River dams during spring 2016. Italicized headings represent smolt age at time detections were recorded at a dam. Means are weighted by sample size (*n*).

Trap site	*n*	Age-0 *Age-1 smolt*	Age-1 *Age-2 smolt*	Age-2 *Age-3 smolt*	Age-3 *Age-4 smolt*
PIT tagged fish with known age (%)					
Catherine Creek	175	28.6	48.0	22.3	1.1
Lostine River	252	32.1	38.1	29.4	0.4
Minam River	209	34.4	30.6	32.5	2.4
Upper Grande Ronde River	94	17.0	52.1	27.7	3.2
Mean		30.0	40.1	28.4	1.5
CV (%)		25.8	24.2	15.1	82.9
PIT tagged fish detected at dams (%)					
Catherine Creek	9	0.0	44.4	55.6	0.0
Lostine River	28	0.0	67.9	32.1	0.0
Minam River	23	0.0	52.2	43.5	4.3
Upper Grande Ronde River	8	0.0	50.0	50.0	0.0
Mean		0.0	57.4	41.2	1.5
CV (%)		0.0	17.5	24.4	147.8

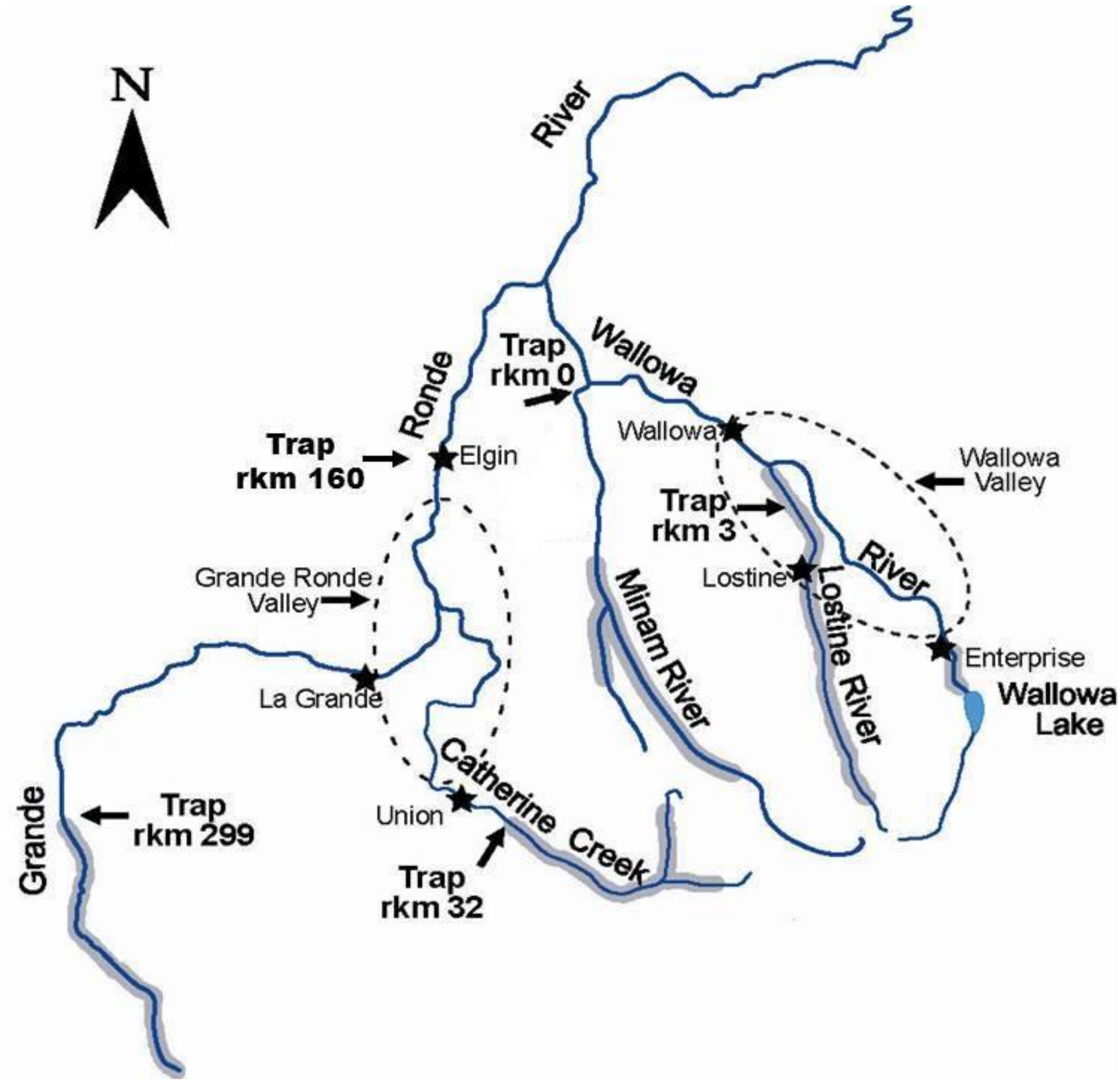

Figure 1. Locations of fish traps in Grande Ronde River Subbasin during the study period. Shaded areas delineate spring Chinook salmon spawning and upper rearing areas. Dashed lines indicate Grande Ronde and Wallowa river valleys. Traps were located at rkm 32 on Catherine Creek, rkm 3 on Lostine River, rkm 0 on Minam River, and rkm 299 on upper Grande Ronde River.

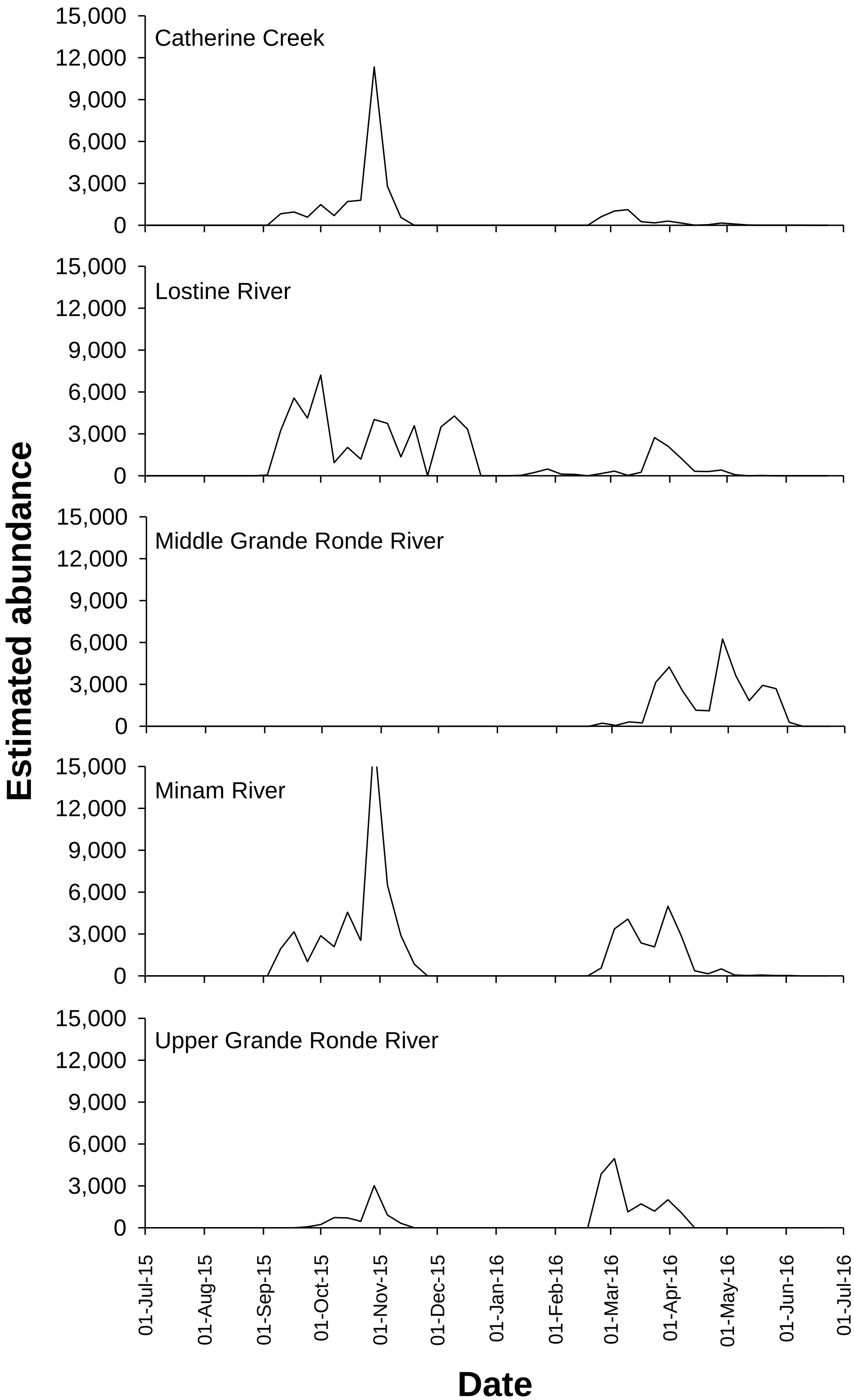

Figure 2. Estimated migration timing and abundance for juvenile spring Chinook salmon migrants sampled by rotary screw traps during MY 2016.

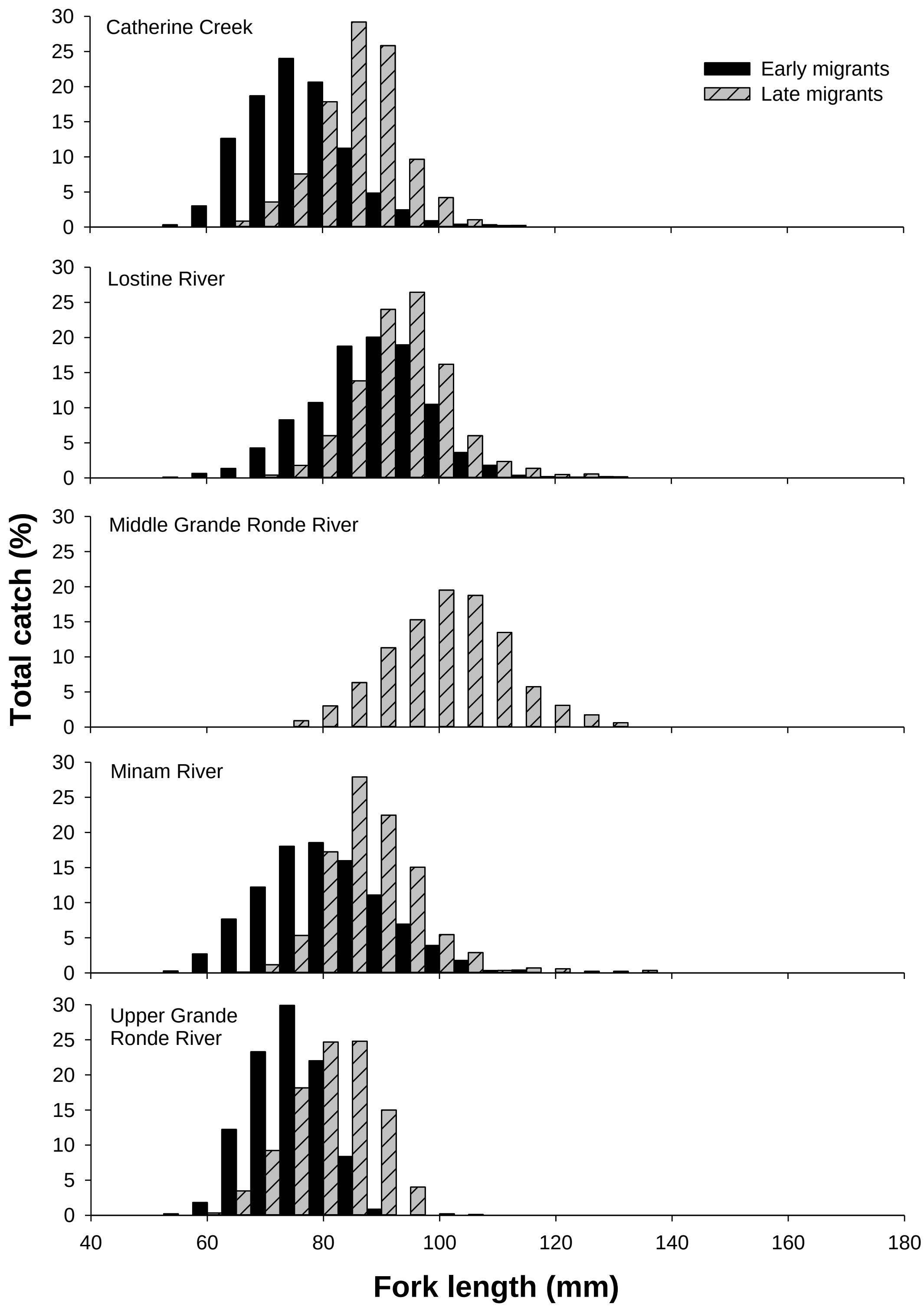

Figure 3. Length frequency distribution (fork length) of early and late migrating juvenile spring Chinook salmon captured at Catherine Creek (rkm 32), Lostine (rkm 3), middle Grande Ronde (rkm 160), Minam (rkm 0), and upper Grande Ronde (rkm 299) river traps during MY 2016.

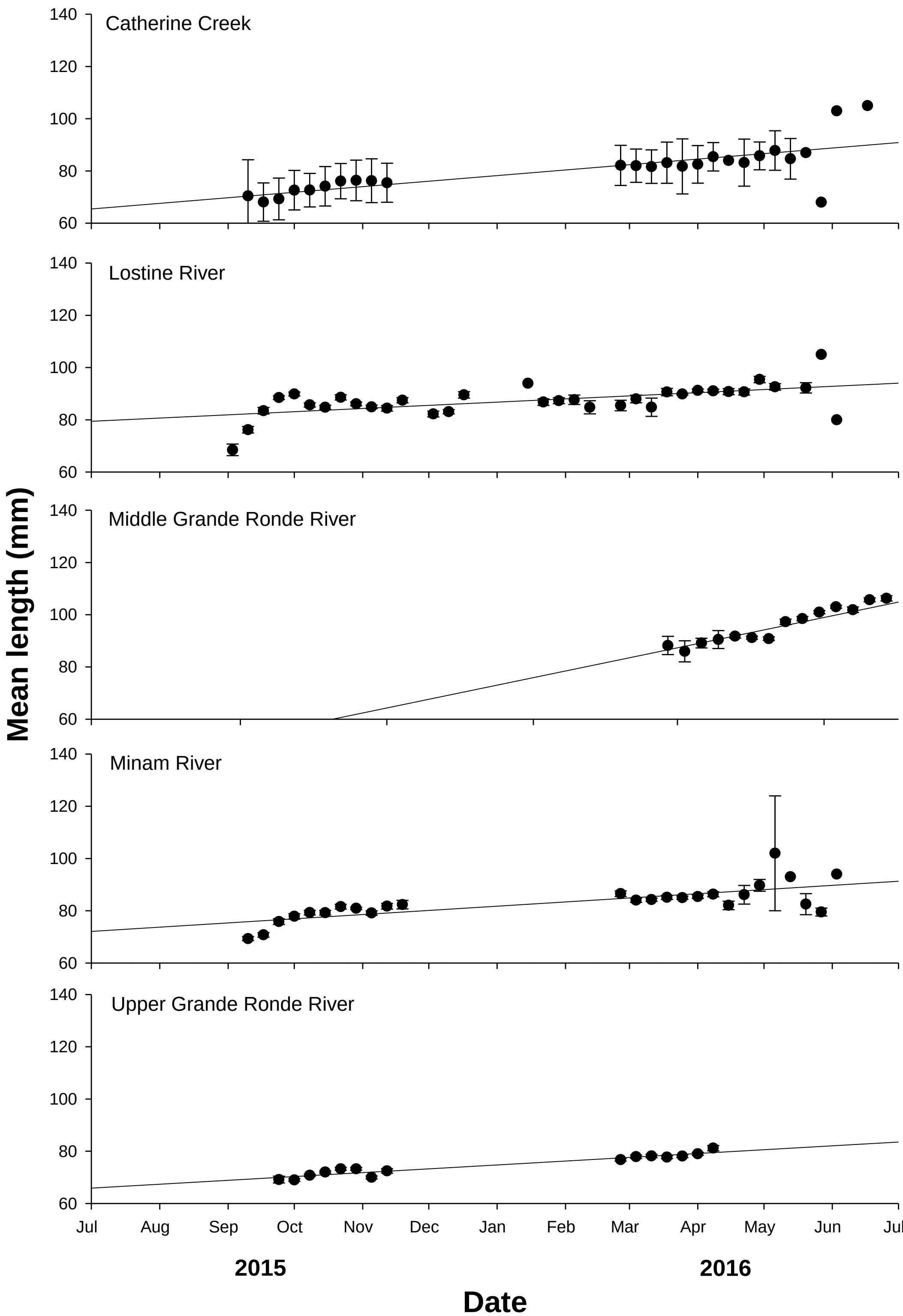

Figure 4. Weekly mean fork lengths and associated standard error for spring Chinook salmon captured by rotary screw traps in Grande Ronde River Subbasin during MY 2016.

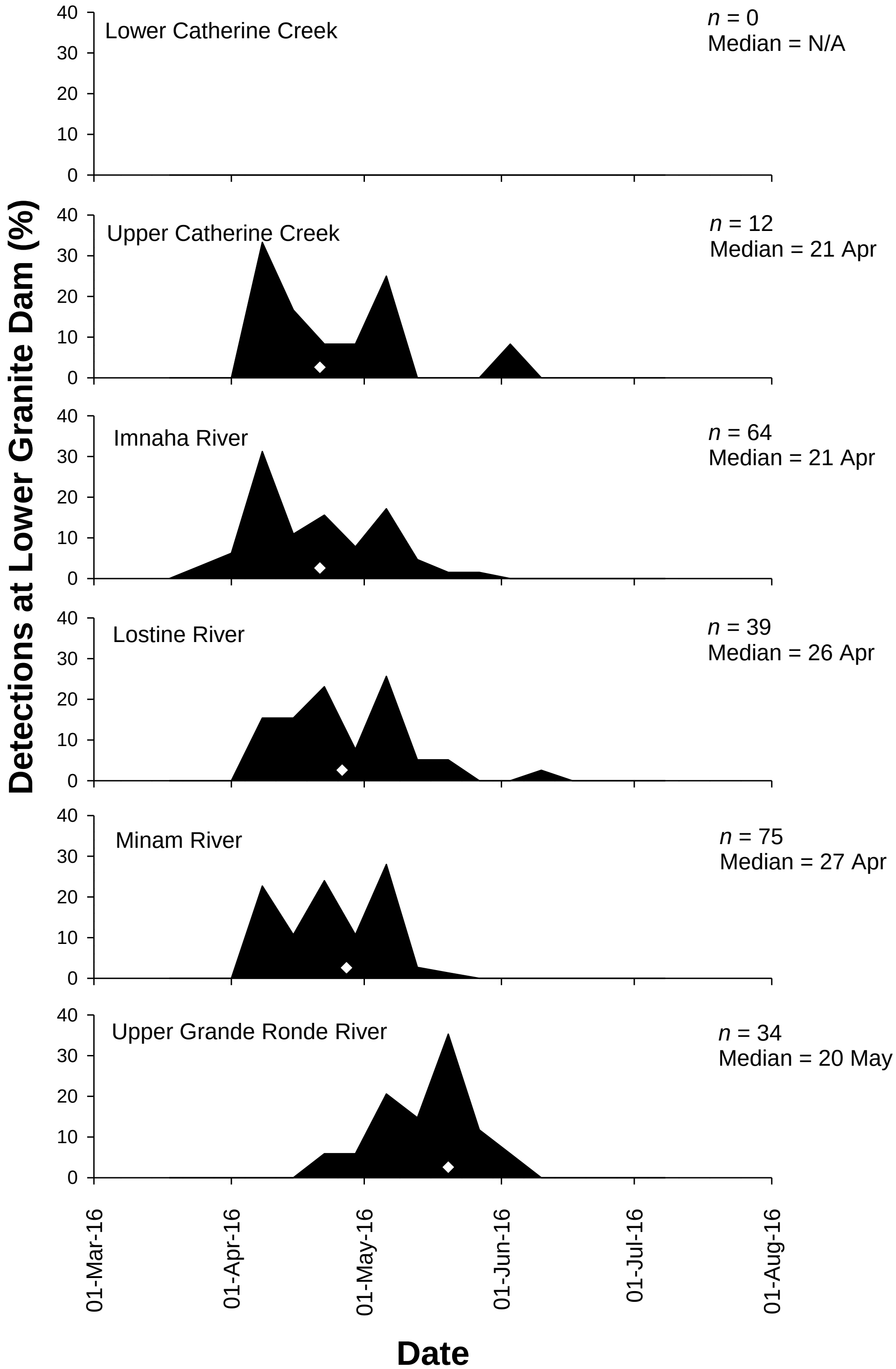

Figure 5. Dates of arrival, during 2016 at Lower Granite Dam, of spring Chinook salmon PIT-tagged as parr in upper and lower Catherine Creek and Imnaha, Lostine, Minam, and upper Grande Ronde rivers during summer 2015. Data were summarized by week and expressed as percentage of total detected. Detections were expanded for spillway flow. ♦ = median arrival date.

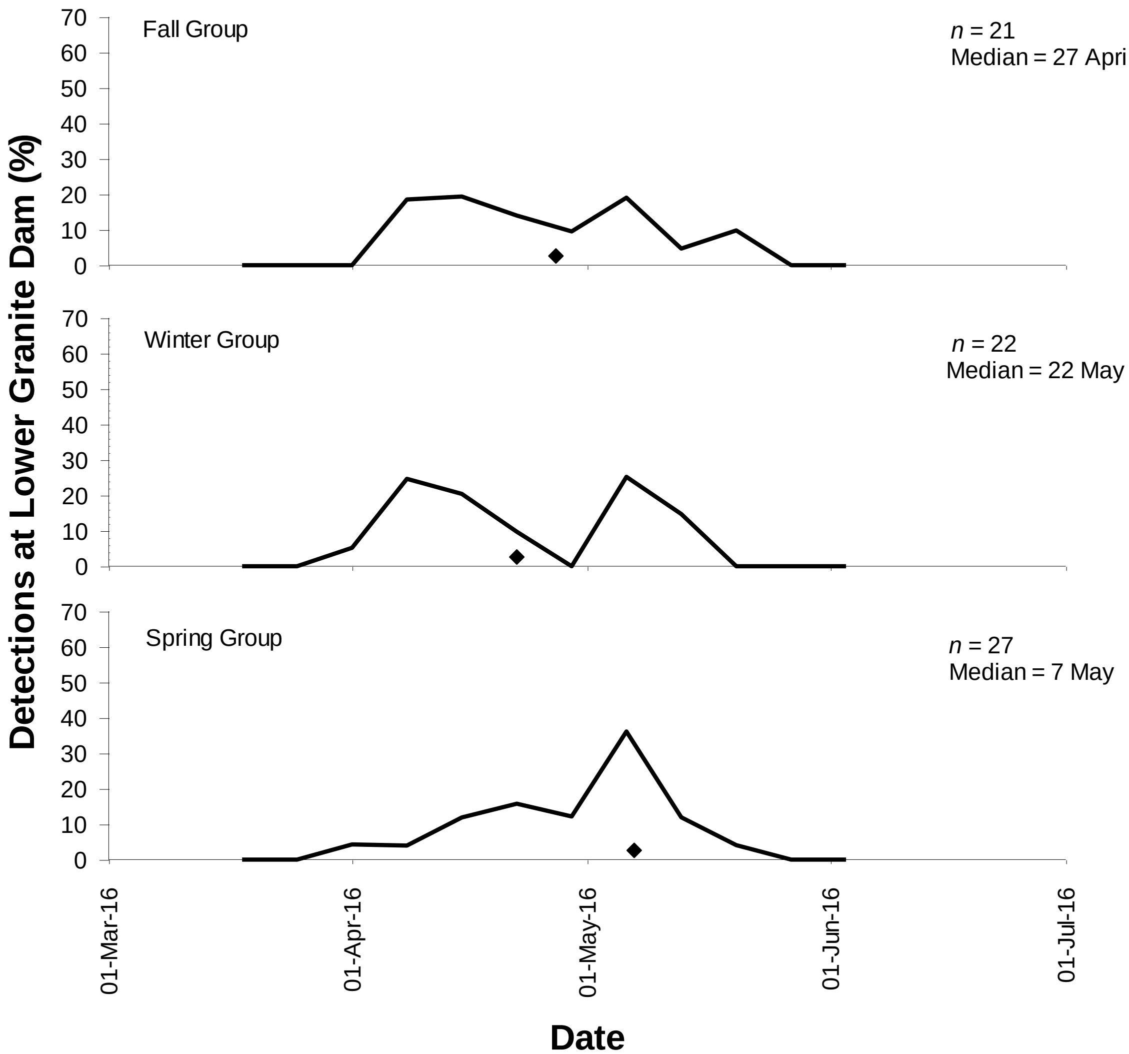

Figure 6. Dates of arrival, during 2016 at Lower Granite dam, for fall, winter, and spring tag groups of juvenile spring Chinook salmon PIT-tagged from Catherine Creek. Data were summarized by week and expressed as percentage of total detected. Detections were expanded for spillway flow. ♦ = median arrival date.

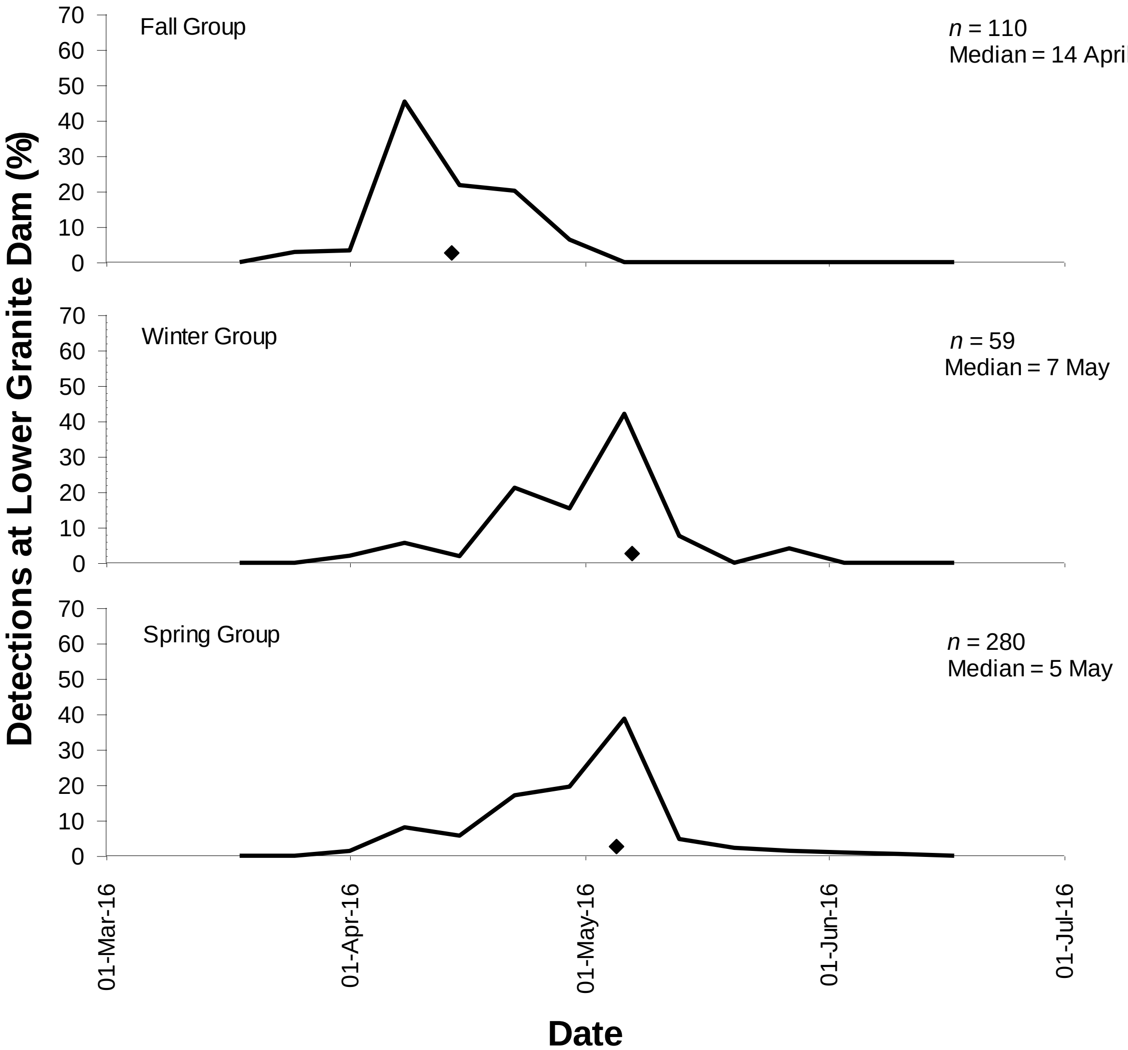

Figure 7. Dates of arrival, during 2016 at Lower Granite dam, for fall, winter, and spring tag groups of juvenile spring Chinook salmon PIT-tagged from Lostine River. Data were summarized by week and expressed as percentage of total detected. Detections were expanded for spillway flow. ♦ = median arrival date.

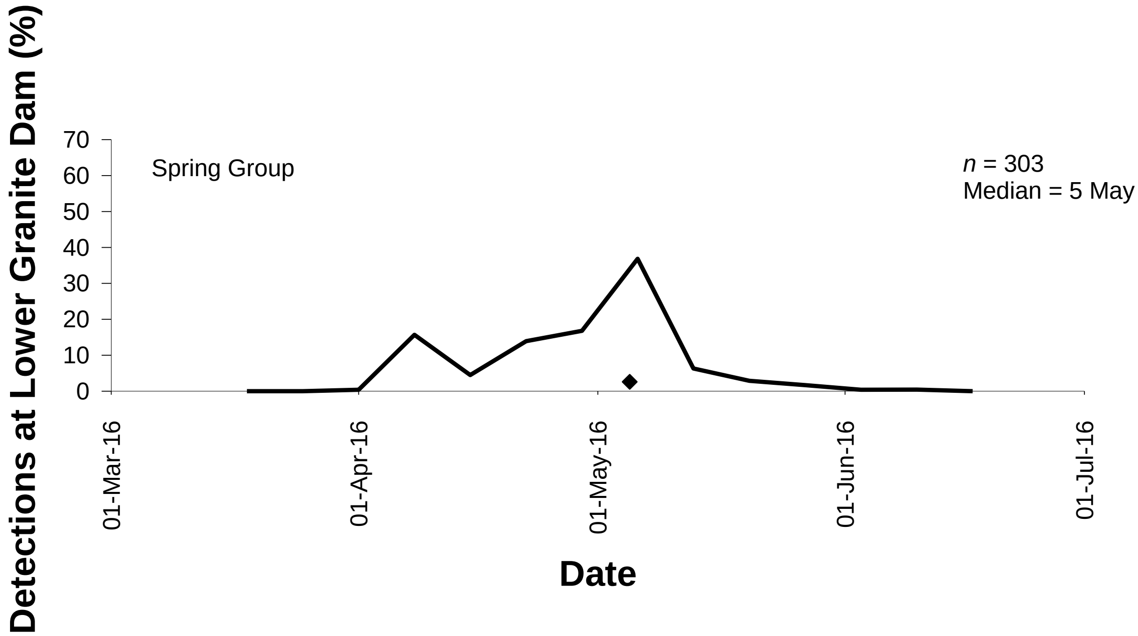

Figure 8. Dates of arrival, during 2016 at Lower Granite dam, for the spring tag group of juvenile spring Chinook salmon PIT-tagged from middle Grande Ronde River. Data were summarized by week and expressed as percentage of total detected. Detections were expanded for spillway flow. ♦ = median arrival date.

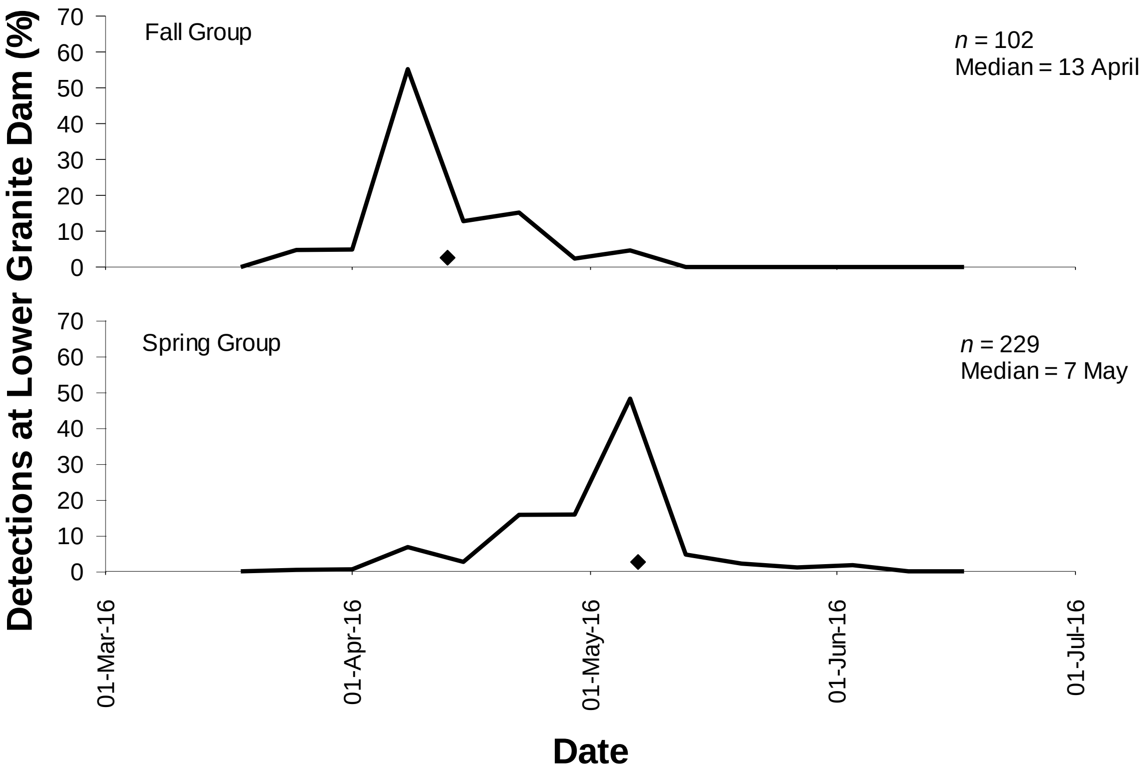

Figure 9. Dates of arrival, during 2016 at Lower Granite dam, for fall and spring tag groups of juvenile spring Chinook salmon PIT-tagged from Minam River. Data were summarized by week and expressed as percentage of total detected. Detections were expanded for spillway flow. ♦= median arrival date.

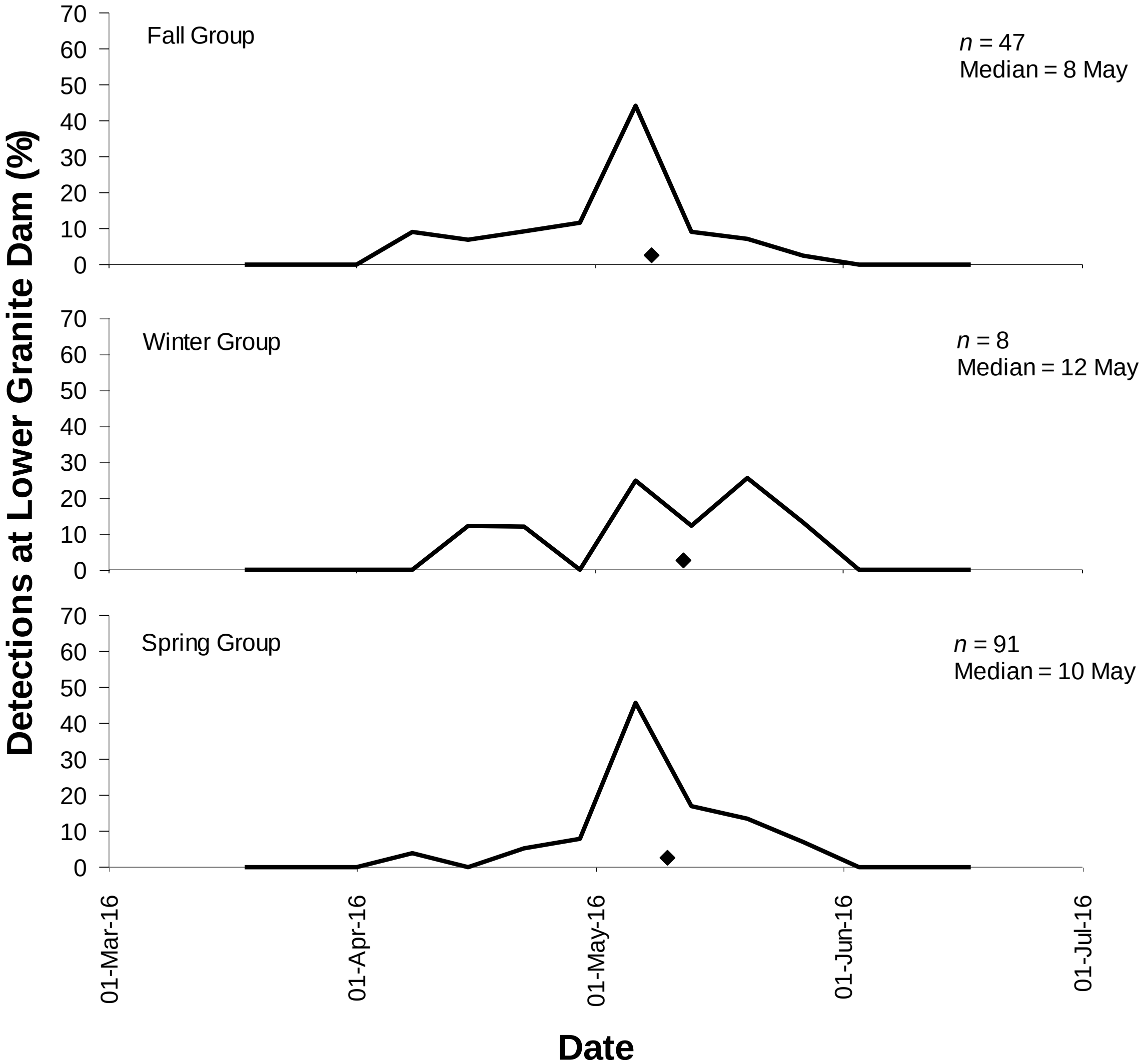

Figure 10. Dates of arrival, during 2016 at Lower Granite dam, for fall, winter, and spring tag groups of juvenile spring Chinook salmon PIT-tagged from upper Grande Ronde River. Data were summarized by week and expressed as percentage of total detected. Detections were expanded for spillway flow. ♦ = median arrival date.

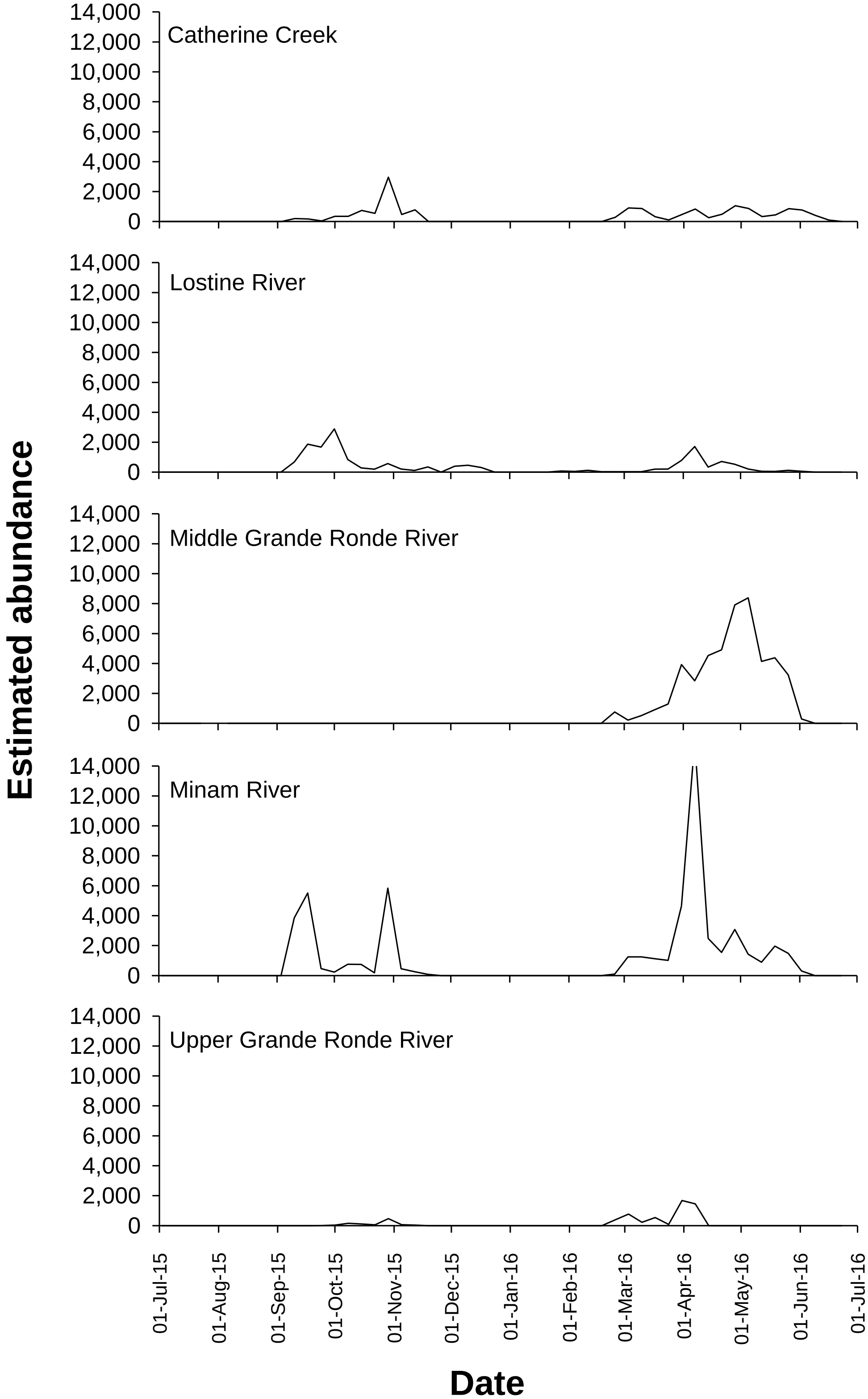

Figure 11. Estimated migration timing and abundance of juvenile summer steelhead migrants captured by rotary screw trap during MY 2016.

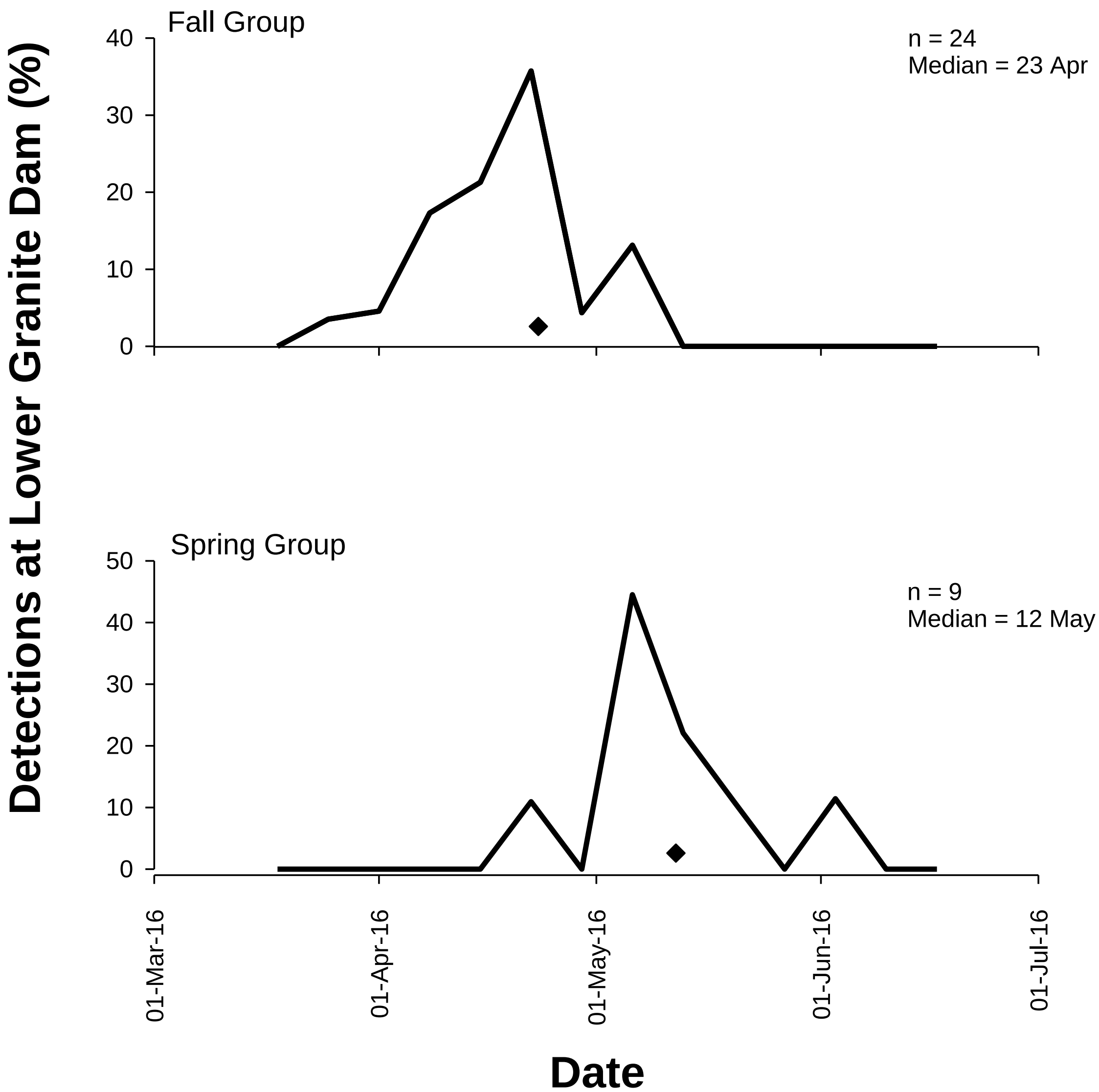

Figure 12. Dates of arrival, in 2016, at Lower Granite Dam for fall and spring tag groups of steelhead PIT-tagged from Catherine Creek, and expressed as a percentage of total detected for each group. Detections were expanded for spillway flow. ♦ = median arrival date.

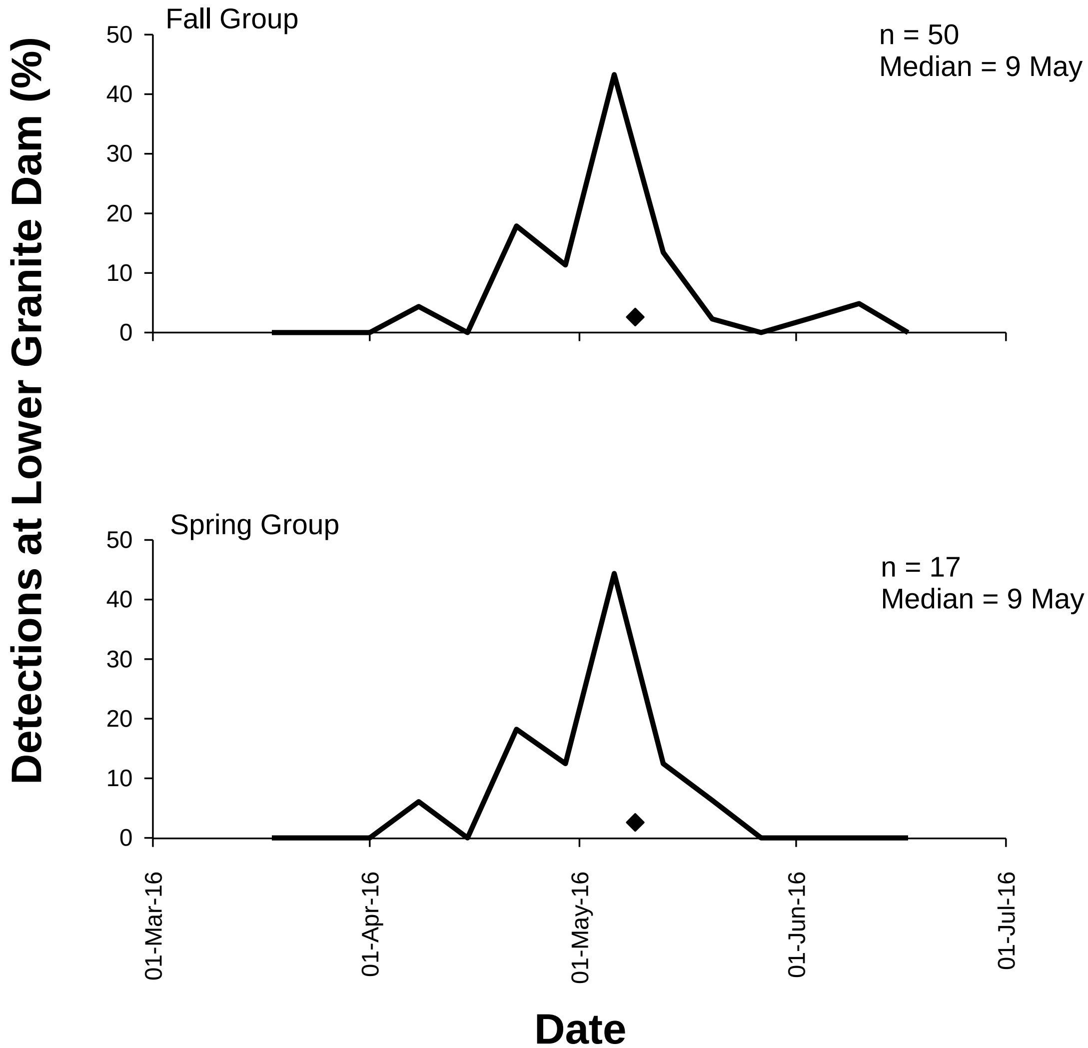

Figure 13. Dates of arrival, in 2016, at Lower Granite Dam for fall and spring tag groups of steelhead PIT-tagged from Lostine River, and expressed as a percentage of total detected for each group. Detections were expanded for spillway flow. ♦ = median arrival date.

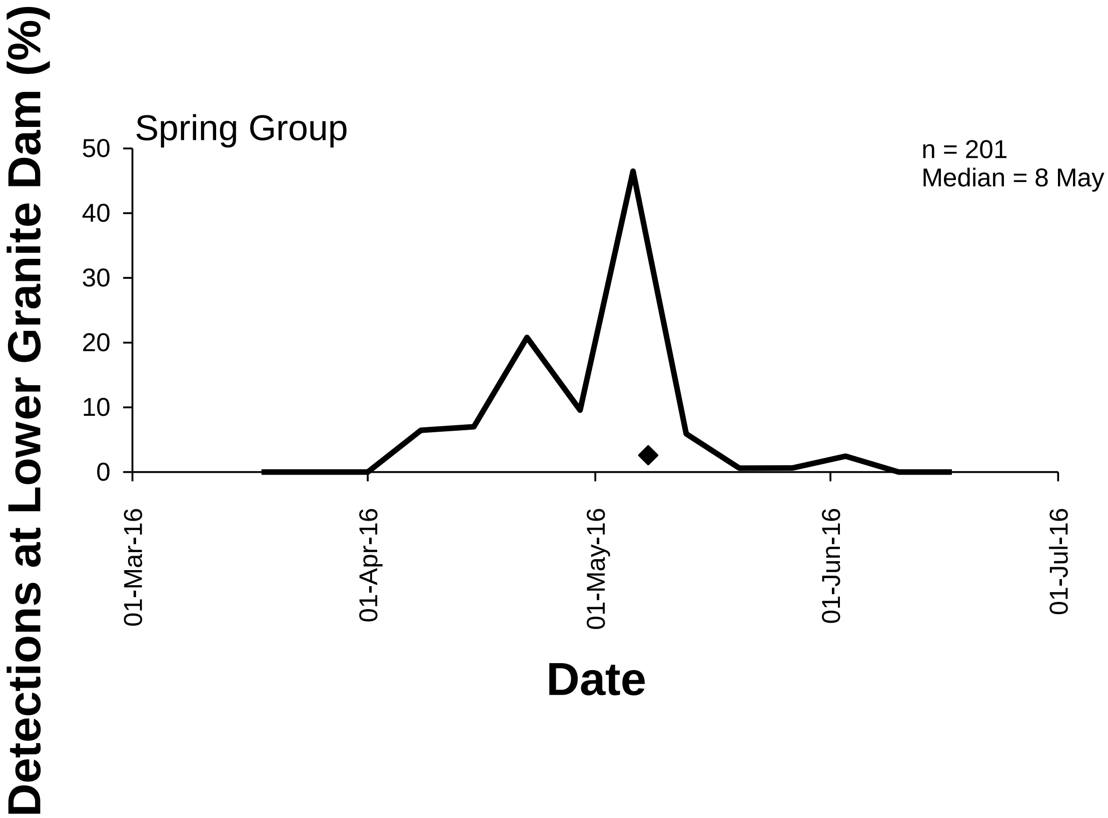

Figure 14. Dates of arrival, in 2016, at Lower Granite Dam for spring tag group of steelhead PIT-tagged from middle Grande Ronde River, and expressed as a percentage of total detected for the group. Detections were expanded for spillway flow. ♦ = median arrival date.

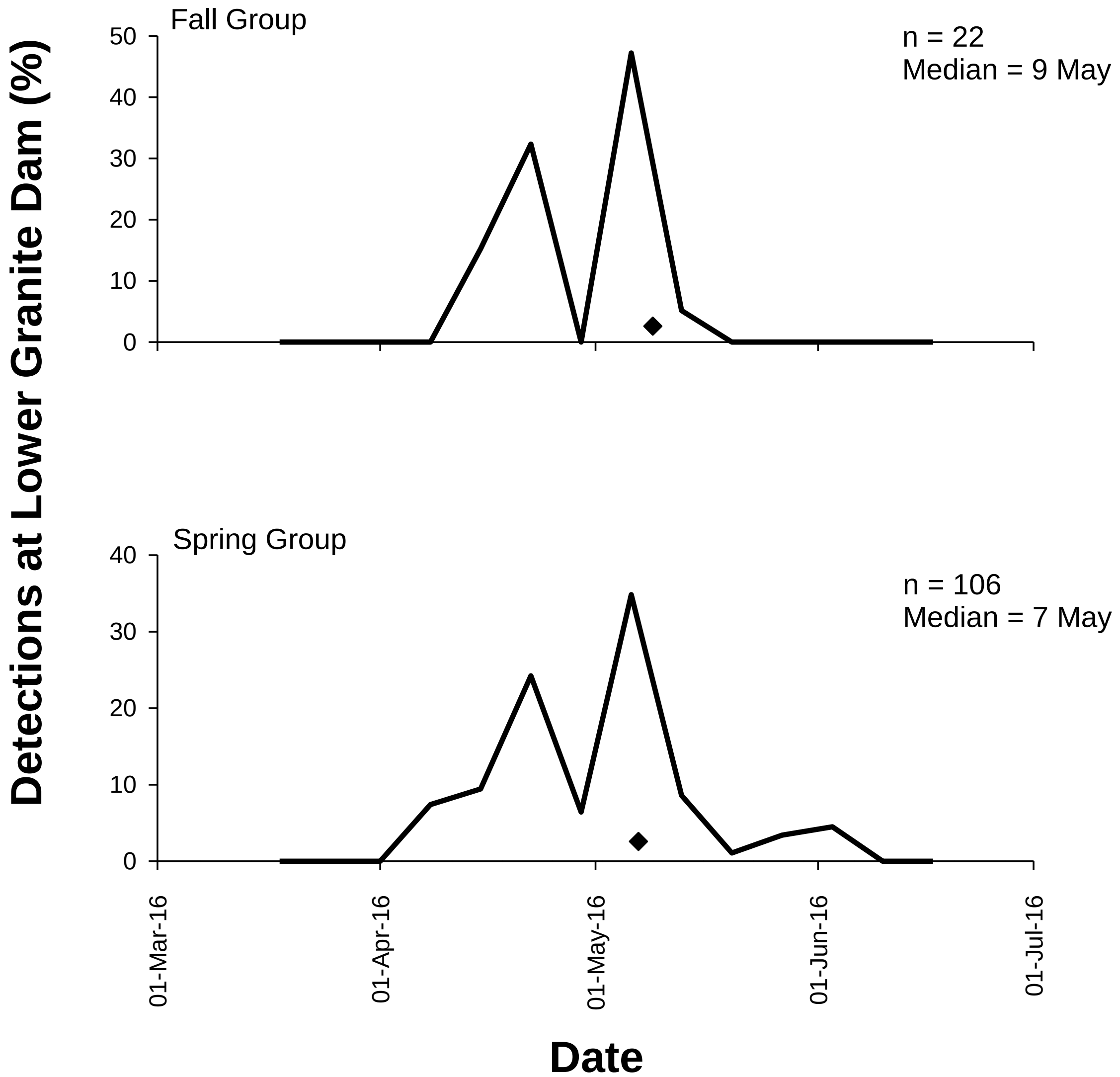

Figure 15. Dates of arrival, in 2016, at Lower Granite Dam for fall and spring tag groups of steelhead PIT-tagged from Minam River, and expressed as a percentage of total detected for each group. Detections were expanded for spillway flow. ♦ = median arrival date.

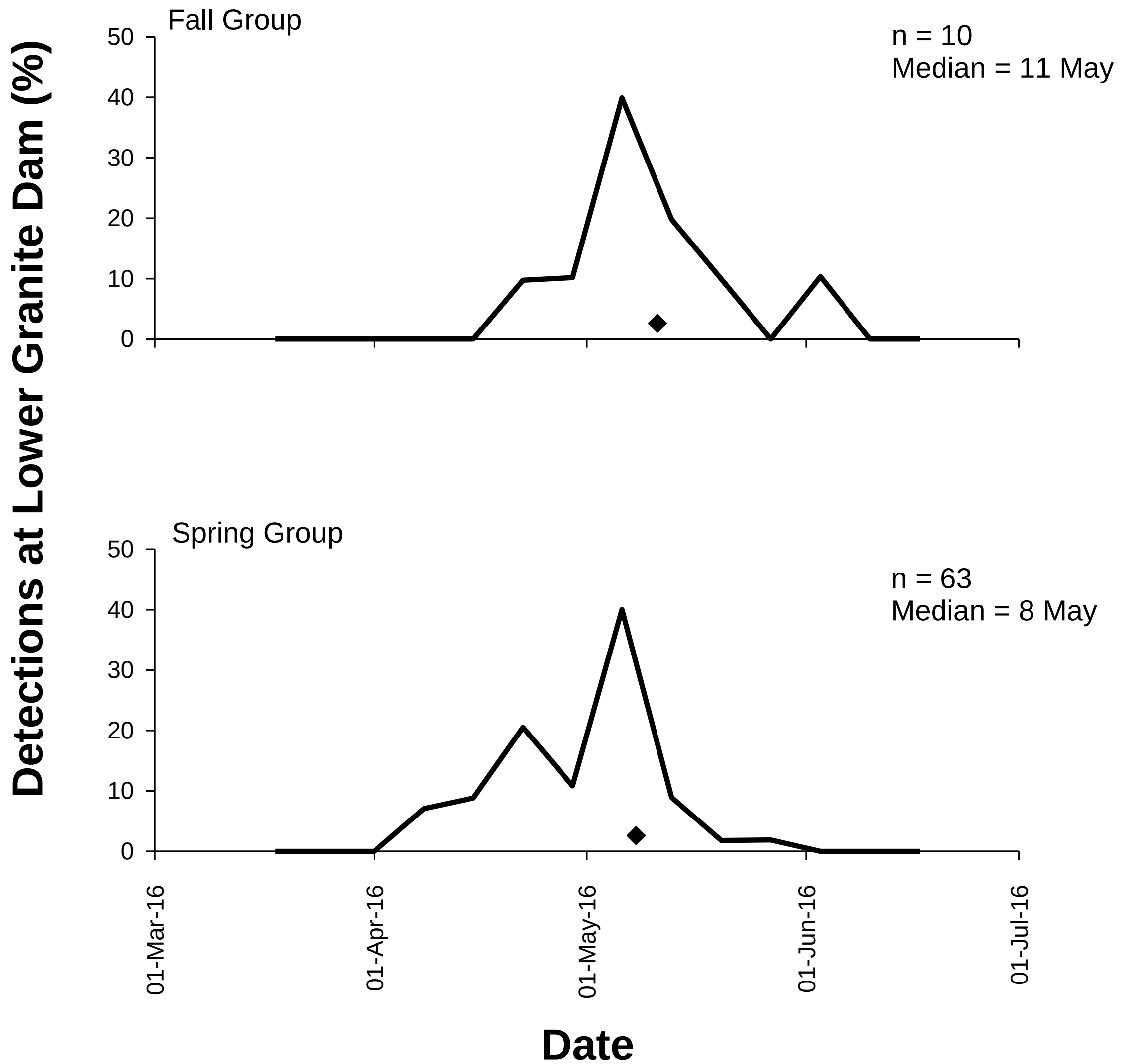

Figure 16. Dates of arrival, in 2016, at Lower Granite Dam for fall and spring tag groups of steelhead PIT-tagged from upper Grande Ronde River, and expressed as a percentage of total detected for each group. Detections were expanded for spillway flow. ♦ = median arrival date.

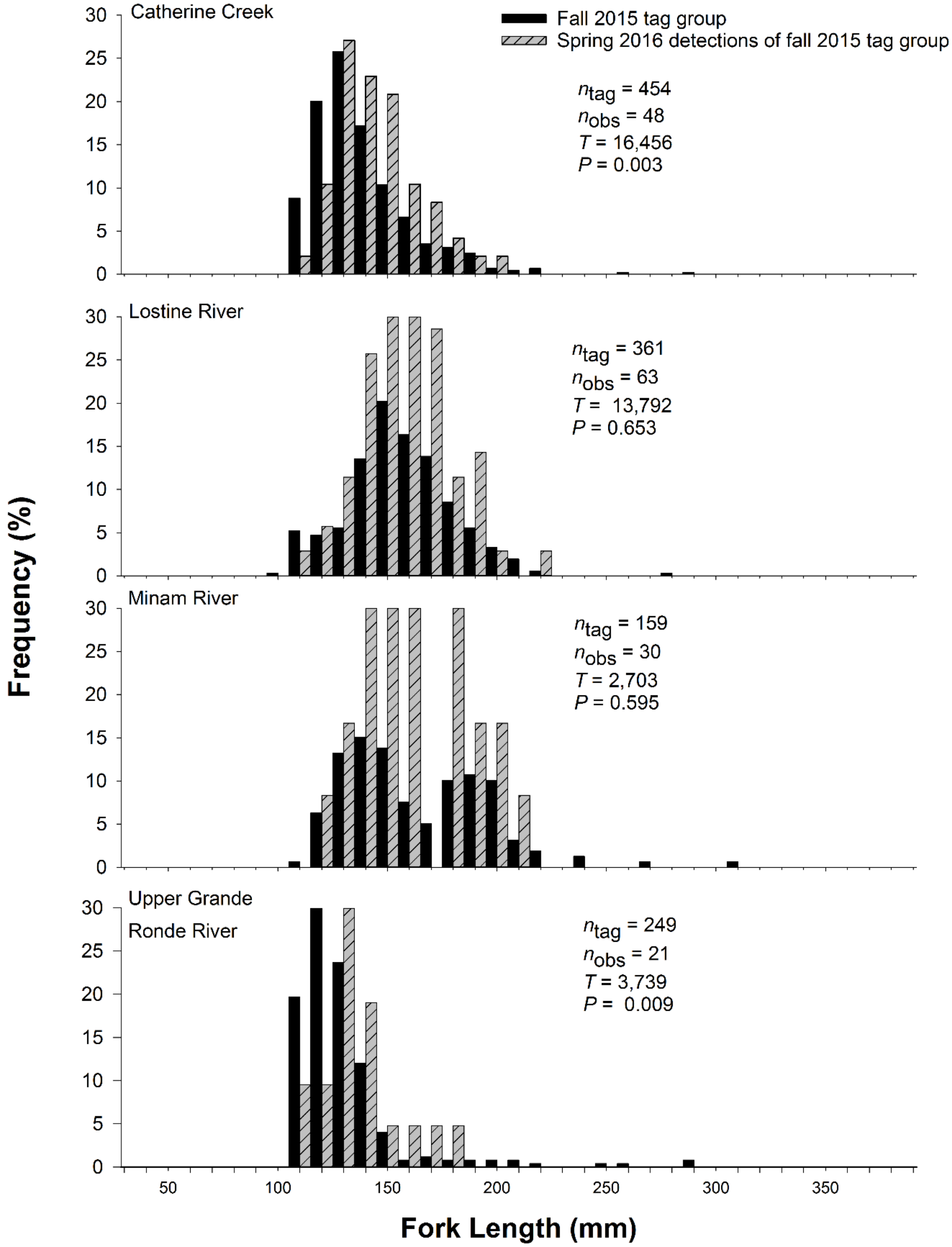

Figure 17. Length frequency distributions for all steelhead PIT-tagged at screw traps during fall 2015 and those subsequently observed at Snake or Columbia River dams during spring 2016. Fork lengths are based on measurements taken at time of tagging. Frequency is expressed as percent of total number tagged (n_{tag}). 'n_{obs}' is number detected.

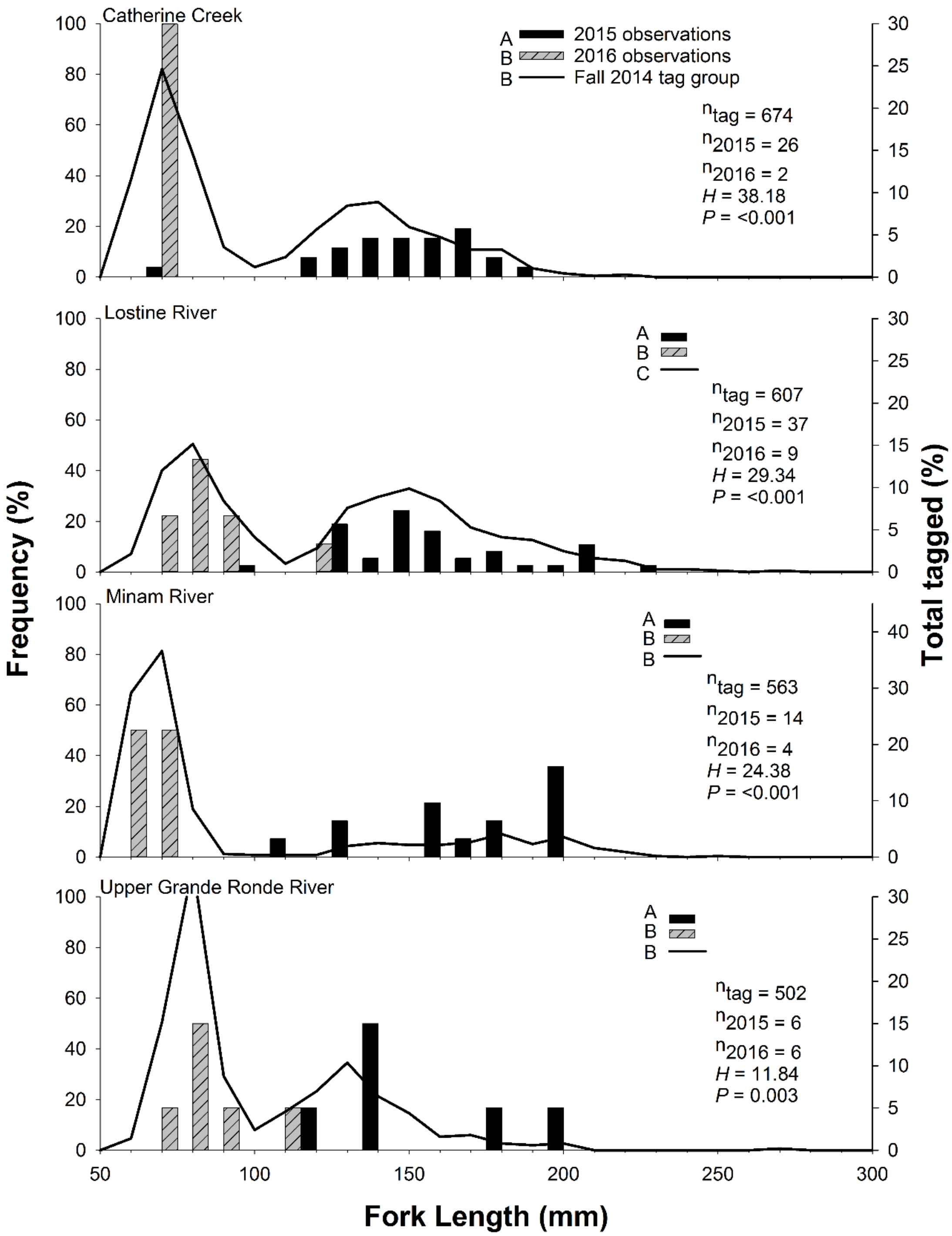

Figure 18. Length frequency distributions for steelhead PIT-tagged at screw traps during fall 2014, and those subsequently observed at Snake or Columbia river dams during 2015 and 2016. Frequency is expressed as percent of total number tagged. ‘H’ is the test statistic for the Kruskal–Wallis one-way ANOVA on ranks of lengths. Dunn’s all pair-wise multiple comparison procedure was employed to compare groups among Catherine Creek, Lostine, and upper Grande Ronde rivers ($\alpha = 0.05$).

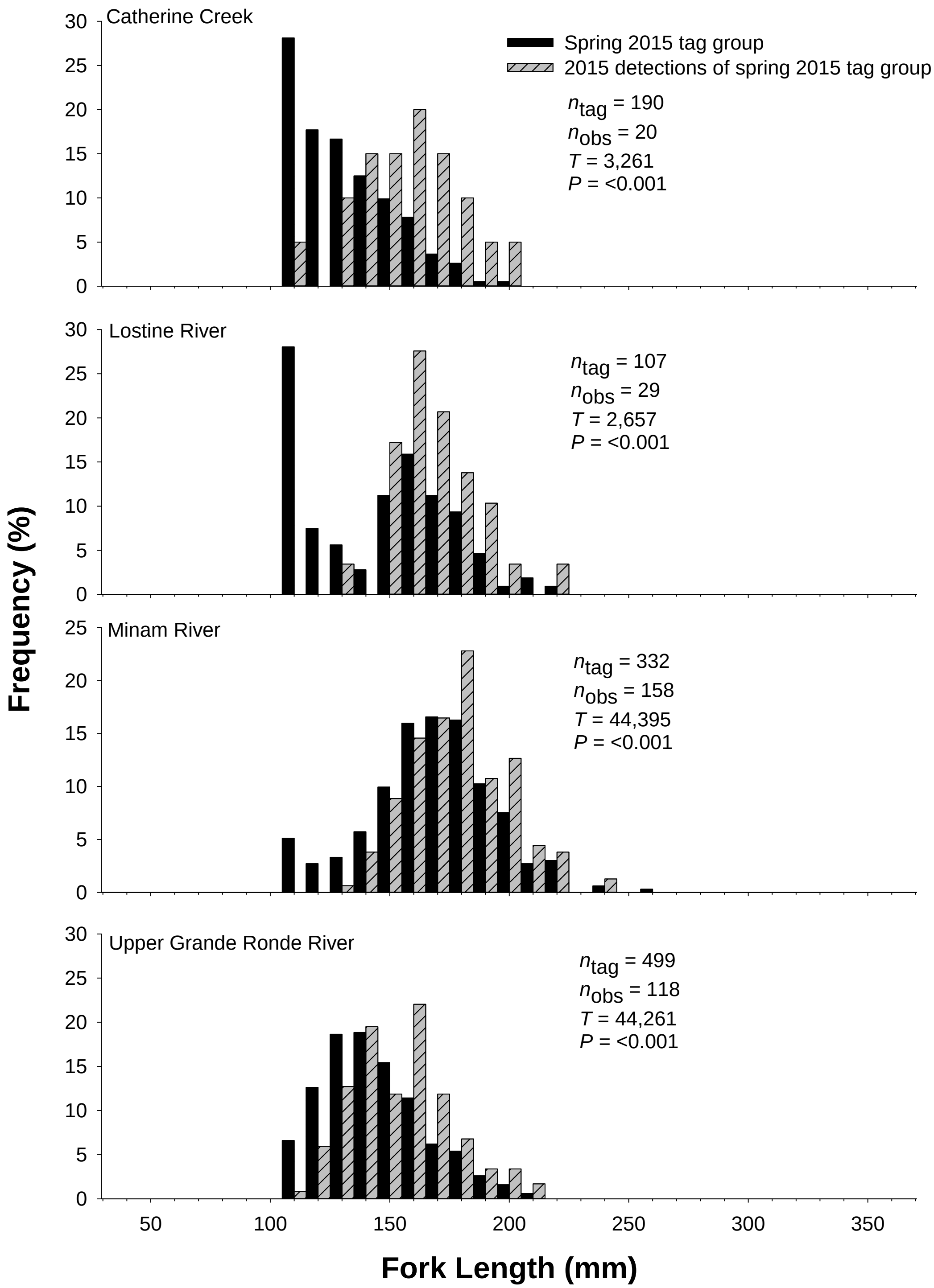

Figure 19. Length frequency distributions for steelhead PIT-tagged at screw traps during spring 2016, and those subsequently observed at Snake or Columbia river dams during spring 2016. Data were compared using the Mann-Whitney rank-sum test. Fork lengths are based on measurements taken at time of tagging. Frequency is expressed as percent of total number tagged (n_{tag}), and 'n_{obs}' represents number detected.

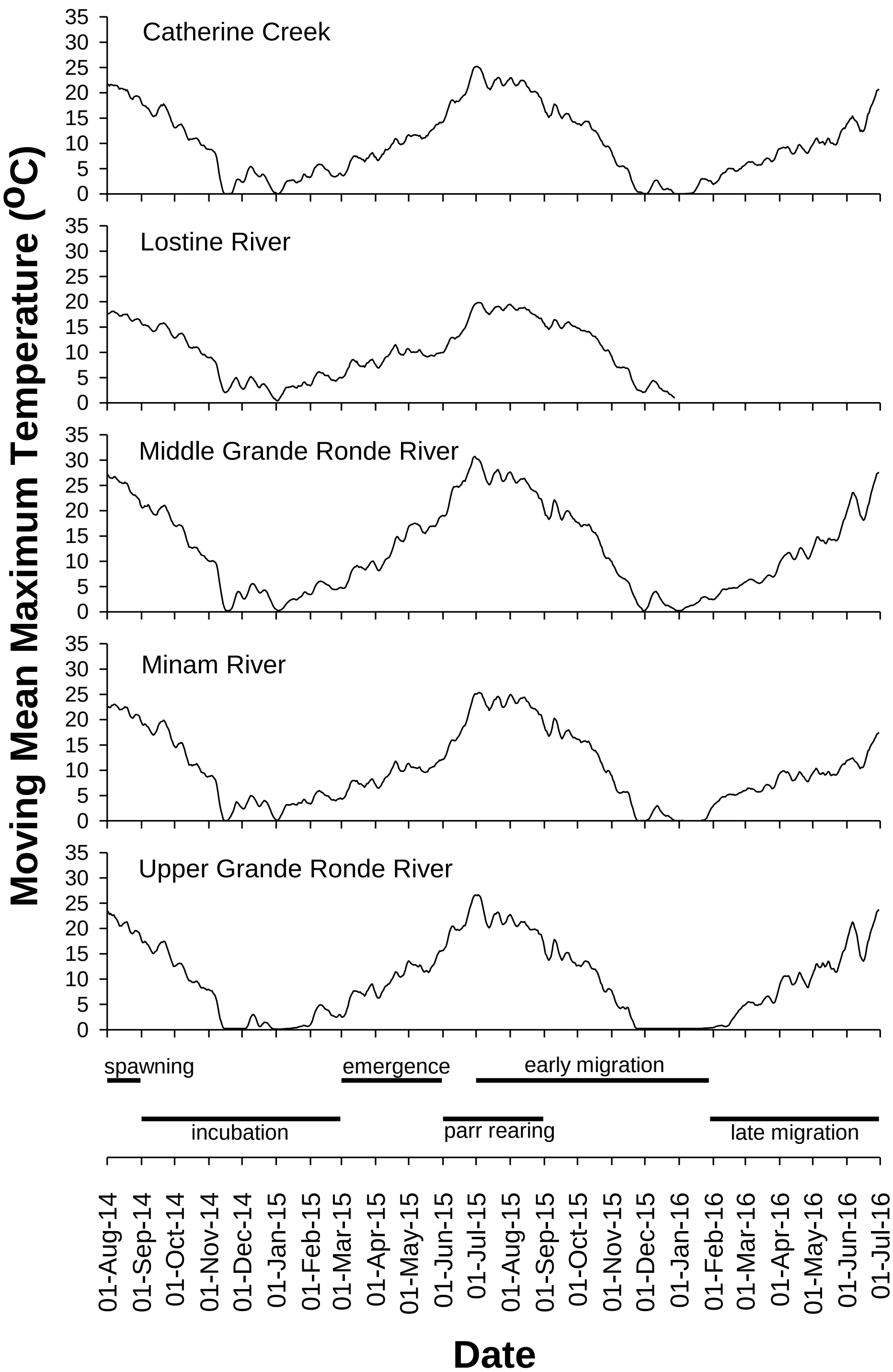

Figure 20. Moving mean of maximum water temperature from four study streams in Grande Ronde River Subbasin during MY 2016. Data corresponds with juvenile spring Chinook salmon in-basin egg-to-emigrant life stages. Missing portions of a trend line represent periods where data were not available.

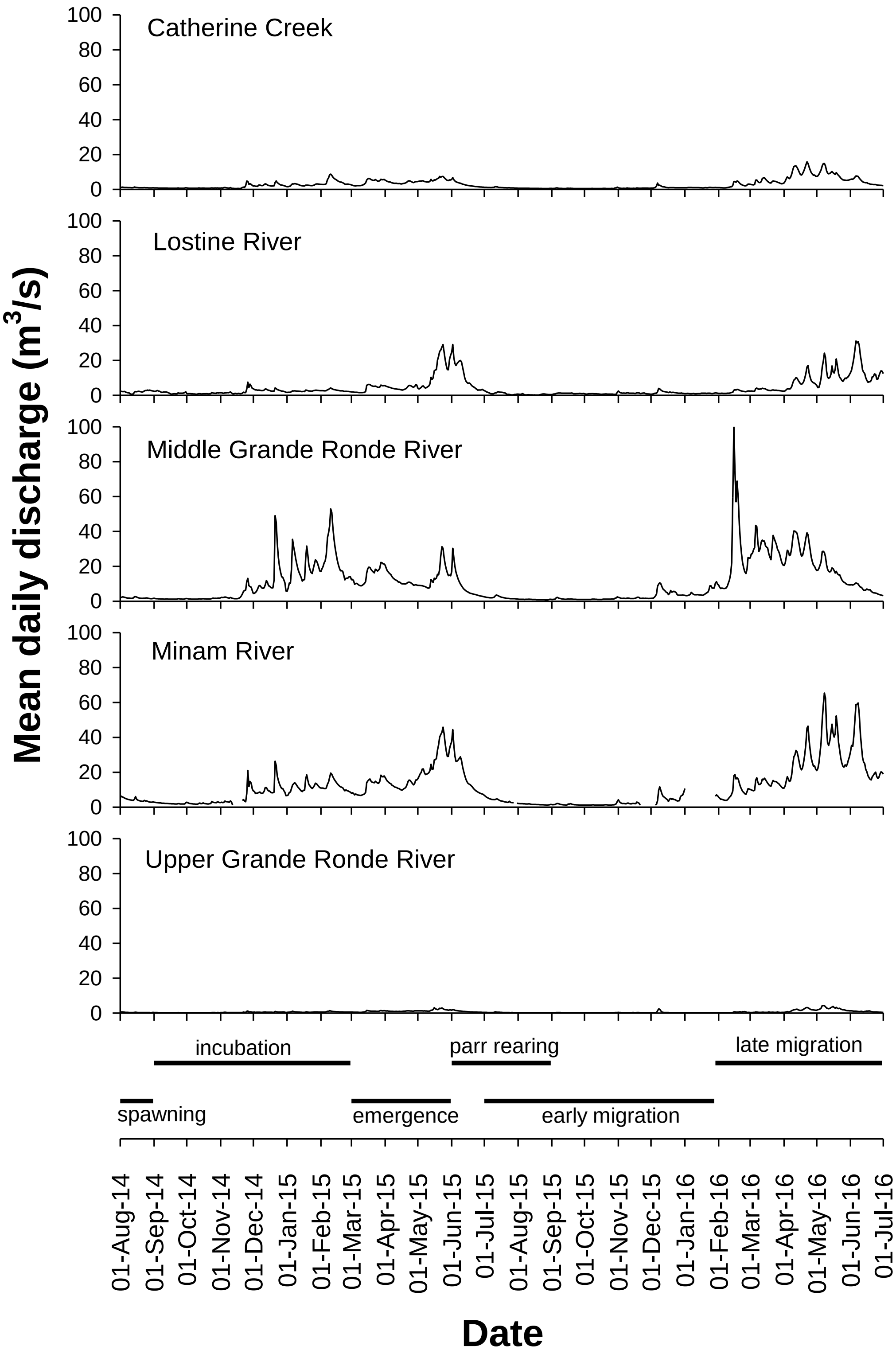

Figure 21. Average daily discharge from four study streams in the Grande Ronde River Subbasin during MY 2016. Data corresponds with juvenile spring Chinook salmon in-basin egg-to-emigrant life stages.

APPENDIX A

A Compilation of Spring Chinook Salmon Data

Appendix Table A-1. Population estimates, median migration dates, and percentages of juvenile spring Chinook salmon population emigrating as late migrants past rotary screw trap sites, 1994–2016. Early migratory period begins 1 July and ends 28 January, while late migratory period begins 29 January and ends 30 June.

			Median migration date		
Stream and MY	Population estimate	95% CI	Early migrants	Late migrants	Percentage migrating late
Catherine Creek					
1995	17,633	2,067	1 Nov[a]	21 Mar	49[a]
1996	6,857	688	20 Oct	11 Mar	27
1997	4,442	1,123	1 Nov[a]	13 Mar	10[a]
1998	9,881	1,209	30 Oct	19 Mar	29
1999	20,311	2,299	14 Nov	23 Mar	38
2000	23,991	2,342	31 Oct	23 Mar	18
2001	21,936	2,282	8 Oct	24 Mar	13
2002	23,362	2,870	12 Oct	2 Apr	9
2003	34,623	2,615	28 Oct	20 Mar	14
2004	64,012	4,203	1 Nov	18 Mar	16
2005	56,097	6,713	11 Oct	26 Mar	10
2006	27,218	2,368	31 Oct	22 Mar	16
2007	13,831	1,032	14 Oct	29 Mar	21
2008	26,151	2,099	19 Oct	30 Mar	22
2009	21,674	3,029	15 Oct	25 Mar	23
2010	43,635	7,152	14 Oct	3 Apr	26
2011	12,656	871	3 Nov	31 Mar	36
2012	58,445	3,393	27 Oct	17 Mar	38
2013	32,175	2,626	22 Oct	9 Mar	18
2014	30,791	2,501	5 Oct	1 Mar	42
2015	12,325	896	25 Oct	29 Mar	17
2016	26,818	2,886	29 Oct	10 Mar	15
Lostine River					
1997	4,496	606	26 Nov[a]	30 Mar	52[a]
1998	17,539	2,610	26 Oct	26 Mar	35
1999	34,267	2,632	12 Nov	18 Apr	41
2000	12,250	887	2 Nov	9 Apr	32
2001	13,610	1,362	29 Sep	20 Apr	23
2002	18,140	2,428	24 Oct	1 Apr	15
2003	28,939	1,865	22 Oct	1 Apr	34
2004[b]	—	—	—	—	—
2005	54,602	6,734	22 Sep	31 Mar	25
2006	54,268	8,812	4 Nov	11 Apr	22

[a] Trap was started late, thereby potentially missing some early migrants.

[b] Limited trapping operations prevented population estimates and migration timing.

Appendix Table A-1. Continued.

Stream and MY	Population estimate	95% CI	Median migration date: Early migrants	Median migration date: Late migrants	Percentage migrating late
Lostine River (continued)					
2007	46,183	4,827	14 Oct	7 Apr	26
2008	26,117	3,516	2 Nov	29 Apr	41
2009	38,935	7,353	15 Oct	30 Mar	21
2010	47,686	3,126	28 Oct	4 Apr	40
2011	65,131	10,873	12 Oct	7 Apr	20
2012	137,830	10,590	18 Oct	4 Apr	25
2013	78,437	9,454	21 Oct	3 Apr	23
2014	68,046	5,999	7 Oct	8 Apr	26
2015	24,133	1,673	22 Oct	10 Apr	28
2016	57,275	8,210	22 Oct	31 Mar	15
Middle Grande Ronde River					
2011[c]	—	—	—	—	—
2012[c]	—	—	—	—	—
2013	31,160	6,751	—	5 May	—
2014	56,469	23,066	—	15 Apr	—
2015	13,133	1,737	—	8 Apr	—
2016	30,600	3,288	—	28 Apr	—
Minam River					
2001	28,209	4,643	8 Oct[a]	27 Mar	64[a]
2002	79,000	10,836	24 Oct[a]	8 Apr	21[a]
2003	63,147	10,659	30 Oct[a]	5 Apr	69[a]
2004	65,185	9,049	13 Nov	29 Mar	34
2005	111,390	26,553	21 Oct	28 Mar	57
2006	50,959	8,262	14 Oct	1 Apr	42
2007	37,719	5,767	5 Nov	22 Mar	31
2008	77,301	11,997	21 Oct	13 Apr	57
2009	43,643	8,936	3 Nov	29 Mar	38
2010	166,018	35,709	15 Oct	3 Apr	55
2011	73,645	10,922	8 Nov	26 Apr	44
2012	95,284	7,501	18 Oct	2 Apr	19
2013	61,106	6,016	18 Oct	3 Apr	28
2014	70,074	7,036	9 Oct	6 Apr	26
2015	19,624	924	25 Oct	23 Mar	51
2016	66,846	6,978	29 Oct	24 Mar	32

[c] Insufficient trap efficiency to produce an estimate.

Appendix Table A-1. Continued.

Stream and MY	Population estimate	95% CI	Median migration date: Early migrants	Median migration date: Late migrants	Percentage migrating late
Upper Grande Ronde River					
1994	24,791	3,193	14 Oct[a]	1 Apr	89[a]
1995[d]	38,725	12,690	30 Oct	31 Mar	87
1996	1,118	192	10 Oct[e]	16 Mar	99
1997	82	30	12 Nov	26 Apr[e]	17
1998	6,922	622	31 Oct	23 Mar	66
1999	14,858	3,122	16 Nov	31 Mar	84
2000	14,780	2,070	30 Oct	3 Apr	74
2001	51	31	1 Sep[e]	10 Apr	88
2002	9,133	1,545	24 Oct	1 Apr	82
2003	4,922	470	12 Oct	19 Mar	73
2004	4,854	642	17 Oct	22 Mar	90
2005	6,257	834	25 Oct	13 Apr	83
2006	34,672	5,319	2 Oct	29 Mar	77
2007	17,109	1,708	20 Oct	13 Mar	69
2008	11,684	3,310	21 Oct	9 Apr	61
2009	34	13	24 Oct[e]	29 Mar[e]	76
2010	20,763	1,938	26 Oct	6 Apr	78
2011	26,066	2,256	2 Nov	25 Mar	56
2012	55,814	4,349	11 Oct	22 Mar	68
2013	21,609	1,234	27 Oct	4 Apr	59
2014	32,842	4,663	1 Oct	29 Mar	50
2015	13,935	544	25 Oct	3 Apr	85
2016	22,353[f]	2,261	29 Oct	3 Mar[f]	71[f]

[d] Trap was located at rkm 257.
[e] Median date based on small sample size.
[f] Spring trap season ended prematurely, missing a portion of late migrants.

Appendix Table A-2. Dates of arrival at Lower Granite Dam (LGD) for spring Chinook salmon smolts PIT-tagged from upper rearing areas during summer and winter, and at screw traps as early and late migrants during migratory years 1993–2016. Numbers of fish detected at Lower Granite Dam were expanded for spillway flow to calculate median arrival date.

Stream and MY	Tag group	Migration period	Number tagged	Number detected at LGD	Arrival dates: Median	Arrival dates: First	Arrival dates: Last
Catherine Creek							
1993	Summer	All	1,094	125	18 May	29 Apr	26 Jun
1994	Summer	All	1,000	91	11 May	13 Apr	26 Jul
1995	Summer	All	999	88	25 May	26 Apr	2 Jul
	Fall	Early	502	65	7 May	22 Apr	19 Jun
	Winter	Late	483	57	13 May	27 Apr	4 Jul
	Spring	Late	348	88	5 Jun	1 May	8 Jul
1996	Summer	All	499	60	1 May	17 Apr	29 May
	Fall	Early	566	76	29 Apr	14 Apr	4 Jun
	Winter	Late	295	14	18 May	19 Apr	14 Jun
	Spring	Late	277	70	17 May	17 Apr	13 Jun
1997	Summer	All	583	51	14 May	24 Apr	10 Jun
	Fall	Early	403	40	12 May	17 Apr	1 Jun
	Winter	Late	102	5	17 May	27 Apr	15 Jun
	Spring	Late	78	22	26 May	28 Apr	1 Jun
1998	Summer	All	499	43	17 May	24 Apr	4 Jun
	Fall	Early	598	66	1 May	3 Apr	3 Jun
	Winter	Late	438	57	11 May	15 Apr	15 Jun
	Spring	Late	453	109	21 May	26 Apr	26 Jun
1999	Summer	All	502	20	26 May	26 Apr	26 Jun
	Fall	Early	656	41	23 May	19 Apr	28 Jun
	Winter	Late	494	35	29 May	23 Apr	9 Jul
	Spring	Late	502	54	21 May	20 Apr	20 Jun
2000	Summer	All	497	30	7 May	12 Apr	7 Jun
	Fall	Early	677	56	3 May	12 Apr	29 May
	Winter	Late	500	22	9 May	25 Apr	1 May
	Spring	Late	431	52	12 May	21 Apr	2 Jul
2001	Summer	All	498	33	17 May	28 Apr	18 Jun
	Fall	Early	494	57	10 May	27 Apr	18 Jun
	Winter	Late	538	27	1 Jun	4 May	6 Jul
	Spring	Late	329	100	30 May	29 Apr	13 Jul
2002	Summer	All	502	17	6 May	15 Apr	22 May
	Fall	Early	515	20	6 May	16 Apr	20 Jun
	Winter	Late	449	15	14 May	24 Apr	26 Jun
	Spring	Late	217	27	26 May	17 Apr	1 Jul

Appendix Table A-2. Continued.

Stream and MY	Tag group	Migration period	Number tagged	Number detected at LGD	Arrival dates Median	First	Last
Catherine Creek (cont.)							
2003	Summer	All	501	17	16 May	14 Apr	9 Jun
	Fall	Early	1,196	59	18 May	14 Apr	31 May
	Winter	Late	531	25	22 May	18 Apr	6 Jun
	Spring	Late	576	95	25 May	13 Apr	23 Jun
2004	Summer	All	467	30	15 May	22 Apr	25 Jun
	Fall	Early	524	45	21 May	15 Apr	15 Jun
	Winter	Late	502	66	21 May	23 Apr	8 Jul
	Spring	Late	525	172	29 May	22 Apr	14 Jul
2005	Summer	All	495	21	8 May	20 Apr	2 Jun
	Fall	Early	544	43	7 May	14 Apr	2 Jun
	Winter	Late	529	28	21 May	18 Apr	20 Jun
	Spring	Late	410	82	31 May	26 Apr	20 Jun
2006	Summer	All	523	7	16 May	28 Apr	19 May
	Fall	Early	500	15	4 May	23 Apr	10 Jun
	Winter	Late	500	19	15 May	26 Apr	9 Jun
	Spring	Late	360	34	4 Jun	2 May	22 Jun
2007	Summer	All	501	6	23 Apr	19 Apr	19 May
	Fall	Early	500	26	2 May	16 Apr	15 May
	Winter	Late	500	12	13 May	21 Apr	20 May
	Spring	Late	363	42	13 May	1 May	13 Jun
2008	Summer	All	1,000	17	25 May	30 Apr	2 Jul
	Fall	Early	499	18	13 May	4 May	15 Jun
	Winter	Late	500	23	18 May	30 Apr	19 Jun
	Spring	Late	484	45	20 May	30 Apr	4 Jul
2009	Summer	All	997	50	10 May	12 Apr	13 Jun
	Fall	Early	500	54	8 May	4 Apr	8 Jun
	Winter	Late	500	15	19 May	3 May	1 Jun
	Spring	Late	498	73	20 May	28 Apr	25 Jun
2010	Summer	All	997	24	4 Jun	24 Apr	21 Jun
	Fall	Early	826	33	21 May	25 Apr	1 Jun
	Winter	Late	498	27	25 May	1 May	24 Jun
	Spring	Late	571	65	20 May	25 Apr	2 Jul
2011	Summer	All	992	48	8 May	31 Mar	25 Jun
	Fall	Early	499	34	11 May	27 Apr	3 Jul
	Winter	Late	497	32	12 May	28 Apr	2 Jul
	Spring	Late	430	69	9 Jun	22 Apr	3 Jul
2012	Summer	All	998	39	5 May	11 Apr	20 Jun
	Fall	Early	1,153	66	28 Apr	31 Mar	3 Jun
	Winter	Late	501	21	14 May	17 Apr	10 Jun
	Spring	Late	1,033	89	16 May	4 Apr	28 Jun

Appendix Table A-2. Continued.

Stream and MY	Tag group	Migration period	Number tagged	Number detected at LGD	Arrival dates Median	First	Last
Catherine Creek (cont.)							
2013	Summer	All	975	10	9 May	13 Apr	14 May
	Fall	Early	1,151	25	9 May	8 Apr	14 Jun
	Winter	Late	598	15	12 May	24 Apr	3 Jun
	Spring	Late	829	33	13 May	13 Apr	13 Jun
2014	Summer (lower)	All	1,000	9	26 May	13 Apr	7 Jun
	Summer (upper)	All	998	34	27 Apr	12 Apr	6 Jun
	Fall	Early	920	51	30 Apr	11 Apr	10 Jun
	Winter	Late	129	10	3 May	18 Apr	18 Jun
	Spring	Late	749	97	8 May	3 Apr	19 Jun
2015	Summer (lower)	All	999	5	6 May	14 Apr	22 May
	Summer (upper)	All	999	7	24 Apr	21 Apr	16 May
	Fall	Early	704	5	18 May	14 May	18 May
	Winter	Late	597	3	14 Apr	6 Apr	21 May
	Spring	Late	218	4	21 May	13 May	3 June
2016	Summer (lower)	All	998	0	—	—	—
	Summer (upper)	All	997	12	21 Apr	10 Apr	4 Jun
	Fall	Early	699	21	27 Apr	11 Apr	5 Jun
	Winter	Late	570	20	22 Apr	6 Apr	14 May
	Spring	Late	462	25	7 May	4 Apr	21 May
Imnaha River							
1993	Summer	All	1,000	74	14 May	15 Apr	23 Jun
1994	Summer	All	998	65	8 May	20 Apr	11 Aug
1995	Summer	All	996	41	2 May	10 Apr	7 Jul
1996	Summer	All	997	158	26 Apr	14 Apr	12 Jun
1997	Summer	All	1,017	98	19 Apr	31 Mar	2 Jun
1998	Summer	All	1,009	159	29 Apr	3 Apr	24 May
1999	Summer	All	1,009	41	8 May	17 Apr	3 Jun
2000	Summer	All	982	63	2 May	12 Apr	16 Jun
2001	Summer	All	1,000	159	30 Apr	8 Apr	28 May
2002	Summer	All	1,001	15	4 May	15 Apr	31 May
2003	Summer	All	1,003	43	8 May	17 Apr	31 May
2004	Summer	All	998	81	4 May	18 Apr	8 Jun
2005	Summer	All	1,001	90	2 May	5 Apr	11 Jun
2006	Summer	All	1,011	40	30 Apr	3 Apr	4 Jun
2007	Summer	All	1,000	59	27 Apr	5 Apr	24 May
2008	Summer	All	1,000	68	7 May	14 Apr	1 Jun
2009	Summer	All	989	85	6 May	4 Apr	16 Jun
2010	Summer	All	1,000	35	14 May	23 Apr	24 Jun
2011	Summer	All	997	68	6 May	29 Mar	16 Jun
2012	Summer	All	998	59	27 Apr	30 Mar	30 May

Appendix Table A-2. Continued.

Stream and MY	Tag group	Migration period	Number tagged	Number detected at LGD	Arrival dates: Median	First	Last
Imnaha River (cont.)							
2013	Summer	All	758	27	8 May	27 Mar	21 May
2014	Summer	All	1,000	56	22 Apr	29 Mar	24 May
2015	Summer	All	998	29	21 Apr	29 Mar	19 May
2016	Summer	All	999	57	21 Apr	28 Mar	27 May
Lostine River							
1993	Summer	All	997	136	4 May	17 Apr	1 Jun
1994	Summer	All	725	77	2 May	19 Apr	7 Jun
1995	Summer	All	1,002	115	2 May	8 Apr	19 Jun
1996	Summer	All	977	129	15 May	17 Apr	19 Jun
1997	Summer	All	527	43	25 Apr	9 Apr	21 May
	Fall	Early	519	53	22 Apr	2 Apr	13 May
	Winter	Late	390	60	2 May	15 Apr	27 May
	Spring	Late	476	109	25 Apr	10 Apr	22 May
1998	Summer	All	—	—	—	—	—
	Fall	Early	500	109	21 Apr	31 Mar	13 May
	Winter	Late	504	96	29 Apr	4 Apr	24 May
	Spring	Late	466	185	28 Apr	4 Apr	1 Jul
1999	Summer	All	506	19	15 May	29 Mar	29 May
	Fall	Early	501	40	26 Apr	31 Mar	18 May
	Winter	Late	491	39	10 May	6 Apr	7 Jun
	Spring	Late	600	88	12 May	9 Apr	8 Jul
2000	Summer	All	509	36	8 May	13 Apr	3 Jun
	Fall	Early	514	59	18 Apr	3 Apr	13 May
	Winter	Late	511	51	9 May	20 Apr	2 Jul
	Spring	Late	355	65	22 May	14 Apr	16 Jul
2001	Summer	All	489	87	9 May	10 Apr	12 Jun
	Fall	Early	500	139	27 Apr	12 Apr	18 May
	Winter	Late	500	113	14 May	16 Apr	19 Jun
	Spring	Late	445	246	12 May	21 Apr	4 Jul
2002	Summer	All	501	23	20 Apr	28 Mar	29 May
	Fall	Early	501	37	17 Apr	30 Mar	5 May
	Winter	Late	564	22	7 May	11 Apr	23 June
	Spring	Late	406	61	7 May	15 Apr	11 June
2003	Summer	All	509	21	8 May	11 Apr	3 Jun
	Fall	Early	900	77	18 Apr	25 Mar	27 May
	Winter	Late	491	42	15 May	13 Apr	8 Jun
	Spring	Late	527	107	4 May	3 Apr	4 Jul
2004	Summer	All	525	26	7 May	14 Apr	15 Jun
	Winter	Late	500	70	11 May	23 Apr	27 May
2005	Summer	All	500	49	28 Apr	5 Apr	18 Jun

Appendix Table A-2. Continued.

Stream and MY	Tag group	Migration period	Number tagged	Number detected at LGD	Arrival dates		
					Median	First	Last
Lostine River (cont.)							
2005	Fall	Early	500	103	20 Apr	5 Apr	9 May
	Winter	Late	500	72	9 May	12 Apr	13 Jun
	Spring	Late	464	174	8 May	13 Apr	19 Jun
2006	Summer	All	1,105	29	28 Apr	5 Apr	9 Jun
	Winter	Late	501	27	12 May	20 Apr	31 May
	Spring	Late	517	112	11 May	6 Apr	3 Jun
2007	Summer	All	500	27	4 May	5 Apr	21 May
	Fall	Early	500	37	17 Apr	27 Mar	12 May
	Winter	Late	500	39	12 May	17 Apr	25 May
	Spring	Late	505	109	11 May	18 Apr	1 Jun
2008	Summer	All	1,000	71	8 May	10 Apr	14 Jun
	Fall	Early	499	69	1 May	7 Apr	22 May
	Winter	Late	500	47	19 May	24 Apr	30 Jun
	Spring	Late	499	130	12 May	15 Apr	11 Jun
2009	Summer	All	989	71	28 Apr	2 Apr	21 May
	Fall	Early	501	59	25 Apr	5 Apr	28 May
	Winter	Late	494	34	31 May	2 Apr	30 Jun
	Spring	Late	591	163	18 May	4 Apr	23 Jun
2010	Summer	All	998	23	15 May	24 Apr	17 Jun
	Fall	Early	1,102	45	30 Apr	19 Apr	17 May
	Winter	Late	500	36	22 May	30 Apr	2 Jul
	Spring	Late	1,085	174	19 May	19 Apr	25 Jun
2011	Summer	All	997	58	4 May	4 Apr	26 Jun
	Fall	Early	1,100	119	28 Apr	28 Mar	22 May
	Winter	Late	500	47	16 May	20 Apr	10 Jun
	Spring	Late	1,751	421	13 May	25 Mar	20 Jun
2012	Summer	All	1,000	27	12 May	30 Mar	22 Jun
	Fall	Early	1,890	117	26 Apr	25 Mar	3 Jun
	Winter	Late	500	20	18 May	5 Apr	11 Jun
	Spring	Late	1,848	364	15 May	27 Mar	25 Jun
2013	Summer	All	999	27	11 May	31 Mar	25 May
	Fall	Early	1,165	54	8 May	2 Apr	19 May
	Winter	Late	595	41	13 May	29 Apr	2 Jun
	Spring	Late	1,238	215	13 May	22 Apr	11 Jun
2014	Summer	All	1,000	57	24 Apr	25 Mar	27 May
	Fall	Early	1,153	99	22 Apr	24 Mar	24 May
	Winter	Late	598	56	19 May	10 Apr	28 Jun
	Spring	Late	1,153	261	9 May	7 Apr	21 Jun
2015	Summer	All	999	10	10 May	29 Mar	26 May
	Fall	Early	1,124	40	6 Apr	21 Mar	28 May

Appendix Table A-2. Continued

Stream and MY	Tag group	Migration period	Number tagged	Number detected at LGD	Arrival dates: Median	First	Last
Lostine River (cont.)							
2015	Winter	Late	597	13	11 May	21 Apr	19 May
	Spring	Late	681	31	11 May	16 Apr	27 May
2016	Summer	All	997	36	26 Apr	8 Apr	11 Jun
	Fall	Early	1,198	94	14 Apr	28 Mar	4 May
	Winter	Late	598	52	7 May	6 Apr	29 May
	Spring	Late	891	232	5 May	4 Apr	10 Jun
Middle Grande Ronde River (rkm 160)							
2002	Spring	Late	167	21	23 May	17 May	18 Jun
2003	Spring	Late	250	90	16 May	22 Apr	18 Jun
2004	Spring	Late	488	286	5 May	21 Apr	5 Jun
2005	Spring	Late	236	118	3 May	6 Apr	29 May
2006	Spring	Late	400	107	16 May	8 Apr	30 May
2011	Spring	Late	71	28	9 May	3 Apr	27 Jun
2012	Spring	Late	437	102	5 May	28 Mar	14 Jun
2013	Spring	Late	818	238	13 May	6 Apr	9 Jun
2014	Spring	Late	530	150	11 May	2 Apr	30 Jun
2015	Spring	Late	844	61	3 May	1 Apr	22 May
2016	Spring	Late	796	250	5 May	5 Apr	11 Jun
Minam River							
1993	Summer	All	994	113	4 May	18 Apr	3 Jun
1994	Summer	All	997	120	29 Apr	18 Apr	13 Aug
1995	Summer	All	996	71	2 May	8 Apr	7 Jun
1996	Summer	All	998	117	24 Apr	10 Apr	7 Jun
1997	Summer	All	589	49	16 Apr	3 Apr	13 May
1998	Summer	All	992	123	29 Apr	3 Apr	30 May
1999	Summer	All	1,006	50	29 Apr	31 Mar	2 Jun
2000	Summer	All	998	74	3 May	10 Apr	29 May
2001	Summer	All	1,000	178	8 May	8 Apr	12 Jun
	Fall	Early	300	107	28 Apr	12 Apr	26 May
	Spring	Late	539	274	14 May	16 Apr	18 Aug
2002	Summer	All	994	30	3 May	16 Apr	31 May
	Fall	Early	537	35	18 Apr	25 Mar	9 May
	Spring	Late	382	42	30 May	8 Apr	23 Jun
2003	Summer	All	1,000	23	13 May	13 Apr	1 Jun
	Fall	Early	849	82	18 Apr	26 Mar	23 May
	Spring	Late	512	95	15 May	31 Mar	1 Jun
2004	Summer	All	996	36	1 May	7 Apr	31 May
	Fall	Early	500	58	28 Apr	2 Apr	21 May
	Spring	Late	412	164	9 May	4 Apr	14 Jun
2005	Summer	All	1,002	95	6 May	8 Apr	8 Jun

Appendix Table A-2. Continued

Stream and MY	Tag group	Migration period	Number tagged	Number detected at LGD	Arrival dates: Median	First	Last
Minam River (cont.)							
2005	Fall	Early	498	115	23 Apr	5 Apr	18 May
	Spring	Late	374	135	9 May	13 Apr	19 Jun
2006	Summer	All	1,007	50	8 May	11 Apr	6 Jun
	Fall	Early	499	45	19 Apr	4 Apr	16 May
	Spring	Late	401	74	17 May	21 Apr	7 Jun
2007	Summer	All	1,000	65	2 May	4 Apr	22 May
	Fall	Early	500	28	16 Apr	30 Mar	12 May
	Spring	Late	217	40	12 May	5 Apr	2 Jun
2008	Summer	All	1,000	87	7 May	17 Apr	11 Jun
	Fall	Early	500	61	2 May	2 Apr	2 Jun
	Spring	Late	496	118	8 May	16 Apr	1 Jun
2009	Summer	All	995	90	12 May	11 Apr	6 Jun
	Fall	Early	500	82	25 Apr	27 Mar	21 May
	Spring	Late	415	99	19 May	7 Apr	3 Jun
2010	Summer	All	985	28	16 May	23 Apr	16 Jun
	Fall	Early	945	51	1 May	22 Apr	30 May
	Spring	Late	1,059	182	17 May	22 Apr	24 Jun
2011	Summer	All	999	53	10 May	3 Apr	4 Jun
	Fall	Early	932	123	27 Apr	27 Mar	20 May
	Spring	Late	1,092	236	17 May	3 Apr	27 Jun
2012	Summer	All	999	52	27 Apr	1 Apr	8 Jun
	Fall	Early	1,299	110	19 Apr	23 Mar	20 May
	Spring	Late	1,018	202	17 May	10 Apr	27 Jun
2013	Summer	All	997	39	12 May	6 Apr	19 May
	Fall	Early	1,205	82	8 May	31 Mar	19 May
	Spring	Late	761	154	13 May	9 Apr	30 May
2014	Summer	All	999	46	24 Apr	25 Mar	26 May
	Fall	Early	1,084	101	16 Apr	27 Mar	26 May
	Spring	Late	1,103	290	19 May	29 Mar	19 May
2015	Summer	All	995	15	26 Apr	2 Apr	21 May
	Fall	Early	1,093	38	8 Apr	27 Mar	11 May
	Spring	Late	958	69	17 May	15 Apr	5 Jun
2016	Summer	All	994	63	27 Apr	9 Apr	22 May
	Fall	Early	1,089	87	13 Apr	26 Mar	9 May
	Spring	Late	748	189	7 May	27 Mar	9 Jun
Upper Grande Ronde River (rkm 299)							
1993	Summer	All	918	117	17 May	23 Apr	20 Jun
1994	Summer	All	1,001	57	29 May	23 Apr	29 Aug
	Fall	Early	405	65	30 Apr	21 Apr	23 Jun
	Spring	Late	573	93	15 May	20 Apr	6 Aug

Appendix Table A-2. Continued

Stream and MY	Tag group	Migration period	Number tagged	Number detected at LGD	Arrival dates: Median	First	Last
Upper Grande Ronde River (rkm 299) (cont.)							
1995	Summer	All	1,000	89	29 May	12 Apr	1 Jul
	Fall	Early	424	57	5 May	11 Apr	2 Jun
	Winter	Late	433	30	28 May	17 Apr	4 Jul
	Spring	Late	368	109	2 Jun	15 Apr	12 Jul
1996	Fall	Early	4	0	—	—	—
	Spring	Late	327	47	16 May	19 Apr	6 Jun
1997	Fall	Early	27	2	23 Apr	22 Apr	24 Apr
	Spring	Late	1	1	14 May	—	—
1998	Fall	Early	592	81	27 Apr	4 Apr	25 May
	Winter	Late	124	5	5 Jun	11 May	26 Jun
	Spring	Late	513	116	5 May	8 Apr	5 Jun
1999	Fall	Early	500	42	29 Apr	31 Apr	1 Jun
	Winter	Late	420	13	27 May	12 May	20 Jun
	Spring	Late	535	83	4 May	18 Apr	20 Jun
2000	Fall	Early	493	45	8 May	12 Apr	6 Jun
	Winter	Late	500	22	26 May	9 May	16 Jul
	Spring	Late	495	91	11 May	15 Apr	20 Jul
2001	Spring	Late	6	4	17 May	4 May	20 May
2002	Fall	Early	344	20	20 May	17 Apr	2 Jun
	Spring	Late	538	71	31 May	14 Apr	28 Jun
2003	Fall	Early	584	46	1 May	3 Apr	26 May
	Spring	Late	571	95	17 May	31 Mar	2 Jun
2004	Fall	Early	180	24	5 May	15 Apr	3 Jun
	Winter	Late	301	68	21 May	26 Apr	17 Jun
	Spring	Late	525	173	21 May	17 Apr	3 Jun
2005	Fall	Early	368	39	7 May	20 Apr	1 Jun
	Winter	Late	449	46	30 May	3 May	19 Jun
	Spring	Late	615	131	19 May	19 Apr	13 Jun
2006	Fall	Early	521	29	18 May	16 Apr	6 Jun
	Winter	Late	464	12	3 Jun	20 May	14 Jun
	Spring	Late	505	49	20 May	30 Mar	20 Jun
2007	Fall	Early	434	54	11 May	14 Apr	3 Jun
	Winter	Late	482	37	15 May	27 Apr	6 Jun
	Spring	Late	501	79	14 May	13 Apr	11 Jun
2008	Summer	All	1,000	55	29 May	8 Apr	23 Jun
	Fall	Early	159	16	18 May	6 May	10 Jun
	Winter	Late	83	3	3 Jun	20 May	9 Jun
	Spring	Late	510	49	30 May	4 May	25 Jun
2009	Fall	Early	4	0	—	—	—
	Spring	Late	10	1	19 May	19 May	19 May

Appendix Table A-2. Continued

Stream and MY	Tag group	Migration period	Number tagged	Number detected at LGD	Arrival dates Median	First	Last
Upper Grande Ronde River (rkm 299) (cont.)							
2010	Summer	All	1,000	73	24 May	27 Apr	25 Jun
	Fall	Early	486	37	13 May	27 Apr	15 Jun
	Winter	Late	498	19	7 Jun	11 May	26 Jun
	Spring	Late	504	80	21 May	28 Apr	24 Jun
2011	Summer	All	993	50	14 Jun	2 Apr	24 Jun
	Fall	Early	499	51	13 May	4 Apr	25 Jun
	Winter	Late	431	29	20 Jun	4 May	4 Jul
	Spring	Late	672	115	5 Jun	24 Apr	26 Jun
2012	Summer	All	1,000	25	18 May	14 Apr	8 Jun
	Fall	Early	606	50	17 May	28 Mar	10 Jun
	Winter	Late	258	4	16 May	18 Apr	22 May
2012	Spring	Late	632	84	19 May	28 Mar	10 Jun
2013	Summer	All	996	23	15 May	6 May	30 May
	Fall	Early	645	46	12 May	28 Apr	22 May
	Winter	Late	576	12	14 May	8 May	21 Jun
	Spring	Late	787	76	14 May	8 May	28 Jun
2014	Summer	All	1,000	44	24 May	13 Apr	16 Jun
	Fall	Early	636	55	5 May	5 Apr	6 Jun
	Winter	Late	125	3	9 May	5 May	2 Jun
	Spring	Late	1,338	186	24 May	7 Apr	2 Jul
2015	Summer	All	1,000	15	14 May	14 Apr	10 Jun
	Fall	Early	679	13	3 May	12 Apr	19 May
	Winter	Late	600	6	15 May	5 May	20 May
	Spring	Late	802	29	18 May	3 May	3 Jun
2016	Summer	All	997	31	20 May	24 Apr	9 Jun
	Fall	Early	699	43	7 May	9 Apr	31 May
	Winter	Late	331	8	12 May	17 Apr	29 May
	Spring	Late	600	76	10 May	11 Apr	2 Jun
Wenaha and South Fork Wenaha rivers							
1993	Summer	All	749	84	28 Apr	14 Apr	15 May
1994	Summer	All	998	93	24 Apr	18 Apr	6 Jun
1995	Summer	All	999	76	26 Apr	9 Apr	15 May
1996	Summer	All	997	105	21 Apr	13 Apr	16 May
1997	Summer	All	62	10	16 Apr	9 Apr	23 Apr

Appendix Table A-3. Number of PIT tagged spring Chinook salmon released by tag group and stream, and survival probability to Lower Granite Dam during migratory years 1993–2016. Summer and winter tag groups were collected upstream of screw traps, while fall and spring tag groups were collected at screw traps. Asterisks indicate that low detections precluded calculation of survival probabilities.

Tag group and stream	MY	Number released	Survival prob
Summer			
Catherine Creek	1993	1,094	0.178 (0
	1994	1,000	0.226 (0
	1995	999	0.154 (0
	1996	499	0.277 (0
	1997	583	0.176 (0
	1998	499	0.211 (0
	1999	502	0.157 (0
	2000	497	0.151 (0
	2001	498	0.087 (0
	2002	502	0.109 (0
	2003	501	0.075 (0
	2004	467	0.072 (0
	2005	495	0.057 (0
	2006	523	0.057 (0
	2007	501	0.042 (
	2008	1,000	0.080 (0
	2009	997	0.147 (0
	2010	995	0.107 (0
	2011	992	0.128 (0
	2012	998	0.116 (0
	2013	975	0.031 (0
Upper Catherine Creek	2014	998	0.092 (0
	2015	999	0.056 (0
	2016	997	0.032 (0
Lower Catherine Creeka	2014	1,000	0.019 (0
	2015	999	0.061 (0
	2016	998	
Imnaha River	1993	1,000	0.141 (0
	1994	998	0.136 (0
	1995	996	0.083 (0
	1996	997	0.268 (0

[a] Fish were collected and tagged downstream of the rotary screw trap.
[b] Data were insufficient to calculate a survival probability.

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Summer			
Imnaha River (continued)	1997	1,017	0.216 (0.179–0.276)
	1998	1,009	0.325 (0.290–0.366)
	1999	1,009	0.173 (0.141–0.219)
	2000	982	0.141 (0.115–0.172)
	2001	1,000	0.181 (0.158–0.206)
	2002	1,001	0.106 (0.079–0.160)
	2003	1,003	0.141 (0.110–0.185)
	2004	998	0.109 (0.090–0.131)
	2005	1,001	0.123 (0.103–0.146)
	2006	1,011	0.144 (0.117–0.180)
	2007	1,000	0.178 (0.147–0.218)
	2008	1,000	0.189 (0.157–0.228)
	2009	989	0.219 (0.187–0.251)
	2010	1,000	0.102 (0.079–0.133)
	2011	997	0.172 (0.145–0.204)
	2012	998	0.182 (0.151–0.221)
	2013	995	0.125 (0.100–0.158)
	2014	1,000	0.128 (0.104–0.156)
	2015	998	0.139 (0.101–0.208)
	2016	999	0.131 (0.106–0.162)
Lostine River	1993	997	0.250 (0.214–0.296)
	1994	725	0.237 (0.188–0.309)
	1995	1,002	0.215 (0.183–0.255)
	1996	977	0.237 (0.191–0.306)
	1997	527	0.213 (0.160–0.310)
	1998	0	—
	1999	506	0.180 (0.145–0.234)
	2000	509	0.212 (0.159–0.294)
	2001	489	0.210 (0.175–0.248)
	2002	501	0.154 (0.117–0.209)
	2003	509	0.155 (0.109–0.238)
	2004	525	0.065 (0.046–0.089)
	2005	500	0.129 (0.101–0.163)
	2006	1,105	0.113 (0.091–0.143)
	2007	500	0.159 (0.112–0.245)
	2008	1,000	0.183 (0.155–0.218)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Summer			
Lostine River (continued)	2009	988	0.208 (0.176–0.241)
	2010	997	0.114 (0.089–0.152)
	2011	997	0.139 (0.115–0.168)
	2012	1,000	0.086 (0.066–0.113)
	2013	999	0.098 (0.072–0.141)
	2014	1,000	0.127 (0.106–0.152)
	2015	999	0.215 (0.087–1.120)
	2016	997	0.081 (0.062–0.107)
Minam River	1993	994	0.187 (0.115–0.230)
	1994	997	0.293 (0.249–0.350)
	1995	996	0.153 (0.124–0.191)
	1996	998	0.208 (0.169–0.264)
	1997	589	0.270 (0.181–0.693)
	1998	992	0.228 (0.199–0.259)
	1999	1,006	0.181 (0.155–0.210)
	2000	998	0.239 (0.199–0.292)
	2001	1,000	0.228 (0.202–0.256)
	2002	994	0.093 (0.074–0.119)
	2003	1,000	0.061 (0.044–0.088)
	2004	996	0.062 (0.047–0.080)
	2005	1,002	0.136 (0.114–0.160)
	2006	1,007	0.145 (0.119–0.178)
	2007	1,000	0.175 (0.147–0.211)
	2008	1,000	0.193 (0.166–0.224)
	2009	995	0.191 (0.162–0.219)
	2010	985	0.131 (0.092–0.205)
	2011	999	0.127 (0.102–0.158)
	2012	999	0.110 (0.090–0.134)
	2013	997	0.106 (0.084–0.135)
	2014	999	0.134 (0.110–0.164)
	2015	995	0.131 (0.079–0.278)
	2016	994	0.124 (0.101–0.153)
Upper Grande Ronde River	1993	918	0.287 (0.237–0.365)
	1994	1,001	0.144 (0.110–0.197)
	1995	1,000	0.173 (0.144–0.207)
	2008	1,000	0.264 (0.224–0.319)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Summer			
Upper Grande Ronde River (cont.)	2009	0	—
	2010	1,000	0.235 (0.195–0.289)
	2011	993	0.125 (0.101–0.156)
	2012	1,000	0.083 (0.063–0.111)
	2013	996	0.098 (0.071–0.143)
	2014	1,000	0.102 (0.083–0.125)
	2015	1,000	0.158 (0.085–0.438)
	2016	997	0.076 (0.056–0.107)
Wenaha/SF Wenaha River	1993	749	0.214 (0.181–0.255)
	1994	998	0.144 (0.121–0.172)
	1995	999	0.146 (0.119–0.180)
	1996	997	0.212 (0.172–0.271)
	1997	62	(b)
Fall trap			
Catherine Creek	1995	502	0.238 (0.193–0.297)
	1996	508	0.358 (0.296–0.446)
	1997	399	0.365 (0.256–0.588)
	1998	582	0.238 (0.194–0.293)
	1999	644	0.202 (0.166–0.250)
	2000	677	0.212 (0.170–0.269)
	2001	508	0.130 (0.103–0.162)
	2002	514	0.154 (0.114–0.245)
	2003	849	0.120 (0.093–0.160)
	2004	524	0.126 (0.099–0.158)
	2005	544	0.122 (0.093–0.161)
	2006	500	0.074 (SE = 0.012)
	2007	500	0.203 (0.143–0.340)
	2008	499	0.153 (0.109–0.256)
	2009	500	0.269 (0.214–0.324)
	2010	821	0.180 (0.132–0.281)
	2011	499	0.156 (0.120–0.207)
	2012	1,153	0.188 (0.155–0.232)
	2013	1,151	0.101 (0.071–0.172)
	2014	920	0.144 (0.117–0.182)
	2015	704	(b)
	2016	699	0.060 (0.043–0.083)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Fall trap			
Lostine River	1997	519	0.312 (0.247–0.465)
	1998	500	0.448 (0.391–0.514)
	1999	501	0.422 (0.349–0.538)
	2000	514	0.317 (0.267–0.380)
	2001	498	0.335 (0.294–0.378)
	2002	500	0.326 (0.258–0.455)
	2003	854	0.287 (0.236–0.365)
	2004	0	—
	2005	500	0.267 (0.227–0.310)
	2006	495	0.269 (0.207–0.406)
	2007	500	0.223 (0.172–0.301)
	2008	499	0.265 (0.221–0.317)
	2009	501	0.312 (0.257–0.367)
	2010	1,099	0.265 (0.191–0.427)
	2011	1,100	0.251 (0.221–0.286)
	2012	1,890	0.162 (0.143–0.184)
	2013	1,167	0.225 (0.173–0.318)
	2014	1,199	0.209 (0.181–0.241)
	2015	1,124	0.168 (0.125–0.246)
	2016	1,198	0.188 (0.161–0.220)
Minam River	2001	300	0.427 (0.371–0.485)
	2002	537	0.249 (0.201–0.326)
	2003	849	0.238 (0.199–0.292)
	2004	500	0.183 (0.150–0.219)
	2005	498	0.293 (0.253–0.337)
	2006	499	0.245 (0.205–0.304)
	2007	500	0.250 (0.186–0.368)
	2008	500	0.283 (0.235–0.344)
	2009	500	0.387 (0.333–0.442)
	2010	944	0.366 (0.243–0.676)
	2011	932	0.286 (0.254–0.320)
	2012	1,299	0.225 (0.196–0.259)
	2013	1,205	0.185 (0.158–0.221)
	2014	1,084	0.227 (0.198–0.259)
	2015	1,093	0.199 (0.143–0.307)
	2016	1,090	0.185 (0.158–0.217)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Fall trap			
Upper Grande Ronde River	1994	405	0.348 (0.284–0.432)
	1995	424	0.228 (0.184–0.281)
	1996	5	(b)
	1997	27	(b)
	1998	590	0.286 (0.244–0.334)
	1999	498	0.269 (0.229–0.315)
	2000	493	0.341 (0.260–0.476)
	2002	344	0.308 (0.198–0.653)
	2003	581	0.184 (0.143–0.247)
	2004	180	0.164 (0.114–0.225)
	2005	368	0.138 (0.105–0.177)
	2006	521	0.171 (0.136–0.232)
	2007	534	0.242 (0.199–0.301)
	2008	159	0.338 (0.257–0.450)
	2009	4	(b)
	2010	485	0.209 (0.162–0.275)
	2011	499	0.225 (0.184–0.273)
	2012	606	0.196 (0.160–0.239)
	2013	645	0.177 (0.141–0.225)
	2014	636	0.201 (0.165–0.245)
	2015	684	0.086 (0.057–0.152)
	2016	699	0.120 (0.090–0.163)
Wallowa River	1999	45	(b)
Winter			
Catherine Creek	1995	482	0.279 (0.230–0.343)
	1996	295	0.312 (0.163–1.008)
	1997	102	0.078 (0.033–0.222)
	1998	437	0.278 (0.226–0.345)
	1999	493	0.285 (0.230–0.367)
	2000	500	0.138 (0.102–0.191)
	2001	522	0.077 (0.054–0.106)
	2002	431	0.203 (0.129–0.476)
	2003	524	0.152 (0.109–0.231)
	2004	502	0.178 (0.145–0.215)
	2005	529	0.112 (0.079–0.178)
	2006	500	0.125 (0.080–0.312)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Winter			
Catherine Creek (continued)	2007	500	0.088 (0.047–0.343)
	2008	500	0.144 (0.108–0.207)
	2009	500	0.110 (0.063–0.157)
	2010	498	0.183 (0.135–0.261)
	2011	497	0.174 (0.135–0.227)
	2012	501	0.099 (0.072–0.135)
	2013	598	0.108 (0.075–0.170)
	2014	129	0.116 (0.064–0.206)
	2015	597	0.040 (0.013–0.555)
	2016	570	0.077 (0.055–0.106)
Lostine River	1997	388	0.445 (0.334–0.650)
	1998	504	0.349 (0.301–0.403)
	1999	491	0.305 (0.259–0.363)
	2000	511	0.397 (0.296–0.576)
	2001	499	0.284 (0.245–0.326)
	2002	564	0.246 (0.170–0.464)
	2003	501	0.226 (0.167–0.337)
	2004	500	0.189 (0.156–0.227)
	2005	500	0.201 (0.166–0.240)
	2006	501	0.177 (0.127–0.304)
	2007	500	0.135 (0.101–0.186)
	2008	500	0.328 (0.270–0.417)
	2009	494	0.192 (0.143–0.240)
	2010	500	0.243 (0.187–0.330)
	2011	500	0.196 (0.158–0.242)
	2012	500	0.076 (0.053–0.107)
	2013	595	0.191 (0.151–0.245)
	2014	598	0.206 (0.169–0.250)
	2015	597	0.281 (0.131–0.994)
	2016	598	0.199 (0.160–0.251)
Upper Grande Ronde River	1994	505	0.248 (0.152–0.519)
	1995	432	0.151 (0.115–0.199)
	1998	124	0.113 (SE = 0.028)
	1999	420	0.118 (0.083–0.183)
	2000	500	0.133 (0.099–0.183)
	2004	301	0.296 (0.245–0.353)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Winter			
Upper Grande Ronde River (cont.)	2005	449	0.207 (0.159–0.306)
	2006	464	0.080 (0.052–0.183)
	2007	482	0.169 (0.132–0.226)
	2008	83	0.361 (0.124–5.029)
	2009	0	—
	2010	498	0.125 (0.092–0.172)
	2011	431	0.124 (0.094–0.160)
	2012	258	0.043 (0.013 = SE)
	2013	576	0.057 (0.038–0.087)
	2014	125	0.072 (0.029–0.265)
	2015	600	0.070 (0.037–0.215)
	2016	331	0.048 (0.026–0.095)
Spring trap			
Catherine Creek	1995	348	0.506 (0.441–0.578)
	1996	276	0.591 (0.480–0.755)
	1997	81	0.413 (0.292–0.580)
	1998	453	0.517 (0.459–0.583)
	1999	502	0.448 (0.379–0.545)
	2000	431	0.452 (0.359–0.598)
	2001	328	0.376 (0.322–0.433)
	2002	217	0.527 (0.411–0.750)
	2003	535	0.365 (0.312–0.431)
	2004	525	0.413 (0.370–0.457)
	2005	410	0.445 (0.366–0.569)
	2006	360	0.367 (0.290–0.526)
	2007	363	0.310 (0.250–0.402)
	2008	484	0.380 (0.309–0.506)
	2009	498	0.491 (0.379–0.604)
	2010	571	0.464 (0.378–0.607)
	2011	430	0.422 (0.347–0.535)
	2012	1,033	0.302 (0.254–0.370)
	2013	829	0.220 (0.164–0.342)
	2014	764	0.340 (0.293–0.398)
	2015	218	0.280 (0.104–3.941)
	2016	462	0.183 (0.129–0.289)
Lostine River	1997	475	0.769 (0.630–1.009)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Spring trap			
Lostine River (continued)	1998	484	0.784 (0.728–0.845)
	1999	599	0.744 (0.664–0.857)
	2000	355	0.660 (0.546–0.823)
	2001	442	0.695 (0.648–0.741)
	2002	406	0.683 (0.589–0.825)
	2003	482	0.495 (0.424–0.591)
	2004	0	—
	2005	464	0.552 (0.503–0.602)
	2006	517	0.619 (0.551–0.722)
	2007	505	0.589 (0.508–0.706)
	2008	499	0.683 (0.616–0.768)
	2009	593	0.692 (0.617–0.766)
	2010	1,099	0.679 (0.589–0.807)
	2011	1,751	0.583 (0.549–0.621)
	2012	1,848	0.550 (0.515–0.589)
	2013	1,237	0.552 (0.495–0.625)
	2014	1,153	0.520 (0.482–0.563)
	2015	681	0.470 (0.307–0.885)
	2016	891	0.516 (0.472–0.565)
Middle Grande Ronde River	2001	4	(b)
	2002	167	0.776 (0.624–1.073)
	2003	250	0.764 (0.668–0.893)
	2004	488	0.721 (0.677–0.764)
	2005	236	0.698 (0.625–0.776)
	2006	400	0.745 (0.666–0.881)
	2011	71	0.726 (0.575–0.920)
	2012	437	0.677 (0.600–0.770)
	2013	819	0.685 (0.634–0.742)
	2014	530	0.677 (0.616–0.744)
	2015	844	0.601 (0.435–0.925)
	2016	796	0.572 (0.524–0.624)
Minam River	2001	536	0.619 (0.576–0.661)
	2002	382	0.532 (0.465–0.644)
	2003	512	0.476 (0.405–0.577)
	2004	412	0.530 (0.480–0.580)
	2005	374	0.555 (0.497–0.620)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Spring trap			
Minam River (continued)	2006	401	0.543 (0.482–0.630)
	2007	217	0.602 (0.519–0.725)
	2008	496	0.623 (0.554–0.710)
	2009	500	0.618 (0.540–0.697)
	2010	1,059	0.636 (0.563–0.734)
	2011	1,092	0.595 (0.542–0.659)
	2012	1,018	0.504 (0.461–0.554)
	2013	761	0.634 (0.559–0.734)
	2014	1,103	0.573 (0.532–0.620)
	2015	958	0.711 (0.461–1.318)
	2016	747	0.464 (0.421–0.511)
Upper Grande Ronde River	1994	571	0.462 (0.387–0.563)
	1995	368	0.609 (0.545–0.683)
	1996	327	0.512 (0.404–0.690)
	1998	512	0.548 (0.487–0.622)
	1999	528	0.538 (0.486–0.601)
	2000	495	0.560 (0.472–0.680)
	2001	6	(b)
	2002	536	0.499 (0.416–0.633)
	2003	571	0.397 (0.346–0.461)
	2004	525	0.420 (0.376–0.464)
	2005	615	0.374 (0.335–0.418)
	2006	505	0.398 (0.318–0.561)
	2007	501	0.373 (0.307–0.469)
	2008	510	0.418 (0.364–0.495)
	2009	10	(b)
	2010	503	0.468 (0.401–0.553)
	2011	672	0.447 (0.392–0.512)
	2012	632	0.405 (0.348–0.476)
	2013	787	0.314 (0.268–0.373)
	2014	808	0.340 (0.296–0.391)
	2015	802	0.303 (0.214–0.505)
	2016	600	0.232 (0.192–0.283)

Appendix Table A-4. Travel time to Lower Granite Dam (LGD) of late migrant juvenile spring Chinook salmon PIT-tagged at screw traps and arriving at Lower Granite Dam the same year. Min = minimum; Max = maximum.

Stream and MY	Distance to LGD (km)	Number detected	Travel time (d)		
			Median	Min	Max
Catherine Creek	362				
1995		88	59.1	20	105
1996		70	54.2	9	91
1997		22	60.4	17	91
1998		109	56.5	12	87
1999		54	63.2	21	90
2000		52	50.5	20	95
2001		100	64.5	15	110
2002		27	52.8	13	75
2003		95	54.8	16	101
2004		172	56.8	10	109
2005		82	49.7	9	109
2006		34	50.1	12	86
2007		42	46.1	14	83
2008		45	65.2	27	119
2009		73	56.7	17	86
2010		65	47.5	17	87
2011		69	59.8	22	106
2012		89	53.4	23	91
2013		33	58.0	17	87
2014		97	57.0	10	108
2015		3	34.0	29	58
2016		25	51.0	21	82
Lostine River	274				
1997		109	21.7	5	54
1998		183	17.8	6	59
1999		88	25.6	5	60
2000		65	32.5	5	90
2001		246	23.6	5	90
2002		61	27.5	8	57
2003		107	41.6	8	90
2004[a]		—	—	—	—
2005		174	32.8	6	75
2006		112	32.0	5	53
2007		109	34.5	6	84
2008		130	20.5	8	64
2009		163	37.0	11	78
2010		174	33.0	8	78

[a] Limited trapping operations.

Appendix Table A-4. Continued.

Stream and MY	Distance to LGD (km)	Number detected	Travel time (d)		
			Median	Min	Max
Lostine River (cont.)					
2011		416	33.1	6	111
2012		364	33.6	3	107
2013		215	28.0	4	97
2014		261	31.0	8	89
2015		31	26.0	9	73
2016		232	30.0	5	88
Middle Grande Ronde River (rkm 164)	262				
2002		21	6.6	3	22
2003		95	56.0	20	84
2004		286	8.5	4	52
2005		118	20.3	4	51
2006		107	5.8	2	50
2011[b]		28	35.4	5	58
2012[b]		102	19.8	5	68
2013[b]		238	9.0	4	63
2014[b]		150	15.0	3	84
2015[b]		61	29.0	9	64
2016[b]		250	10.0	3	63
Minam River	245				
2001		274	39.5	9	106
2002		42	32.4	5	52
2003		95	45.3	10	71
2004		164	38.1	6	82
2005		135	38.3	8	68
2006		74	33.4	6	58
2007		40	33.4	9	62
2008		118	42.6	8	74
2009		99	37.8	7	79
2010		182	38.4	9	77
2011		236	33.4	5	77
2012		202	37.8	5	73
2013		154	36.5	5	67
2014		290	38.0	6	84
2015		69	39.0	16	70
2016		189	38.0	6	70

[b] Trap was located at rkm 160; distance to LGD was 258 km.

Appendix Table A-4. Continued.

Stream and MY	Distance to LGD (km)	Number detected	Travel time (d)		
			Median	Min	Max
Upper Grande Ronde River (rkm 299)	397				
1994		93	45.1	17	130
1995[c]		114	19.5	6	81
1996		47	64.7	14	88
1997		1	56.7	—	—
1998		116	48.6	25	71
1999		83	39.1	16	92
2000		91	50.5	12	98
2001		4	37.5	29	56
2002		71	46.5	12	79
2003		95	56.0	20	84
2004		173	52.5	10	95
2005		131	36.7	11	74
2006		49	49.9	21	77
2007		79	54.7	10	73
2008		49	59.4	37	92
2009		1	54.6	—	—
2010		80	47.5	10	90
2011		115	57.7	5	93
2012		84	47.6	7	86
2013		76	44.0	11	79
2014		186	22.0	3	93
2015		29	50.0	12	68
2016		76	56.0	22	90

[c] Trap was located at rkm 257; distance to LGD was 355 km.

Appendix Table A-5. Overwinter survival rates of spring Chinook salmon parr overwintering upstream of screw traps on Catherine Creek and Lostine and Grande Ronde rivers. Screw traps are located on Catherine Creek at rkm 32, Lostine River at rkm 3, and upper Grande Ronde River at rkm 299, except during MY 1995 when upper Grande Ronde River trap was at rkm 257. Survival rates were calculated by dividing winter tag group survival probability by that of the spring tag group.

		Overwinter survival in upper rearing areas		
BY	MY	Catherine Creek	Lostine River	Upper Grande Ronde River
1992	1994	—	—	0.54
1993	1995	0.55	—	0.25
1994	1996	0.53	—	—
1995	1997	0.19	0.58	—
1996	1998	0.54	0.45	0.21
1997	1999	0.64	0.41	0.22
1998	2000	0.31	0.60	0.24
1999	2001	0.20	0.41	—
2000	2002	0.39	0.36	—
2001	2003	0.38	0.46	—
2002	2004	0.43	0.30	0.70
2003	2005	0.25	0.36	0.55
2004	2006	0.34	0.29	0.20
2005	2007	0.28	0.23	0.45
2006	2008	0.38	0.48	0.86
2007	2009	0.22	0.28	—
2008	2010	0.39	0.36	0.27
2009	2011	0.40	0.34	0.27
2010	2012	0.33	0.14	0.11
2011	2013	0.49	0.35	0.18
2012	2014	0.34	0.40	0.21
2013	2015	0.14	0.60	0.23
2014	2016	0.42	0.39	0.21

Appendix Table A-6. Comparisons of overwinter survival of spring Chinook salmon parr in rearing areas upstream (above screw trap) and downstream (below screw trap) on Catherine Creek and Lostine and upper Grande Ronde rivers. Early migrant life history corresponds to overwintering downstream; late migrant life history corresponds to overwintering upstream. Screw traps operated in the same location in each study stream with exception of upper Grande Ronde River trap which operated at rkm 299 in all years but MY 1995 when it was located at rkm 257. Each *P*-value was based on the maximum likelihood ratio test comparing fit of the null model (fall tag group survival = winter tag group survival) to fit of the full model (fall tag group survival ≠ winter tag group survival).

	Catherine Creek		Lostine River		Upper Grande Ronde River	
MY	Area/life history with higher overwinter survival	*P*-value	Area/life history with higher overwinter survival	*P*-value	Area/life history with higher overwinter survival	*P*-value
1994	—	—	—	—	Equivalent	0.331
1995	Equivalent	0.278	—	—	Downstream/early migrants	0.020
1996	Equivalent	0.766	—	—	—	—
1997	Downstream/early migrants	0.016	Equivalent	0.133	—	—
1998	Equivalent	0.289	Downstream/early migrants	0.014	Downstream/early migrants	<0.001
1999	Upstream/late migrants	0.025	Downstream/early migrants	0.014	Downstream/early migrants	0.002
2000	Downstream/early migrants	0.031	Equivalent	0.211	Downstream/early migrants	<0.001
2001	Downstream/early migrants	0.009	Equivalent	0.090	—	—
2002	Equivalent	0.403	Equivalent	0.350	—	—
2003	Equivalent	0.283	Equivalent	0.263	—	—
2004	Upstream/late migrants	0.026	—	—	Upstream/late migrants	0.001
2005	Equivalent	0.733	Downstream/early migrants	0.021	Upstream/late migrants	0.030
2006	Equivalent	0.061	Equivalent	0.144	Equivalent	0.070
2007	Downstream/early migrants	<0.001	Equivalent	0.115	Downstream/early migrants	0.012
2008	Equivalent	0.800	Equivalent	0.115	Equivalent	0.931
2009	Downstream/early migrants	0.003	Downstream/early migrants	0.003	—	—
2010	Equivalent	0.949	Equivalent	0.719	Downstream/early migrants	0.014
2011	Equivalent	0.655	Downstream/early migrants	0.031	Downstream/early migrants	0.001
2012	Downstream/early migrants	0.001	Downstream/early migrants	<0.001	Downstream/early migrants	<0.001
2013	Equivalent	0.314	Equivalent	0.394	Downstream/early migrants	<0.001
2014	Equivalent	0.499	Equivalent	0.880	Downstream/early migrants	<0.001
2015	—	—	Equivalent	0.962	Equivalent	0.078
2016	Equivalent	0.313	Equivalent	0.736	Downstream/early migrants	0.001

Appendix Table A-7. Estimated number of wild spring Chinook salmon smolt equivalents leaving tributaries during spring, and at Lower Granite Dam (LGD). Brood year represents the year eggs were deposited, while migration year refers to the calendar year smolts emigrated.

		Early migrants			Late migrants				
Stream, BY	MY	Migrant abundance estimate	95% CI	Survival to LGD	Migrant abundance estimate	95% CI	Survival to LGD	Estimated smolt equivalents leaving tributary	Estimated smolt equivalents at LGD
Catherine Creek									
1993	1995	8,966	1,337	0.238	8,667	1,577	0.506	12,884	6,519
1994	1996	4,985	440	0.358	1,872	529	0.591	4,892	2,891
1995	1997	4,029	1,118	0.365	413	103	0.413	3,974	1,641
1996	1998	7,058	1,140	0.238	2,823	403	0.517	6,072	3,139
1997	1999	12,607	2,010	0.202	7,704	1,115	0.448	13,388	5,998
1998	2000	19,769	2,156	0.212	4,222	914	0.452	13,494	6,099
1999	2001	18,996	2,213	0.130	2,940	558	0.376	9,508	3,575
2000	2002	21,183	2,846	0.154	2,179	373	0.527	8,369	4,411
2001	2003	29,763	2,399	0.120	4,860	1,039	0.365	14,645	5,345
2002	2004	53,712	3,796	0.126	10,300	1,804	0.413	26,687	11,022
2003	2005	50,630	6,500	0.122	5,467	1,680	0.445	19,348	8,610
2004	2006	22,823	2,176	0.074	4,365	934	0.367	8,967	3,291
2005	2007	10,936	788	0.203	2,895	677	0.310	10,056	3,117
2006	2008	20,502	1,700	0.153	5,649	1,231	0.380	13,904	5,283
2007	2009	16,618	2,723	0.269	5,056	1,328	0.491	14,160	6,953
2008	2010	32,358	6,356	0.180	11,277	3,277	0.464	23,829	11,056
2009	2011	8,079	332	0.156	4,515	1,057	0.422	7,593	3,166
2010	2012	36,404	986	0.188	22,041	3,247	0.302	44,703	13,500
2011	2013	26,393	2,519	0.101	5,782	741	0.220	17,899	3,938
2012	2014	18,012	1,308	0.144	12,779	2,132	0.340	20,408	6,939

Appendix Table A-7. Continued.

Stream, BY	Migration year	Early migrants: Migrant abundance estimate	Early migrants: 95% CI	Early migrants: Survival to LGD	Late migrants: Migrant abundance estimate	Late migrants: 95% CI	Late migrants: Survival to LGD	Estimated smolt equivalents leaving tributary	Estimated smolt equivalents at LGD
Catherine Creek (cont.)									
2013	2015	10,261	290	(a)	1,996	542	0.280	(a)	(a)
2014	2016	22,743	2,809	0.060	4,075	664	0.183	11,532	2,110
Lostine River									
1995	1997	2,175	239	0.312	2,321	557	0.769	3,203	2,463
1996	1998	11,381	2,373	0.448	6,158	1,089	0.784	12,661	9,927
1997	1999	20,133	1,966	0.422	14,134	1,749	0.744	25,554	19,012
1998	2000	8,370	835	0.317	3,880	299	0.660	7,900	5,214
1999	2001	10,478	1,246	0.335	3,132	549	0.695	8,183	5,687
2000	2002	15,358	2,371	0.326	2,782	522	0.683	10,112	6,907
2001	2003	19,048	1,459	0.287	9,891	1,161	0.495	20,935	10,363
2002	2004[b]	—	—	—	—	—	—	—	—
2003	2005	41,163	6,185	0.267	13,439	2,662	0.552	33,349	18,409
2004	2006	42,563	8,705	0.269	11,705	1,372	0.619	30,202	18,695
2005	2007	34,250	4,720	0.223	11,933	1,013	0.589	24,900	14,666
2006	2008	15,354	2,601	0.265	10,763	2,366	0.683	16,720	11,420
2007	2009	30,896	7,261	0.312	8,039	1,160	0.692	22,009	15,203
2008	2010	28,529	2,717	0.265	19,157	1,545	0.679	30,291	20,567
2009	2011	51,699	10,822	0.251	13,057	1,053	0.583	35,341	20,588
2010	2012	103,001	8,715	0.162	34,829	6,016	0.550	65,167	35,842
2011	2013	60,619	8,894	0.225	17,818	3,208	0.552	42,527	23,475
2012	2014	50,518	5,426	0.209	17,528	2,558	0.520	37,832	19,673
2013	2015	17,314	1,553	0.168	6,819	623	0.470	13,008	6,114
2014	2016	48,509	8,166	0.188	8,766	849	0.516	26,440	13,643

[a] Small tag group size and low recaptures at LGD precluded estimating survival probabilities and smolt equivalents.
[b] Limited trapping operations prevented abundance estimates.

Appendix Table A-7. Continued.

Stream, BY	Migration year	Early migrants: Migrant abundance estimate	Early migrants: 95% CI	Early migrants: Survival to LGD	Late migrants: Migrant abundance estimate	Late migrants: 95% CI	Late migrants: Survival to LGD	Estimated smolt equivalents leaving tributary	Estimated smolt equivalents at LGD
Minam River									
1999	2001	10,224	2,820	0.427	17,985	3,689	0.619	25,038	15,498
2000	2002	62,708	10,088	0.249	16,292	3,957	0.532	45,642	24,282
2001	2003	19,674	3,738	0.238	43,473	9,982	0.476	53,310	25,376
2002	2004	42,978	5,732	0.183	22,207	7,002	0.530	37,047	19,635
2003	2005	47,924	2,782	0.293	63,466	26,407	0.555	88,766	49,265
2004	2006	29,492	6,275	0.245	21,467	5,374	0.543	34,774	18,882
2005	2007	25,875	5,517	0.250	11,844	1,680	0.602	22,589	13,599
2006	2008	33,592	5,337	0.283	43,709	10,744	0.623	58,968	36,737
2007	2009	27,167	6,710	0.387	16,476	5,902	0.618	33,488	20,696
2008	2010	75,070	13,489	0.366	90,948	33,063	0.636	134,149	85,318
2009	2011	41,128	6,511	0.286	32,517	8,769	0.595	52,396	31,110
2010	2012	77,172	6,660	0.225	18,112	3,451	0.504	52,564	26,492
2011	2013	43,900	4,917	0.185	17,206	3,466	0.634	30,016	19,030
2012	2014	51,948	6,590	0.227	18,126	2,465	0.573	38,706	22,178
2013	2015	9,679	587	0.199	9,945	713	0.711	12,654	8,997
2014	2016	45,379	5,988	0.185	21,467	3,582	0.464	39,560	18,356
Upper Grande Ronde River									
1992	1994	2,616	188	0.348	22,175	3,188	0.462	24,145	11,155
1993	1995	4,859	1,881	0.228	33,866	12,560	0.609	35,685	21,732
1994	1996	13	15	(a)	1,105	192	0.512	(a)	(a)
1995	1997	68	28	(a)	14	11	(a)	(a)	(a)
1996	1998	2,408	316	0.286	4,514	535	0.548	5,771	3,162
1997	1999	2,440	187	0.269	12,418	3,116	0.538	13,638	7,337

Appendix Table A-7. Continued.

Stream, BY	Migration year	Early migrants: Migrant abundance estimate	Early migrants: 95% CI	Early migrants: Survival to LGD	Late migrants: Migrant abundance estimate	Late migrants: 95% CI	Late migrants: Survival to LGD	Estimated smolt equivalents leaving tributary	Estimated smolt equivalents at LGD
Upper Grande Ronde River (cont.)									
1998	2000	3,839	386	0.341	10,941	2,033	0.560	13,279	7,436
1999	2001	6	9	(a)	45	30	(a)	(a)	(a)
2000	2002	1,625	180	0.308	7,508	1,564	0.499	8,511	4,247
2001	2003	1,350	105	0.184	3,572	458	0.397	4,198	1,666
2002	2004	467	81	0.164	4,387	637	0.420	4,569	1,919
2003	2005	1,094	123	0.138	5,163	825	0.374	5,567	2,082
2004	2006	7,846	1,248	0.171	26,826	5,170	0.398	30,197	12,018
2005	2007	5,356	306	0.242	11,753	1,680	0.373	15,228	5,680
2006	2008	4,576	1,721	0.338	7,108	2,828	0.418	10,808	4,518
2007	2009	8	9	(a)	26	10	(a)	(a)	(a)
2008	2010	4,584	571	0.209	16,179	1,851	0.468	18,226	8,529
2009	2011	11,072	713	0.225	14,061	2,200	0.447	19,474	8,776
2010	2012	17,824	449	0.196	37,990	4,326	0.405	46,616	18,879
2011	2013	8,958	802	0.177	12,651	939	0.314	17,701	5,558
2012	2014	16,362	1,217	0.201	16,480	4,502	0.340	26,153	8,892
2013	2015	2,152	66	0.086	11,783	540	0.303	12,394	3,755
2014	2016	6,423	352	0.120	15,930[c]	2,234	0.232	19,252	4,467

[c] Spring trap season ended prematurely, missing portion of late migrants.

APPENDIX B

A Compilation of Steelhead Data

Appendix Table B-1. Population estimates, median migration dates, and percentage of steelhead population emigrating as late migrants past trap sites, 1997–2016 migratory years. Early migratory period begins 1 July of the preceding year and ends 28 January of the migratory year. Late migratory period begins 29 January and ends 30 June.

			Median migration date		
Stream and MY	Population estimate	95% CI	Early migrants	Late migrants	Late migrants (%)
Catherine Creek					
1997	25,229	4,774	23 Nov[a]	14 Apr	42[a]
1998	20,742	2,076	22 Sep	4 Apr	58
1999	19,628	3,549	2 Nov	15 Apr	75
2000	35,699	6,024	30 Oct	16 Apr	61
2001	20,586	4,082	24 Sep	31 Mar	56
2002	45,799	6,271	12 Oct	1 May	58
2003	29,593	5,095	14 Oct	18 May	59
2004	26,642	4,324	31 Oct	23 Apr	63
2005	27,192	5,686	15 Oct	20 May	66
2006	23,243	8,142	13 Oct	13 Apr	62
2007	13,715	1,704	16 Oct	4 May	27
2008	24,011	9,268	19 Oct	13 Apr	64
2009	17,098	3,198	14 Oct	10 Apr	35
2010	11,494	2,213	2 Nov	18 Apr	52
2011	24,619	8,836	27 Oct	24 Apr	91
2012	17,198	2,732	12 Oct	30 Apr	84
2013	38,823	6,704	28 Oct	21 Apr	79
2014	25,939	4,463	1 Oct	10 Apr	79
2015	11,275	1,652	20 Oct	13 May	69
2016	15,998	1,484	29 Oct	28 Apr	59
Lostine River					
1997	4,309	710	21 Nov[a]	1 May	63[a]
1998	10,271	2,152	4 Oct	24 Apr	46
1999	23,643	2,637	17 Oct	1 May	35
2000	11,981	1,574	19 Oct	21 Apr	44
2001	16,690	3,242	4 Oct	27 Apr	55
2002	21,019	2,958	18 Oct	17 Apr	31
2003	37,106	4,798	2 Oct	25 Apr	30
2004[b]	—	—	—	—	—
2005	31,342	8,234	23 Sep	25 Apr	26
2006	28,710	7,068	3 Oct	18 Apr	11
2007	13,162	1,867	5 Oct	28 Apr	26
2008	21,493	4,087	6 Oct	30 Apr	43
2009	14,792	5,332	14 Oct	10 Apr	26

[a] Trap was started late, thereby potentially missing some early migrants.
[b] Limited trapping operations prevented complete population estimates and migration timing.

Appendix Table B-1. Continued.

Stream and MY	Population estimate	95% CI	Median migration date: Early migrants	Median migration date: Late migrants	Late migrants (%)
Lostine River (cont.)					
2010	14,764	2,213	6 Oct	26 Apr	31
2011	10,785	642	17 Nov	24 Apr	33
2012	14,401	3,764	11 Oct	22 Apr	41
2013	30,326	4,304	7 Oct	7 May	48
2014	22,094	4,646	1 Oct	2 May	28
2015	15,099	1,352	3 Oct	4 May	32
2016	16,331	2,553	1 Oct	7 Apr	33
Middle Grande Ronde River					
2011[c]	—	—	—	—	—
2012[c]	—	—	—	—	—
2013	81,713	16,523	—	11 May	—
2014	132,413	54,664	—	25 Apr	—
2015	30,940	6,801	—	27 Apr	—
2016	48,239	5,542	—	28 Apr	—
Minam River					
2001	28,113	10,537	3 Oct[a]	28 Apr	86[a]
2002	44,872	19,786	24 Oct[a]	25 Apr	82[a]
2003	43,743	20,680	10 Nov[a]	1 May	99[a]
2004	24,846	13,564	29 Oct	28 Apr	97
2005	105,853	75,607	16 Sep	18 Apr	94
2006	103,141	62,607	2 Oct	22 Apr	78
2007	11,831	3,330	1 Oct	30 Apr	72
2008	62,675	21,725	19 Oct	30 Apr	81
2009	22,940	9,167	13 Nov	21 Apr	72
2010	50,224	16,210	15 Oct	18 Apr	73
2011	29,925	19,416	31 Oct	7 May	92
2012	16,474	6,555	11 Oct	21 Apr	83
2013	28,582	14,161	16 Oct	2 May	79
2014	48,605	7,824	1 Oct	26 Apr	54
2015	21,111	1,707	1 Oct	4 May	62
2016	56,532	15,668	17 Sep	7 Apr	68
Upper Grande Ronde River					
1997	15,104	3,184	25 Oct	27 Mar	92
1998	10,133	1,612	8 Aug	27 Mar	60
1999	6,108	1,309	8 Nov	29 Apr	95
2000	17,845	3,526	30 Sep	8 Apr	94
2001	16,067	4,076	11 Oct	8 May	96
2002	17,286	1,715	24 Oct	15 Apr	94
2003	14,729	2,302	6 Oct	23 Apr	93

[c] Insufficient trap efficiency to produce an estimate.

Appendix Table B-1. Continued.

Stream and MY	Population estimate	95% CI	Median migration date: Early migrants	Median migration date: Late migrants	Late migrants (%)
Upper Grande Ronde River (cont.)					
2004	13,126	1,487	15 Oct	11 Apr	91
2005	8,210	1,434	25 Oct	4 May	86
2006	13,188	2,819	2 Oct	12 Apr	86
2007	12,632	1,766	20 Oct	10 Apr	87
2008	7,296	1,405	13 Nov	28 Apr	95
2009	7,471	1,678	10 Nov	20 Apr	96
2010	8,081	1,425	15 Oct	20 Apr	90
2011	21,462	4,859	30 Oct	15 Apr	90
2012	12,497	1,925	12 Oct	12 Apr	97
2013	18,726	2,349	29 Oct	10 Apr	88
2014	19,774	2,951	30 Sep	9 Apr	82
2015	23,030	1,516	25 Oct	8 May	96
2016	6,033[d]	946	29 Oct	31 Mar[d]	85[d]

[d] Spring trap season ended prematurely, thereby missing a portion of late migrants.

Appendix Table B-2. Dates of arrival at Lower Granite Dam for steelhead PIT-tagged upstream of the screw trap in Catherine Creek and tributaries during summer, and at screw traps during fall and spring of the same migratory year, 2000–2016. Numbers of fish detected were expanded for spillway flow to calculate median arrival date.

Stream and MY	Tag group	Number tagged	Number detected	Median	Arrival dates First	Last
Catherine Creek						
2000	Fall	989	43	20 Apr	2 Apr	29 Jun
	Spring	502	63	6 May	6 Apr	10 Jun
2001	Summer	1,169	26	8 May	25 Apr	25 Jun
	Fall	561	66	6 May	18 Apr	12 Jun
	Spring	266	88	14 May	22 Apr	11 Jun
2002	Summer	1,108	32	20 May	14 Apr	25 Jun
	Fall	723	10	12 May	16 Apr	17 Jun
	Spring	504	95	22 May	20 Apr	1 Jul
2003	Summer	1,043	27	26 May	26 Apr	1 Jun
	Fall	918	26	8 May	27 Mar	3 Jun
	Spring	364	52	26 May	22 Apr	3 Aug
2004	Summer	1,046	54	11 May	10 Apr	18 Aug
	Fall	512	38	7 May	3 Apr	20 Jun
	Spring	598	150	22 May	26 Apr	24 Jul
2005	Summer	1,024	81	8 May	4 Apr	3 Jun
	Fall	473	35	8 May	23 Apr	8 Jun
	Spring	623	55	10 May	18 Apr	27 Jun
2006	Summer	632	19	2 May	15 Apr	9 Jun
	Fall	934	23	30 Apr	2 Apr	22 May
	Spring	500	32	7 May	15 Apr	31 May
2007	Summer	609	3	12 May	2 May	13 May
	Fall	859	21	5 May	2 Apr	9 Jun
	Spring	370	15	9 May	4 May	3 Jun
2008	Fall	600	20	4 May	22 Apr	4 Jul
	Spring	604	21	19 May	22 Apr	12 Jun
2009	Fall	517	57	8 May	28 Mar	18 Jun
	Spring	357	64	7 May	16 Apr	15 Jun
2010	Fall	592	30	4 May	22 Apr	4 Jun
	Spring	574	32	14 May	22 Apr	25 Jun
2011	Fall	589	32	3 May	2 Apr	21 May
	Spring	775	107	10 May	8 Apr	22 Jun
2012	Fall	503	41	5 May	14 Apr	8 Jun
	Spring	808	40	6 May	13 Apr	29 May
2013	Fall	648	7	15 May	11 May	14 June
	Spring	1,042	15	14 May	28 Apr	16 May
2014	Fall	601	24	27 Apr	1 Apr	26 May
	Spring	1,054	34	18 May	12 Apr	7 Jun

Appendix Table B-2. Continued.

Stream and MY	Tag group	Number tagged	Number detected	Arrival dates Median	First	Last
Catherine Creek (cont.)						
2015	Fall	674	3	28 Apr	11 Apr	14 May
	Spring	158	1	27 May	27 May	27 May
2016	Fall	454	24	23 Apr	31 Mar	12 May
	Spring	192	9	12 May	26 Apr	7 Jun
Lostine River						
2000	Fall	777	116	10 May	26 Mar	16 Jun
	Spring	532	166	6 May	13 Apr	13 Jun
2001	Fall	421	13	12 May	16 Apr	13 Jun
	Spring	345	164	14 May	13 Apr	18 Aug
2002	Fall	837	40	8 May	10 Apr	24 Jun
	Spring	351	72	23 May	19 Apr	30 Jun
2003	Fall	999	48	26 May	25 Mar	22 Jun
	Spring	451	116	26 May	3 Apr	15 Jun
2004	Fall[a]	—	—	—	—	—
	Spring[a]	—	—	—	—	—
2005	Fall	760	73	10 May	2 Apr	18 Jun
	Spring	232	52	9 May	10 Apr	20 May
2006	Fall	827	21	19 May	6 Apr	8 Jun
	Spring	270	23	1 May	18 Apr	22 May
2007	Fall	1,000	46	13 May	27 Apr	10 Jun
	Spring	273	16	10 May	18 Apr	16 May
2008	Fall	599	13	17 May	6 May	26 May
	Spring	473	31	12 May	20 Apr	13 Jun
2009	Fall	584	51	30 Apr	17 Apr	3 Jun
	Spring	570	65	18 May	19 Apr	11 Jun
2010	Fall	800	36	20 May	23 Apr	6 Jun
	Spring	600	37	21 May	25 Apr	22 Jun
2011	Fall	589	32	17 May	2 Apr	29 May
	Spring	602	60	15 May	21 Apr	5 Jun
2012	Fall	590	34	17 May	29 Mar	8 Jun
	Spring	433	51	7 May	23 Apr	31 May
2013	Fall	605	22	12 May	2 May	1 Jun
	Spring	654	32	13 May	7 May	2 Jun
2014	Fall	606	21	21 May	6 Apr	6 Jun
	Spring	349	55	19 May	23 Apr	19 Jun
2015	Fall	607	4	20 May	19 May	22 May
	Spring	225	16	22 May	19 May	9 Jun
2016	Fall	361	50	9 May	14 Apr	15 Jun
	Spring	107	17	9 May	14 Apr	23 May

[a] Limited trap operations in 2004

Appendix Table B-2. Continued.

Stream and MY	Tag group	Number tagged	Number detected	Arrival dates Median	First	Last
Middle Grande Ronde River						
2011	Spring	189	20	15 May	16 Apr	9 Jun
2012	Spring	431	50	7 May	28 Mar	5 Jun
2013	Spring	1,421	187	14 May	6 Apr	17 Jun
2014	Spring	728	147	13 May	31 Mar	17 Jun
2015	Spring	890	50	9 May	24 Mar	26 May
2016	Spring	787	201	8 May	9 Apr	9 Jun
Minam River						
2001	Fall	32	6	9 May	2 May	17 May
	Spring	454	240	7 May	26 Apr	29 Aug
2002	Fall	262	5	11 May	17 Apr	31 May
	Spring	197	48	20 May	16 Apr	2 Jun
2003	Fall	42	6	13 Apr	2 Apr	27 May
	Spring	503	129	21 May	2 Apr	6 Jun
2004	Fall	60	2	24 May	23 May	1 Jun
	Spring	217	52	11 May	28 Apr	25 Jun
2005	Fall	79	7	8 May	1 May	10 May
	Spring	333	67	10 May	7 Apr	18 Jun
2006	Fall	81	5	28 Apr	18 Apr	6 May
	Spring	437	64	2 May	8 Apr	3 Jun
2007	Fall	107	2	14 May	12 May	3 Jun
	Spring	293	29	7 May	3 May	16 May
2008	Fall	495	14	13 May	24 Apr	7 Jun
	Spring	591	53	11 May	19 Apr	8 Jun
2009	Fall	131	13	28 Apr	17 Apr	20 May
	Spring	350	56	29 Apr	12 Apr	22 May
2010	Fall	417	1	28 Apr	28 Apr	28 Apr
	Spring	503	32	20 May	23 May	19 Jun
2011	Fall	43	6	12 May	5 Apr	25 May
	Spring	615	169	12 May	5 Apr	18 Jun
2012	Fall	144	7	24 Apr	11 Apr	23 May
	Spring	568	109	25 Apr	12 Apr	10 Jun
2013	Fall	232	6	12 May	10 Apr	16 May
	Spring	396	70	12 May	12 Apr	9 Jun
2014	Fall	478	8	24 May	27 Mar	31 May
	Spring	670	87	8 May	2 Apr	12 Jun
2015	Fall	563	1	9 May	9 May	9 May
	Spring	607	51	20 May	8 Apr	9 Jun
2016	Fall	159	22	9 May	15 Apr	12 May
	Spring	332	106	7 May	9 Apr	9 Jun

Appendix Table B-2. Continued.

Stream and MY	Tag group	Number tagged	Number detected	Arrival dates Median	First	Last
Upper Grande Ronde River						
2000	Fall	110	7	30 Apr	18 Apr	26 May
	Spring	462	73	7 May	31 Mar	28 Jun
2001	Fall	61	10	7 May	28 Apr	29 Jun
	Spring	475	180	5 May	26 Apr	28 Aug
2002	Fall	165	9	7 May	26 Apr	1 Jun
	Spring	543	86	22 May	14 Apr	25 Jun
2003	Fall	309	11	18 May	8 Apr	1 Jun
	Spring	583	101	25 May	4 Apr	24 Jun
2004	Fall	108	1	23 May	23 May	23 May
	Spring	853	190	17 May	15 Apr	14 Jun
2005	Fall	288	16	10 May	19 Apr	19 May
	Spring	643	150	11 May	21 Apr	27 Jun
2006	Fall	53	4	10 May	25 Apr	17 May
	Spring	500	62	10 May	15 Apr	27 May
2007	Fall	485	16	9 May	15 Apr	6 Jun
	Spring	600	59	13 May	7 Apr	12 Jun
2008	Fall	136	18	15 May	19 Apr	28 May
	Spring	601	110	11 May	25 Apr	7 Jun
2009	Fall	109	6	20 May	3 May	6 Jun
	Spring	612	128	9 May	11 Apr	16 Jun
2010	Fall	276	11	14 May	23 Apr	10 Jun
	Spring	612	40	20 May	14 Apr	22 Jun
2011	Fall	562	24	11 May	11 Apr	31 May
	Spring	625	108	15 May	12 Apr	23 Jun
2012	Fall	197	12	3 May	21 Apr	18 Jun
	Spring	776	132	12 May	6 Apr	3 Jun
2013	Fall	613	17	13 May	9 May	11 Jun
	Spring	805	53	13 May	18 Apr	10 Jun
2014	Fall	585	36	10 May	30 Mar	2 Jun
	Spring	1,054	82	16 May	2 Apr	23 Jun
2015	Fall	502	0	—	—	—
	Spring	979	39	18 May	15 Apr	9 Jun
2016	Fall	249	10	11 May	22 Apr	11 Jun
	Spring	499	63	8 May	11 Apr	27 May

Appendix Table B-3. Columbia and Snake river detections and probability of surviving and migrating in the first year to Lower Granite Dam for steelhead PIT-tagged from upper rearing areas of Catherine Creek during summer and at screw traps during fall and spring.

Tag group and stream	MY tagged	Number tagged	Number detected MY	Number detected MY + 1	Number detected MY + 2	Probability of surviving and migrating in the first year (95% CI)
Summer						
Catherine Creek						
	2001	413	22	7	0	0.056 (0.012–0.083)
	2002	838	65	9	0	0.101 (0.075–0.140)
	2003	510	23	7	0	0.048 (0.031–0.071)
	2004	527	42	18	0	0.081 (0.059–0.108)
	2005	704	58	3	0	0.082 (0.063–0.104)
	2006	418	40	1	0	0.138 (0.090–0.252)
	2007	334	10	1	0	0.072 (0.024–0.992)
Little Catherine Creek						
	2001	415	0	3	0	(a)
	2007	275	1	1	0	(a)
Middle Fork Catherine Creek						
	2006	214	1	0	0	(a)
Milk Creek						
	2003	532	27	3	0	0.062 (0.040–0.100)
North Fork Catherine Creek						
	2001	117	2	1	1	(a)
	2002	270	8	2	1	0.035 (0.015–0.085)
	2005	320	14	6	0	0.044 (0.024–0.074)
South Fork Catherine Creek						
	2001	225	5	4	0	0.022 (0.002–0.042)
	2004	519	20	10	1	0.035 (SE = 0.008)
Catherine Creek and tribs combined						
	2001	1,170	29	15	1	0.026 (0.017–0.036)
	2002	1,108	73	11	1	0.084 (0.064–0.114)
	2003	1,042	50	10	0	0.054 (0.040–0.073)
	2004	1,046	62	28	1	0.058 (0.048–0.082)
	2005	1,024	72	9	0	0.070 (0.055–0.087)
	2006	632	41	1	0	0.094 (0.061–0.173)
	2007	609	11	2	0	0.045 (0.015–0.062)
Fall						
Catherine Creek						
	2000	996	73	14	0	0.099 (0.075–0.133)
	2001	562	67	0	0	0.120 (0.095–0.149)
	2002	723	31	4	0	0.069 (0.040–0.152)
	2003	918	56	11	0	0.085 (0.059–0.143)
	2004	512	53	6	0	0.128 (0.095–0.177)

[a] Data were insufficient to calculate a survival probability.

Appendix Table B-3. Continued.

Tag group and stream	MY tagged	Number tagged	Number detected MY	Number detected MY + 1	Number detected MY + 2	Probability of surviving and migrating in the first year (95% CI)
Fall						
Catherine Creek (cont.)						
	2005	473	44	2	0	0.087 (SE = 0.013)
	2006	934	61	12	0	0.077 (0.058–0.110)
	2007	859	59	8	0	0.084 (0.059–0.155)
	2008	600	37	18	0	0.079 (0.052–0.142)
	2009	517	106	4	0	0.259 (0.207–0.336)
	2010	592	77	6	0	0.190 (0.135–0.315)
	2011	589	78	9	0	0.185 (0.137–0.273)
	2012	503	82	2	0	0.197 (0.154–0.263)
	2013	648	28	5	0	0.059 (0.034–0.221)
	2014	601	48	3	0	0.099 (0.071–0.143)
	2015	676	26	2	—	0.056 (0.030–0.225)
	2016	454	53	—	—	0.154 (0.117–0.224)
Lostine River						
	2000	777	158	11	0	0.264 (0.222–0.315)
	2001	423	17	18	0	0.045 (0.027–0.073)
	2002	837	106	18	0	0.154 (0.124–0.194)
	2003	999	100	30	0	0.111 (0.090–0.138)
	2005	760	108	27	0	0.150 (0.124–0.180)
	2006	827	59	15	0	0.085 (0.063–0.125)
	2007	999	96	23	0	0.160 (0.110–0.279)
	2008	599	49	29	0	0.082 (SE = 0.011)
	2009	584	91	6	0	0.167 (0.136–0.204)
	2010	800	98	30	0	0.168 (0.127–0.245)
	2011	589	88	14	0	0.183 (0.143–0.245)
	2012	590	72	19	0	0.250 (0.158–0.512)
	2013	605	51	15	0	0.100 (0.072–0.146)
	2014	606	35	19	0	0.117 (0.063–0.359)
	2015	607	37	9	—	0.170 (0.064–0.679)
	2016	361	63	—	—	0.227 (0.168–0.334)
Minam River						
	2001	32	7	2	0	0.225 (0.103–0.396)
	2002	262	11	10	0	0.134 (0.041–1.971)
	2003	42	8	0	0	0.238 (0.105–1.663)
	2004	60	3	2	0	(a)
	2005	79	10	1	0	0.127 (SE = 0.037)
	2006	81	7	1	0	0.086 (SE = 0.031)
	2007	107	10	1	0	(a)
	2008	495	33	24	0	0.090 (0.057–0.173)
	2009	132	19	2	0	0.165 (0.103–0.258)
	2010	417	5	18	1	(a)

Appendix Table B-3. Continued.

Tag group and stream	MY tagged	Number tagged	Number detected MY	MY + 1	MY + 2	Probability of surviving and migrating in the first year (95% CI)
Fall						
Minam River (continued)						
	2011	43	14	1	0	0.450 (0.245–1.181)
	2012	144	24	0	0	0.196 (0.124–0.394)
	2013	232	12	2	0	0.060 (0.031–0.139)
	2014	478	12	9	0	0.030 (0.015–0.091)
	2015	563	14	4	—	0.025 (<0.000–0.134)
	2016	159	30	—	—	0.248 (0.164–0.413)
Upper Grande Ronde River						
	2000	110	16	0	0	0.227 (0.118–0.650)
	2001	61	12	0	0	0.223 (0.122–0.398)
	2002	165	21	1	0	0.185 (0.108–0.387)
	2003	309	17	1	0	0.094 (0.043–0.956)
	2004	108	1	1	0	0.009 (SE = 0.009)
	2005	288	20	2	0	0.071 (SE = 0.016)
	2006	53	5	0	0	0.094 (SE = 0.040)
	2007	485	34	12	0	0.121 (0.065–0.488)
	2008	136	41	0	0	0.420 (0.294–0.657)
	2009	109	24	2	0	0.253 (0.164–0.460)
	2010	276	21	10	0	0.098 (0.059–0.171)
	2011	562	70	6	0	0.134 (0.106–0.169)
	2012	197	25	2	0	0.134 (0.089–0.195)
	2013	614	48	3	0	0.104 (0.073–0.164)
	2014	585	61	2	0	0.137 (0.102–0.188)
	2015	503	6	6	—	(a)
	2016	249	21	—	—	0.096 (0.059–0.178)
Spring (FL ≥ 115 mm)						
Catherine Creek						
	2000	305	104	2	0	0.490 (0.392–0.630)
	2001	248	95	2	0	0.400 (0.339–0.465)
	2002	504	213	2	0	0.532 (0.465–0.615)
	2003	360	107	2	0	0.360 (0.291–0.472)
	2004	411	187	1	0	0.474 (0.423–0.526)
	2005	181	69	2	0	0.453 (0.353–0.623)
	2006	222	96	0	0	0.540 (0.421–0.790)
	2007	169	26	2	0	0.179 (0.108–0.546)
	2008	128	48	0	0	0.520 (0.358–1.002)
	2009	261	127	0	0	0.582 (0.495–0.694)
	2010	288	100	1	0	0.527 (0.382–0.884)
	2011	629	269	2	0	0.492 (0.439–0.557)
	2012	327	97	1	0	0.391 (0.308–0.526)

Appendix Table B-3. Continued.

Tag group and stream	MY tagged	Number tagged	Number detected MY	MY + 1	MY + 2	Probability of surviving and migrating in the first year (95% CI)
Spring (FL ≥ 115 mm)						
Catherine Creek (continued)						
	2013	214	39	0	0	0.364 (0.189–1.609)
	2014	255	58	0	0	0.463 (0.291–0.947)
(FL ≥ 100mm)						
	2015	158	9	1	—	(a)
	2016	192	20	—	—	0.200 (0.101–0.399)
Lostine River						
	2000	443	234	4	0	0.635 (0.570–0.708)
	2001	330	189	16	0	0.594 (0.538–0.651)
	2002	351	171	6	0	0.625 (0.538–0.739)
	2003	448	269	4	0	0.705 (0.633–0.795)
	2005	90	56	1	0	0.641 (0.532–0.766)
	2006	89	57	0	0	0.629 (SE = 0.051)
	2007	104	35	3	0	(a)
	2008	128	76	1	0	0.714 (0.576–0.967)
	2009	268	151	1	0	0.646 (0.563–0.754)
	2010	189	93	4	0	0.831 (0.585–1.490)
	2011	243	160	3	0	0.736 (0.652–0.845)
	2012	150	90	0	0	0.822 (0.669–1.055)
	2013	174	70	6	0	0.485 (0.379–0.669)
	2014	146	81	0	0	0.755 (0.593–1.059)
(FL ≥ 100mm)						
	2015	225	51	10	—	1.071 (0.346–13.284)
	2016	107	29	—	—	0.317 (0.218–0.479)
Middle Grande Ronde River						
	2011	81	44	3	0	0.657 (0.503–0.899)
	2012	252	103	1	0	0.588 (0.467–0.775)
	2013	1,164	382	2	0	0.537 (0.464–0.631)
	2014	557	258	0	0	0.687 (0.593–0.811)
(FL ≥ 100mm)						
	2015	890	225	2	—	0.828 (0.443–2.338)
	2016	787	324	—	—	0.595 (0.519–0.696)
Minam River						
	2001	442	269	8	0	0.632 (0.584–0.680)
	2002	197	109	1	0	0.722 (0.598–0.898)
	2003	501	272	0	0	0.662 (0.590–0.753)
	2004	120	68	2	0	0.588 (0.493–0.686)
	2005	161	91	3	0	0.566 (0.485–0.647)
	2006	274	168	1	0	0.665 (0.584–0.809)
	2007	178	68	2	0	0.684 (0.432–1.638)
	2008	291	175	1	0	0.819 (0.689–1.027)

Appendix Table B-3. Continued.

Tag group and stream	MY tagged	Number tagged	Number detected MY	Number detected MY + 1	Number detected MY + 2	Probability of surviving and migrating in the first year (95% CI)
Spring (FL ≥ 115 mm)						
Minam River (continued)						
	2009	204	119	4	0	0.670 (0.577–0.789)
	2010	178	77	1	0	1.039 (0.627–2.396)
	2011	520	351	9	0	0.802 (0.735–0.883)
	2012	374	238	1	0	0.758 (0.677–0.862)
	2013	274	165	0	0	0.813 (0.674–1.053)
	2014	286	147	1	0	0.794 (0.644–1.036)
(FL ≥ 100mm)						
	2015	607	185	8	—	0.858 (0.530–1.763)
	2016	332	158	—	—	0.598 (0.513–0.708)
Upper Grande Ronde River						
	2000	324	100	2	0	0.400 (0.326–0.497)
	2001	465	196	5	0	0.451 (0.402–0.503)
	2002	543	192	1	0	0.450 (0.387–0.529)
	2003	579	205	3	0	0.461 (0.393–0.552)
	2004	475	223	2	0	0.492 (0.443–0.542)
	2005	371	186	2	0	0.553 (0.490–0.628)
	2006	342	168	1	0	0.522 (0.454–0.629)
	2007	464	119	3	0	0.315 (0.246–0.453)
	2008	518	263	3	0	0.626 (0.588–0.708)
	2009	533	256	1	0	0.573 (0.513–0.643)
	2010	316	119	0	1	0.547 (0.434–0.728)
	2011	487	258	1	0	0.631 (0.566–0.708)
	2012	659	256	1	0	0.513 (0.447–0.595)
	2013	432	123	4	0	0.435 (0.343–0.580)
	2014	481	154	1	0	0.522 (0.420–0.675)
(FL ≥ 100mm)						
	2015	979	137	5	—	0.312 (0.200–0.617)
	2016	499	118	—	—	0.312 (0.251–0.399)
Spring (FL < 115 mm)						
Catherine Creek						
	2000	189	0	10	1	(a)
	2001	19	1	2	0	(a)
	2002	7	0	1	0	(a)
	2003	4	1	0	0	(a)
	2004	187	5	17	0	0.027 (SE = 0.012)
	2005	442	1	22	0	(a)
	2006	278	3	8	0	(a)
	2007	201	0	23	1	(a)
	2008	476	9	40	0	0.019 (SE = 0.006)
	2009	96	0	8	1	(a)

Appendix Table B-3. Continued.

Tag group and stream	MY tagged	Number tagged	Number detected MY	MY + 1	MY + 2	Probability of surviving and migrating in the first year (95% CI)
Spring (FL < 115 mm)						
Catherine Creek (continued)						
	2010	286	2	27	1	(a)
	2011	147	0	17	0	(a)
	2012	481	0	13	3	(a)
	2013	827	0	33	1	(a)
	2014	799	4	15	0	(a)
Lostine River						
	2000	84	0	9	0	(a)
	2001	21	1	1	0	(a)
	2002	0	0	0	0	(a)
	2003	1	0	0	0	(a)
	2005	142	0	24	0	(a)
	2006	179	1	16	0	(a)
	2007	177	0	26	0	(a)
	2008	345	3	43	0	0.009 (SE = 0.005)
	2009	302	0	29	0	(a)
	2010	411	0	50	1	(a)
	2011	359	0	40	0	(a)
	2012	283	0	12	0	(a)
	2013	480	0	46	0	(a)
	2014	203	0	16	0	(a)
Middle Grande Ronde River						
	2011	108	0	11	1	(a)
	2012	177	1	8	0	(a)
	2013	255	0	14	0	(a)
	2014	171	0	0	0	(a)
Minam River						
	2001	9	0	0	0	(a)
	2002	1	0	0	0	(a)
	2003	0	0	0	0	(a)
	2004	97	0	9	1	(a)
	2005	171	0	10	0	(a)
	2006	163	0	7	0	(a)
	2007	117	0	14	0	(a)
	2008	300	0	36	1	(a)
	2009	146	0	16	0	(a)
	2010	324	0	26	1	(a)
	2011	95	1	10	0	(a)
	2012	194	0	11	0	(a)
	2013	122	0	7	0	(a)
	2014	384	0	18	0	(a)

Appendix Table B-3. Continued.

Tag group and stream	MY tagged	Number tagged	Number detected MY	MY + 1	MY + 2	Probability of surviving and migrating in the first year (95% CI)
Spring (FL < 115 mm)						
Upper Grande Ronde River						
	2000	129	0	5	0	(a)
	2001	7	0	0	0	(a)
	2002	17	2	1	0	0.118 (SE = 0.078)
	2003	5	0	0	0	(a)
	2004	378	5	29	1	0.016 (SE = 0.008)
	2005	271	0	9	2	(a)
	2006	157	2	9	2	(a)
	2007	136	0	7	2	(a)
	2008	83	0	6	0	(a)
	2009	78	0	5	2	(a)
	2010	295	0	26	1	(a)
	2011	138	3	9	0	(a)
	2012	118	1	3	0	(a)
	2013	373	0	8	1	(a)
	2014	225	0	4	2	(a)

Appendix Table B-4. Early migrant steelhead fork lengths at tagging from screw traps on Catherine Creek and Lostine, Minam, and upper Grande Ronde rivers during 1999–2015, summarized by dam detections.

Stream and year tagged	Year detected	*N*	Length at tagging (mm) Median	Min	Percentile 25th	Percentile 75th	Max
Catherine Creek							
1999	(a)	986	101	60	76	142	200
	2000	73	148	67	133	162	195
	2001	14	77	61	73	86	118
2000	(a)	561	136	76	124	150	204
	2001	67	139	102	126	152	195
2001	(a)	723	85	62	75	124	193
	2002	30	128	78	91	136	170
	2003	4	71	62	67	75	75
2002	(a)	918	111	60	81	141	245
	2003	56	143	99	133	154	177
	2004	13	74	65	71	83	167
2003	(a)	512	117	59	85	133	240
	2004	54	131	81	118	146	185
	2005	6	77	65	71	82	118
2004	(a)	473	124	58	81	140	191
	2005	44	136	85	123	152	189
	2006	2	81	75	78	84	87
2005	(a)	934	91	55	77	134	246
	2006	61	140	82	127	154	208
	2007	12	78	69	71	79	94
2006	(a)	856	135	60	118	153	331
	2007	58	144	81	127	160	227
	2008	8	83	60	76	93	105
2007	(a)	597	80	57	72	116	216
	2008	37	123	75	84	144	187
	2009	17	77	62	72	80	85
2008	(a)	518	135	71	125	145	207
	2009	106	140	110	129	156	178
2009	(a)	592	140	55	121	158	305
	2010	77	148	95	133	161	198
2010	(a)	588	127	55	81	146	340
	2011	78	145	121	134	178	204
	2012	9	86	63	74	98	108
2011	(a)	586	127	55	82	146	340
	2012	78	145	121	134	177	204
	2013	7	148	71	125	162	208
2012	(a)	648	80	55	70	122	227
	2013	28	128	72	121	152	205

[a] Data represents all the early migrants tagged regardless of detection history.

Appendix Table B-4. Continued.

Stream and year tagged	Year detected	*N*	Length at tagging (mm) Median	Min	Percentile 25th	75th	Max
Catherine Creek (cont.)							
2012	2014	5	74	56	60	75	78
2013	(a)	601	80	55	67	125	365
	2014	48	132	90	121	154	99
	2015	3	83	74	79	122	160
2014	(a)	676	78	55	65	132	218
	2015	22	151	68	134	163	183
	2016	2	65	64	64	65	65
2015	(a)	454	127	100	118	143	286
	2016	53	135	100	126	149	197
Lostine River							
1999	(a)	773	153	66	140	168	286
	2000	157	157	121	144	170	259
	2001	11	105	79	85	119	141
2000	(a)	421	80	61	73	91	235
	2001	17	161	95	146	178	212
2000	2002	18	86	65	80	89	106
2001	(a)	824	100	60	85	155	262
	2002	105	155	87	140	169	205
	2003	19	82	68	78	94	161
2002	(a)	999	93	62	73	155	348
	2003	98	152	68	136	175	263
	2004	33	75	66	70	84	263
2003	(b)	—	—	—	—	—	—
2004	(a)	758	92	57	77	148	246
	2005	108	148	73	135	166	205
	2006	27	77	62	71	85	101
2005	(a)	827	83	59	72	140	298
	2006	59	155	82	138	165	188
	2007	15	75	62	71	78	101
2006	(a)	1,000	132	55	84	150	278
	2007	96	143	103	133	161	236
	2008	23	69	60	64	78	124
2007	(a)	599	86	57	76	125	235
	2008	49	142	73	123	175	222
	2009	27	79	68	72	80	95
2008	(a)	584	145	59	116	169	275
	2009	90	159	115	145	177	150
2009	(a)	800	124	59	74	159	297
	2010	99	151	83	138	170	213

[b] No early migrants were tagged in the Lostine River because the trap was not operated.

Appendix Table B-4. Continued.

Stream and year tagged	Year detected	*N*	Length at tagging (mm) Median	Min	Percentile 25th	75th	Max
Lostine River (cont.)							
2010	(a)	587	130	59	81	159	307
	2011	88	156	92	138	175	249
	2012	14	73	66	70	80	91
2011	(a)	589	130	59	81	158	307
	2012	88	156	92	139	175	249
	2013	24	92	58	68	133	186
2012	(a)	605	81	55	68	136	234
	2013	57	147	88	129	165	203
	2014	15	72	63	69	90	119
2013	(a)	606	78	55	69	132	270
	2014	35	157	120	136	174	214
	2015	16	77	59	71	80	118
2014	(a)	607	125	56	77	152	262
	2015	35	149	95	140	175	221
	2016	9	74	69	71	81	116
2015	(a)	361	150	92	137	164	278
	2016	63	151	108	140	163	211
Minam River							
2000	(a)	32	122	58	69	153	218
	2001	7	147	114	126	155	183
	2002	2	68	63	65	70	72
2001	(a)	262	66	55	61	117	318
	2002	11	132	120	124	147	185
	2003	10	65	60	63	68	85
2002	(a)	42	104	65	72	146	199
	2003	8	161	133	135	169	185
2003	(a)	60	106	60	67	133	206
	2004	3	118	115	115	118	118
	2005	2	68	65	66	69	70
2004	(a)	79	73	59	65	161	226
2004	2005	10	167	73	147	173	210
	2006	1	67	—	—	—	—
2005	(a)	81	71	58	64	153	218
	2006	7	161	119	143	178	209
	2007	1	61	—	—	—	—
2006	(a)	107	112	59	67	134	230
	2007	10	131	122	128	134	153
	2008	4	70	63	65	74	75
2007	(a)	495	71	58	66	90	210
	2008	33	149	65	129	168	210

Appendix Table B-4. Continued.

Stream and year tagged	Year detected	Length at tagging (mm)					
					Percentile		
		N	Median	Min	25th	75th	Max
Minam River (cont.)							
2007	2009	24	77	61	68	74	90
2008	(a)	132	121	56	66	154	224
	2009	19	158	127	143	175	212
2009	(a)	417	66	58	63	71	272
	2010	5	155	115	117	190	214
2010	(a)	43	142	67	116	179	241
	2013	12	194	156	176	206	224
	2014	3	69	63	66	132	134
2013	(a)	478	66	55	60	76	263
	2014	12	147	73	139	169	212
	2015	9	68	60	65	74	78
2014	(a)	563	64	55	59	96	248
	2015	13	164	103	154	196	199
	2016	4	61	58	59	63	63
2015	(a)	159	151	102	133	182	306
	2016	30	149	119	134	173	203
Upper Grande Ronde River							
1999	(a)	108	133	71	122	148	205
2000	(a)	60	124	86	101	145	180
	2001	12	152	115	134	161	180
2001	(a)	165	115	62	80	130	193
	2002	21	130	110	120	150	163
	2003	1	111	—	—	—	—
2002	(a)	309	111	63	76	131	200
	2003	17	133	120	125	140	155
	2004	1	77	—	—	—	—
2003	(a)	108	77	61	71	110	160
	2004	1	113	—	—	—	—
	2005	1	70	—	—	—	—
2004	(a)	288	114	62	90	125	179
	2005	20	127	101	118	137	159
	2006	2	81	72	77	86	90
2005	(a)	53	113	63	73	128	190
	2006	5	136	110	127	176	190
2006	(a)	478	112	54	87	123	190
	2007	33	131	99	119	140	180
	2008	12	104	79	87	112	130
2007	(a)	136	132	59	126	148	309
	2008	41	132	112	126	148	199
2008	(a)	109	126	71	118	134	257

Appendix Table B-4. Continued.

Stream and year tagged	Year detected	Length at tagging (mm)					
					Percentile		
		N	Median	Min	25th	75th	Max
Upper Grande Ronde River (cont.)							
2008	2009	25	129	114	127	142	181
2009	(a)	276	126	61	79	147	279
	2010	21	134	85	118	166	205
2010	(a)	560	121	60	80	133	355
	2011	70	132	88	125	143	194
	2012	6	86	79	81	98	105
2011	(a)	562	121	60	80	133	355
	2012	70	132	88	125	143	194
	2013	3	121	109	115	122	123
2012	(a)	612	117	56	78	132	250
	2013	48	130	101	125	149	192
	2014	18	127	78	113	142	173
2013	(a)	585	111	55	77	129	232
	2014	61	131	100	121	140	192
	2015	2	76	68	72	80	84
2014	(a)	503	79	56	72	122	331
	2015	5	136	112	130	173	192
	2016	6	74	62	72	80	109
2015	(a)	249	119	100	111	129	288
	2016	21	128	102	121	136	176

Appendix Table B-5. Late migrant steelhead fork lengths at tagging from screw traps on Catherine Creek and Lostine, Minam, and upper Grande Ronde rivers during 2000–2016, summarized by dam detections.

Stream and year tagged	Year detected	*N*	Length at tagging (mm) Median	Min	Percentile 25th	Percentile 75th	Max
Catherine Creek							
2000	(a)	494	132	61	86	150	210
	2000	103	152	120	143	167	210
	2001	12	79	70	73	104	125
	2002	1	87	—	—	—	—
2001	(a)	247	142	115	131	154	190
	2001	96	150	115	138	161	190
	2002	2	120	115	117	122	124
2002	(a)	503	152	115	139	164	260
	2002	212	156	115	144	166	208
	2003	2	126	123	124	127	128
2003	(a)	360	145	115	132	156	203
	2003	107	150	118	137	161	201
	2004	2	122	122	122	122	122
2004	(a)	598	135	62	102	152	202
	2004	192	148	94	135	160	202
	2005	18	77	63	72	82	130
2005	(a)	623	93	60	82	123	195
	2005	70	155	109	139	172	195
	2006	24	87	65	77	101	127
2006	(a)	500	98	60	81	146	203
	2006	99	151	87	138	163	199
	2007	8	83	80	82	87	105
2007	(a)	370	111	61	91	147	222
	2007	26	153	118	143	164	181
	2008	25	95	66	85	97	142
	2009	1	90	—	—	—	—
2008	(a)	603	85	60	77	107	206
	2008	57	147	83	123	161	206
	2009	18	77	62	73	82	85
2009	(a)	357	138	62	109	153	195
	2009	128	147	97	138	162	194
	2010	8	76	70	72	83	95
2010	(a)	574	115	62	81	156	265
	2010	102	158	92	143	175	225
	2011	28	82	67	74	96	129

[a] Data represents all the late migrants tagged, regardless of detection history.

Appendix Table B-5. Continued.

Stream and year tagged	Year detected	Length at tagging (mm)					
					Percentile		
		N	Median	Min	25th	75th	Max
Catherine Creek (cont.)							
2011	(a)	775	150	58	132	165	227
	2011	268	160	121	146	172	227
	2012	20	89	59	80	99	139
2012	(a)	809	93	55	75	144	265
	2012	97	155	123	144	169	233
	2013	19	92	61	74	111	202
2013	(a)	1,042	80	55	71	102	221
	2013	39	158	122	141	175	221
	2014	35	82	55	71	92	172
2014	(a)	1,054	84	55	74	112	214
	2014	62	143	79	129	154	214
	2015	13	83	67	71	85	114
2015	(a)	158	139	100	115	156	250
	2015	9	150	134	145	162	176
	2016	1	115	—	—	—	—
2016	(a)	192	121	100	108	139	192
	2016	20	152	103	134	163	192
Lostine River							
2000	(a)	526	160	66	145	175	329
	2000	234	168	123	157	179	236
	2001	13	89	66	80	128	158
2001	(a)	323	163	115	148	180	292
	2001	182	172	121	157	185	292
	2002	16	141	115	121	156	160
2002	(a)	351	158	115	141	178	326
	2002	171	163	115	152	180	244
	2003	6	127	122	122	131	138
2003	(a)	447	162	115	150	174	289
	2003	267	163	132	152	175	208
	2004	4	125	115	118	141	152
2004	(a)	416	115	61	86	153	215
	2004	122	163	105	148	180	215
	2005	24	87	73	81	104	130
2005	(a)	232	99	64	83	156	226
	2005	56	178	141	160	188	226
	2006	25	84	69	80	97	133
2006	(a)	270	89	61	76	149	243
	2006	58	169	106	157	183	243
	2007	16	79	65	73	89	94
2007	(a)	281	94	60	81	142	292

Appendix Table B-5. Continued.

Stream and year tagged	Year detected	Length at tagging (mm)					
					Percentile		
		N	Median	Min	25th	75th	Max
Lostine River (cont.)							
2007	2007	35	167	130	154	182	210
	2008	29	82	62	78	94	169
2008	(a)	473	92	62	82	124	238
	2008	79	160	90	150	172	238
	2009	44	90	64	81	95	115
2009	(a)	577	105	60	83	159	228
	2009	151	166	124	153	176	217
	2010	29	88	70	73	103	117
2010	(a)	600	92	64	82	145	244
	2010	93	166	124	156	179	228
	2011	53	86	64	80	95	144
2011	(a)	601	99	63	84	162	229
	2011	160	172	131	159	187	229
	2012	43	90	72	83	99	155
2012	(a)	430	78	56	68	146	220
	2012	90	156	133	147	172	220
	2013	14	77	61	69	87	200
2013	(a)	654	84	55	73	124	217
	2013	69	163	126	155	182	217
	2014	52	84	55	76	97	159
2014	(a)	349	98	55	78	156	211
	2014	80	165	138	154	174	211
	2015	14	83	64	74	88	105
2015	(a)	225	151	78	115	169	204
	2015	46	173	124	158	182	202
	2016	10	111	86	104	134	151
2016	(a)	107	146	101	108	162	212
	2016	29	160	126	153	173	212
Minam River							
2001	(a)	442	160	115	144	177	227
	2001	269	167	124	151	183	227
2001	2002	8	136	118	125	151	169
2002	(a)	197	158	115	147	179	219
	2002	108	164	119	151	185	219
	2003	1	135	—	—	—	—
2003	(a)	500	164	116	152	178	224
	2003	271	165	127	153	178	218
	2004	1	194	—	—	—	—
2004	(a)	217	133	59	86	168	239
	2004	68	169	117	154	180	239

Appendix Table B-5. Continued.

Stream and year tagged	Year detected	Length at tagging (mm)					
					Percentile		
		N	Median	Min	25th	75th	Max
Minam River (cont.)							
2004	2005	11	102	71	82	106	122
2005	(a)	332	110	62	76	160	288
	2005	91	163	127	149	180	215
	2006	13	76	69	74	111	142
2006	(a)	437	141	58	79	165	218
	2006	168	164	115	149	180	213
	2007	8	76	67	71	87	139
2007	(a)	293	144	63	87	172	220
	2007	68	174	118	160	187	201
	2008	13	85	75	80	91	130
2008	(a)	591	108	60	78	160	217
	2008	175	164	118	151	178	209
	2009	38	83	60	72	90	179
2009	(a)	344	135	63	84	160	232
	2009	119	163	124	150	180	232
	2010	20	79	64	72	93	124
2010	(a)	502	82	62	73	145	217
	2010	77	160	127	141	176	209
	2011	27	75	65	72	87	117
2011	(a)	612	166	65	138	185	236
	2011	351	175	113	159	189	236
	2012	19	104	73	86	121	160
2012	(a)	566	151	55	77	178	252
	2012	236	174	127	159	188	245
	2013	20	88	63	77	178	218
2013	(a)	396	158	58	91	178	223
	2013	169	175	127	162	186	223
	2014	9	81	62	69	172	204
2014	(a)	670	94	53	73	155	223
	2014	148	167	80	153	187	223
	2015	15	83	67	77	99	116
2015	(a)	607	170	100	156	186	241
	2015	174	177	132	165	190	229
	2016	8	112	101	108	117	136
2016	(a)	332	163	100	148	179	259
	2016	158	172	124	157	187	232
Upper Grande Ronde River							
2000	(a)	453	133	71	108	152	225
	2000	99	155	115	139	166	208
	2001	6	80	72	77	109	126

Appendix Table B-5. Continued.

Stream and year tagged	Year detected	Length at tagging (mm)					
					Percentile		
		N	Median	Min	25th	75th	Max
Upper Grande Ronde River (cont.)							
2001	(a)	465	147	115	135	163	219
	2001	196	156	115	145	171	207
	2002	5	143	121	127	150	152
2002	(a)	543	150	115	135	164	216
	2002	192	155	115	144	170	209
	2003	1	159	—	—	—	—
2003	(a)	578	150	115	136	164	199
	2003	204	158	115	142	169	199
	2004	4	130	117	119	168	197
2004	(a)	853	123	60	82	147	204
	2004	228	148	98	135	167	202
	2005	31	81	64	74	98	123
2005	(a)	642	130	65	91	152	208
	2005	186	150	117	141	164	197
	2006	11	89	69	81	95	140
	2007	2	82	70	76	88	94
2006	(a)	500	132	62	94	150	276
	2006	170	150	111	135	166	203
	2007	10	91	65	76	105	124
2007	(a)	600	142	65	118	157	230
	2007	119	157	121	146	168	230
	2008	119	157	121	146	168	230
	2009	2	74	70	72	76	78
2008	(a)	601	147	60	132	162	223
	2008	265	155	117	142	165	203
	2009	9	105	78	104	117	124
2009	(a)	611	146	72	133	165	250
	2009	256	157	117	143	172	233
	2010	6	99	76	85	105	123
2010	(a)	612	125	63	81	156	328
	2010	119	157	121	144	173	228
	2011	26	81	71	77	87	114
2011	(a)	625	146	62	122	163	241
	2011	260	156	112	142	168	241
	2012	10	96	84	86	100	115
2012	(a)	775	140	59	127	157	210
	2012	256	151	113	138	166	210
	2013	17	110	70	92	138	175
2013	(a)	805	124	56	79	150	209
	2013	122	158	124	141	171	205

Appendix Table B-5. Continued.

Stream and year tagged	Year detected	Length at tagging (mm)					
					Percentile		
		N	Median	Min	25th	75th	Max
Upper Grande Ronde River (cont.)							
	2014	31	103	63	80	127	207
2014	(a)	706	133	57	103	151	205
	2014	302	155	115	143	173	246
	2015	5	82	75	79	103	119
2015	(a)	979	157	100	140	175	281
	2015	131	164	119	149	183	240
	2016	5	110	102	107	110	195
2016	(a)	499	135	100	123	152	205
	2016	118	149	109	133	161	205

Appendix Table B-6. Steelhead fork lengths at tagging from rearing areas upstream of the Catherine Creek screw trap, including tributaries, during summer 2000–2006, summarized by migration history.

Tag group, migration history	Length at tagging (mm)					
				Percentile		
	N	Median	Min	25th	75th	Max
Summer 2000						
All PIT tagged	1,163	113	59	90	137	263
Captured in trap fall 2000	22	124	83	113	135	152
Captured in trap spring 2001	5	125	88	106	141	142
Migrated past trap during MY 2001	50	127	83	113	139	170
Migrated past trap during MY 2002	6	93	63	92	101	136
Migrated past trap during MY 2003	0	—	—	—	—	—
Still upstream after MY 2001	12	92	63	84	106	136
Still upstream after MY 2002	1	92	—	—	—	—
Still upstream after MY 2003	0	—	—	—	—	—
Detected at dams during MY 2001	29	130	85	114	143	170
Detected at dams during MY 2002	15	92	72	78	103	133
Detected at dams during MY 2003	1	83	—	—	—	—
Summer 2001						
All PIT tagged	1,108	112	63	97	130	221
Captured in trap fall 2001	46	117	99	110	126	147
Captured in trap spring 2002	9	129	97	122	142	168
Migrated past trap MY 2002	118	123	96	112	135	168
Migrated past trap MY 2003	8	94	68	81	108	118
Migrated past trap MY 2004	0	—	—	—	—	—
Still upstream after MY 2002	14	95	68	86	105	177
Still upstream after MY 2003	1	134	—	—	—	—
Still upstream after MY 2004	0	—	—	—	—	—
Detected at dams during MY 2002	73	128	96	112	137	161
Detected at dams during MY 2003	11	99	82	93	101	118
Detected at dams during MY 2004	1	71	—	—	—	—
Summer 2002						
All PIT tagged	1,043	115	73	103	130	230
Captured in trap fall 2002	46	115	90	108	128	154
Captured in trap spring 2003	10	115	88	105	128	143
Migrated past trap MY 2003	53	117	88	108	128	153
Migrated past trap MY2004	14	97	75	86	104	111
Migrated past trap MY2005	0	—	—	—	—	—
Still upstream after spring 2003	3	101	86	94	103	104
Still upstream after spring 2004	0	—	—	—	—	—
Still upstream after spring 2005	0	—	—	—	—	—
Detected at dams during 2003	50	121	86	105	134	169
Detected at dams during 2004	10	98	75	86	105	111

Appendix Table B-6. Continued.

Tag group, migration history	Length at tagging (mm)					
				Percentile		
	N	Median	Min	25th	75th	Max
Summer 2003						
All PIT tagged	1,165	106	58	89	127	229
Captured in trap fall 2003	16	115	92	104	124	149
Captured in trap spring 2004	12	123	91	109	131	167
Migrated past trap MY 2004	81	121	78	110	133	171
Migrated past trap MY2005	5	91	78	85	92	96
Migrated past trap MY2006	0	—	—	—	—	—
Still upstream after spring 2004	4	107	97	101	109	110
Still upstream after spring 2005	0	—	—	—	—	—
Still upstream after spring 2006	0	—	—	—	—	—
Detected at dams during 2004	62	123	78	110	137	171
Detected at dams during 2005	28	91	65	81	99	111
Detected at dams during 2006	1	71	—	—	—	—
Summer 2004						
All PIT tagged	1,024	127	56	109	146	229
Captured in trap fall 2004	18	130	111	122	147	172
Captured in trap spring 2005	3	142	137	140	149	156
Migrated past trap MY 2005	90	139	105	125	155	185
Migrated past trap MY 2006	3	101	78	90	103	104
Migrated past trap MY 2007	0	—	—	—	—	—
Still upstream after spring 2005	1	179	—	—	—	—
Still upstream after spring 2006	1	107	—	—	—	—
Still upstream after spring 2007	0	—	—	—	—	—
Detected at dams during 2005	72	141	105	127	156	185
Detected at dams during 2006	9	103	80	99	108	120
Detected at dams during 2007	0	—	—	—	—	—
Summer 2005						
All PIT tagged	632	119	55	106	141	279
Captured in trap fall 2005	10	118	89	114	123	139
Captured in trap spring 2006	3	115	96	106	118	121
Migrated past trap MY 2006	52	122	89	115	144	186
Migrated past trap MY 2007	1	105	—	—	—	—
Migrated past trap MY 2008	0	—	—	—	—	—
Still upstream after spring 2006	1	101	—	—	—	—
Still upstream after spring 2007	0	—	—	—	—	—
Still upstream after spring 2008	0	—	—	—	—	—
Detected at dams during 2006	41	126	96	116	149	186
Detected at dams during 2007	1	99	—	—	—	—
Detected at dams during 2008	1	99	—	—	—	—
Detected at dams during 2009	0	—	—	—	—	—

Appendix Table B-6. Continued.

Tag group, migration history	Length at tagging (mm)					
				Percentile		
	N	Median	Min	25th	75th	Max
Summer 2006						
All PIT tagged	609	109	59	90	129	268
Captured in trap fall 2006	18	124	95	107	131	167
Captured in trap spring 2007	3	86	74	80	111	135
Migrated past trap MY 2007	30	124	74	107	134	177
Migrated past trap MY 2008	2	75	72	73	76	77
Still upstream after spring 2007	0	—	—	—	—	—
Still upstream after spring 2008	0	—	—	—	—	—
Detected at dams during 2007	10	130	107	108	136	177
Detected at dams during 2008	3	96	79	88	111	125
Detected at dams during 2009	0	—	—	—	—	—