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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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 2011 (MY11) from 1 July 2010 through 30 June 2011. 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 lower Columbia River hydrosystem until spring 2011. 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

CONTENTS (continued)

Page

TABLES

FIGURES

FIGURES (continued)

Number | Page

FIGURES (continued)

APPENDIX TABLES

APPENDIX TABLES (continued)

EXECUTIVE SUMMARY

Objectives

1. 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.

2. 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.

3. 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.

4. 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.

5. 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.

6. 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.

7. 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 2011, with the exception of documenting in-basin migration patterns and estimating abundance of spring Chinook salmon and summer steelhead juveniles at the middle Grande Ronde River trap site.

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 9 September 2010 through 23 June 2011. 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 9 September 2010 to 28 January 2011 with a peak during fall. 'Late' migrants emigrated from upper rearing areas from 31 January 2011 to 18 June 2011 with a peak during spring. At Catherine Creek trap, we estimated 12,594 juvenile spring Chinook salmon migrated from upper rearing areas with 64% leaving as early migrants. At Lostine River trap, we estimated 64,756 juvenile spring Chinook salmon migrated from upper rearing areas with 80% leaving as early migrants. At Minam River trap, we estimated 73,645 juvenile spring Chinook salmon migrated from upper rearing areas with 56% leaving as early migrants. At upper Grande Ronde River trap, we estimated 25,133 juvenile spring Chinook salmon migrated from upper rearing areas with 44% leaving as early migrants. At middle Grande Ronde River trap, insufficient trap efficiency prohibited an abundance estimate of juvenile Chinook salmon produced by the Upper Grande Ronde Watershed.

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 2010, were detected at Lower Granite Dam between 29 March and 26 June 2011. Median dates of arrival at Lower Granite Dam for Catherine Creek and Imnaha, Lostine, Minam, and upper Grande Ronde rivers were significantly different during MY 2011 (Kruskal–Wallis, $P < 0.05$). Upper Grande Ronde River dates of arrival were latest of all five groups and were significantly different from those of Catherine Creek and Imnaha, Lostine, and Minam rivers (Dunn test, $P < 0.05$). Median arrival dates, at Lower Granite Dam, of juvenile spring Chinook salmon from all study streams, ranged from 4 May to 14 June. Survival probabilities to Lower Granite Dam, for parr tagged during summer 2010, were 0.128 for Catherine Creek and 0.172 for Imnaha, 0.139 for Lostine, 0.127 for Minam, and 0.125 for upper Grande Ronde river populations.

Chinook salmon tagged at the traps were detected at Lower Granite Dam between 25 March and 3 July 2011. 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 0.156 to 0.286, while late migrants ranged from 0.422 to 0.595. Survival probabilities fall within ranges previously observed for all populations. Catherine Creek juvenile spring Chinook salmon, which overwintered downstream from the trap site (early migrants), survival probabilities were not significantly different than those that overwintered upstream (late migrants) (Maximum Likelihood Ratio test, $P > 0.05$). However, Lostine and upper Grande Ronde river juvenile spring Chinook salmon, which overwintered downstream from trap sites (early migrants), had significantly higher survival probabilities compared to those that overwintered upstream (late migrants) (Maximum Likelihood Ratio test, $P < 0.05$).

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 2011. Based on migration timing and abundance, early and late migration patterns were identified, similar to those for spring Chinook salmon. For MY 2011, we estimated 26,947 steelhead migrants emigrated from upper rearing areas in Catherine Creek with 8% migrating as early migrants. We estimated 10,922 steelhead emigrated from Lostine River, with 66% migrating as early migrants. We estimated 29,925 steelhead emigrated from Minam River with 8% migrating as early migrants. We estimated 22,644 steelhead migrants emigrated from upper rearing areas of upper Grande Ronde River with 10% migrating as early migrants. At middle Grande Ronde River trap, insufficient trap efficiency prohibited an abundance estimate of juvenile steelhead produced by the Upper Grande Ronde Watershed.

Steelhead collected at trap sites during MY 2011 were comprised of five age groups. Early and late migrants ranged from 0 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 2 April to 23 June 2011. Early and late migrant median arrival dates ranged from 3 May to 17 May and 10 May to 15 May, respectively.

Probabilities of surviving and migrating in the first year to Lower Granite Dam for early migrating steelhead ranged from 0.134 (upper Grande Ronde River) to 0.450 (Minam River). Probabilities of surviving and migrating in the first year to Lower Granite Dam for late migrants, greater than 115mm, ranged from 0.492 (Catherine Creek) to 0.802 (Minam River). For all five groups of smaller late-migrating fish (<115mm), insufficient detections at Lower Granite dam prohibited estimating probability of migrating and surviving in spring 2011. It should be noted that lack of detections, for small steelhead (<115mm), is not necessarily due to low survival, but more likely a result of these fish being less likely to emigrate in the first year.

Stream Condition

Daily mean water temperature typically fell within DEQ standards, at all five trap locations, during the period 2009 BY spring Chinook salmon were in the Grande Ronde River Subbasin (1 August 2009–30 June 2011). The 2009 BY encountered daily mean water temperatures in excess of DEQ standard of 17.8°C for 17 of 699 d in Catherine Creek and 0 of 681 d in Lostine, 0 of 103 d in middle Grande Ronde, 47 of 699 d in

Minam, and 7 of 699 d in upper Grande Ronde rivers. Temperatures preferred by juvenile Chinook salmon (10–15.6°C) occurred during 15% of hours logged for Catherine Creek and 20% for Lostine, 28% for middle Grande Ronde, 11% for Minam, and 18% for upper Grande Ronde rivers. These optimal temperatures tended to occur April–June and August–October. Water temperatures considered lethal to Chinook salmon (>25° C) did not occur in Catherine Creek or Lostine, middle Grande Ronde, Minam, or upper Grande Ronde rivers. 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; however, during 2011, small peaks in river flow were observed in these streams as early as mid-January. Middle Grande Ronde and Minam rivers experienced more variable discharge. Spring run-off typically occurred from April through July with peak flows occurring during mid-June for Catherine Creek and middle Grande Ronde, Minam, and upper Grande Ronde rivers. Spring run-off initiated later on Lostine River (May–July) with peak flows occurring during mid-June.

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 2011. 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. A dual trap design was employed on Minam River below spawning and rearing areas at rkm 0 and 3 in an effort to increase trap efficiency and sample sizes. 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 hand held thermometers.

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

$$\hat{E}_j = R_j \big/ M_j \,, \tag{1}$$

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

$$\hat{N}_j = U_j \big/ \hat{E}_j \,, \tag{2}$$

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) 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

$$95\%\,CI = 1.96\sqrt{V}\ , \tag{3}$$

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

$$\hat{P}_i = S_i / C\ , \tag{4}$$

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

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

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) 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 2010 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 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 2010 through 28 January 2011 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 each 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 2010) than spring tag groups, which were tagged as migrants (29 January–30 June 2011) 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 500 fish from Catherine Creek and Lostine and upper Grande Ronde rivers.

Spring migrants (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 600 fish at each trap throughout the late migration period.

During MY 2011, 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 2011 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):

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

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 2.2b (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:

$$\hat{S}_{s,overwinter} = \frac{\hat{S}_{s,winter}}{\hat{S}_{s,spring}} \tag{7}$$

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 ($\hat{Q}_{s,tributary}$):

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

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

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

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 2010 and 2011 to monitor and compare smolt migration timing to Lower Granite Dam and survival probabilities from tagging to Lower Granite Dam. Fish tagged during summer 2011 will be analyzed with the 2012 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 159 d between 13 September 2010 and 14 June 2011 (Table 2). A distinct early and late migration was exhibited by juvenile spring Chinook salmon at this trap site (Figure 2). Systematic subsampling comprised 10 of 90 d the trap was fished during the late migration period, and 122 juvenile Chinook salmon were caught during this period. Median emigration date for early migrants passing the trap was 3 November 2010, and median emigration date for late migrants was 31 March 2011 (Appendix Table A-1). Both dates fall within the range of median dates previously reported.

We estimated a minimum of 12,594 ± 1,107 juvenile spring Chinook salmon emigrated from upper Catherine Creek rearing areas during MY 2011. This migrant estimate was within ranges previously reported during this study (Appendix Table A-1). Based on total minimum estimate, 64% (8,079 ± 332) migrated early and 36% (4,515 ± 1,057) migrated late. Principally, migration from Catherine Creek has consistently been observed during the early migrant period.

Lostine River: The trap fished for 197 d between 9 September 2010 and 16 May 2011 (Table 2). Distinct early and late migrations were evident at this trap site (Figure 2). Systematic subsampling comprised 5 of 93 d the trap was fished during the late migration period, and 369 juvenile Chinook salmon were caught during this period. Median emigration date for early migrants was 12 October 2010, and 7 April 2011 for late migrants (Appendix Table A-1). Both dates fall within ranges previously reported for this study.

We estimated a minimum of 64,756 ± 10,873 juvenile spring Chinook salmon emigrated from Lostine River during MY 2011. Based on the minimum estimate, 80% (51,699 ± 10,822) of juvenile spring Chinook salmon migrated early, while 20% (13,057 ± 1,053) migrated late. Percentage of late migrants is the second lowest reported for this study (Appendix Table A-1). The Lostine River population appears to be similar to that of Catherine Creek in that the largest emigration has been typically observed during the early migrant period (Appendix Table A-1).

Middle Grande Ronde River: The trap fished for 64 d between 18 March 2011 and 23 June 2011 (Table 2). Insufficient trap efficiency precluded abundance and migration timing estimation.

Minam River: The trap fished for 147 d between 16 September 2010 and 16 May 2011 (Table 2). Distinct early and late migrations were evident (Figure 2). Median emigration date of early migrants was 8 November 2010, and median date for late migrants was 26 April 2011 (Appendix Table A-1). Early migrant median date falls within ranges previously reported for this study, while late migrant median date is the latest reported since trapping began in 2001.

We estimated a minimum of 73,645 ± 10,922 juvenile spring Chinook salmon emigrated from Minam River during MY 2011. Based on the minimum estimate, 56% (41,128 ± 6,511) of juvenile spring Chinook salmon migrated early and 44% (32,517 ± 8,769) migrated late. Percentage of late migrants is within ranges reported from previous years of this study (Appendix Table A-1).

Upper Grande Ronde River: The trap fished for 131 d between 14 September 2010 and 6 June 2011 (Table 2). Distinct early and late migration was exhibited by juvenile spring Chinook salmon at this trap site (Figure 2). Systematic subsampling comprised 9 of 75 d the trap was fished during the late migration period; 325 juvenile Chinook salmon were caught during this period. Median emigration date for early migrants was 2 November 2010, and 25 March 2011 for late migrants (Appendix Table A-1). Both dates fall within ranges previously reported for this study.

We estimated a minimum of 25,133 ± 2,313 juvenile spring Chinook salmon emigrated from upper Grande Ronde River during MY 2011. Based on the minimum estimate, 44% (11,072 ± 713) of juvenile spring Chinook salmon migrated early and 56% (14,061 ± 2,200) migrated late. Percentage of late migrants is second lowest reported from previous years of this study (Appendix Table A-1).

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 2010, 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 Catherine Creek and Imnaha, Lostine, Minam, and upper Grande Ronde rivers during summer 2010 were detected at Lower Granite Dam from 29 March to 26 June 2011 (Appendix Table A-2). Period of detection at Lower Granite Dam among the five populations ranged from 63 d (Minam River) to 87 d (Catherine Creek). Median date of arrival ranged from 4 May to 14 June (Figure 5). Median dates of arrival at Lower Granite Dam for Catherine Creek and Imnaha, Lostine, Minam, and upper Grande Ronde rivers were significantly different during MY 2011 (Kruskal–Wallis, $P < 0.05$). *Dunn's* multiple comparison tests revealed that median dates of arrival for Catherine Creek and Imnaha, Lostine, and Minam rivers were not significantly different in MY 2011. Median date of arrival at Lower Granite Dam for upper Grande Ronde River was significantly different than those for Catherine Creek and Imnaha, Lostine, and Minam rivers during MY 2011 (Kruskal-Wallis, $P < 0.05$). Median arrival dates for summer tag groups from Catherine Creek, and Imnaha, Lostine, and Minam rivers fell into previously reported ranges, while upper Grande Ronde River median arrival date was the latest observed during this multiyear study (Appendix Table A-2).

Survival Probabilities: Survival probabilities to Lower Granite Dam for parr tagged during summer 2010 were 0.128 for Catherine Creek, 0.172 for Imnaha, 0.139 for Lostine, 0.127 for Minam, and 0.125 for upper Grande Ronde river populations (Table 5). Generally, survival probabilities during MY 2011 fell within ranges previously reported; however, upper Grande Ronde River survival probability was the lowest reported survival estimate previously reported (Appendix Table A-3).

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 fall, winter, and spring tag groups of Catherine Creek were 11 May, 12 May and 9 June 2011, respectively (Figure 6). Median arrival dates at Lower Granite Dam for fall, winter, and spring tag groups for Lostine River were 28 April, 16 May and 13 May 2011, respectively (Figure 7). Median arrival date for the spring tag group from middle Grande Ronde River was 9 May (Figure 8). Median arrival dates at Lower Granite Dam for fall and spring tag groups of Minam River were 27 April and 17 May 2011, respectively (Figure 9). Median arrival date at Lower Granite Dam for fall, winter, and spring tag groups from upper Grande Ronde River were 13 May, 20 June, and 5 June 2011, respectively (Figure 10). Median arrival dates of the spring tag group from Catherine Creek and winter tag group from upper Grande Ronde River were later than previously observed. 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 Lostine and upper Grande Ronde rivers (Mann–Whitney rank-sum test, $P < 0.001$). There was no detectable difference in median arrival date between Catherine Creek early and late migrants ($P = 0.226$). 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 22 to 106 d with a median of 60 d ($n = 69$). Travel time for Lostine River late migrants ranged from 6 to 111 d with a median of 33 d ($n = 416$). Travel time for middle Grande Ronde River late migrants ranged from 5 to 58 d with a median of 35 d ($n = 28$). Travel time for Minam River late migrants ranged from 5 to 77 d with a median of 33 d ($n = 236$). Travel time for upper Grande Ronde River late migrants ranged from 5 to 93 d with a median of 58 d ($n = 115$). Median travel times during MY

2011 were within previously observed ranges for Catherine Creek and Lostine, Minam, and upper Grande Ronde rivers (Appendix Table A-4).

Survival Probabilities: Catherine Creek fall, winter, and spring tag group survival probabilities to Lower Granite Dam were 0.156, 0.174, and 0.422, respectively. Survival probabilities for Lostine River fall, winter, and spring tag groups were 0.251, 0.196, and 0.583, respectively. Probability of survival for the middle Grande Ronde River spring tag group was 0.726. Survival probabilities for Minam River fall and spring tag groups were 0.286 and 0.595, respectively. Upper Grande Ronde River fall, winter, and spring tag group survival probabilities to Lower Granite Dam were 0.225, 0.124, and 0.447, 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 2009 fish in upper rearing areas of Catherine Creek was 40%, and was similar to those previously observed during this multiyear study (Appendix Table A-5). During MY 2011, difference in survival between fish that overwintered upstream and those downstream of the Catherine Creek trap was not significant (Maximum Likelihood Ratio test, $P = 0.655$). Higher survival rates were observed for fish overwintering downstream of the Catherine Creek trap in MY 1997, 2000-2001, 2007, and 2009 (Appendix Table A-6); however, overwinter survival has generally been similar between upstream and downstream overwintering fish (10 of 17 migratory years).

Overwinter survival of BY 2009 fish in upper rearing areas of Lostine River was 34%, and was similar to those previously observed during this multiyear study (Appendix Table A-5). During MY 2011, overwinter survival between fish that overwintered upstream and those downstream of Lostine River trap was significantly different (Maximum Likelihood Ratio test, $P = 0.031$). For Lostine River, we have generally observed equivalent overwinter survival rates between upstream and downstream overwintering areas (9 of 14 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 2009 fish in upper rearing areas of upper Grande Ronde River was 27%, and was generally similar to those previously observed during this multiyear study (Appendix Table A-5). During MY 2011, 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, and 2010-2011. (Appendix Table A-6). Upstream overwintering conferred better survival in MY 2004-2005. Survival rates were equivalent between overwintering areas for MY 1994, 2006 and 2008 (Appendix Table A-6).

Smolt Equivalents: An estimated 7,593 smolt equivalents emigrated from Catherine Creek rearing reaches during spring of MY 2011, and 3,189 of those successfully emigrated to Lower Granite Dam (Appendix Table A-7). Both estimates are within previously reported ranges of smolt equivalent estimates from MY 1995-2011. 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. Highest smolt equivalent estimates leaving Catherine Creek rearing areas during spring and estimated at Lower Granite Dam occurred during MY 2004 (26,687 and 11,022, respectively; Appendix Table A-7).

An estimated 35,341 smolt equivalents emigrated from Lostine River rearing areas during spring of MY 2011, and 20,498 successfully emigrated to Lower Granite Dam (Appendix Table A-7). Generally, both estimates are higher than previously reported estimates of smolt equivalent estimates from MY 1997-2010. Lowest smolt equivalent estimates occurred during MY 1997 (Appendix Table A-7). The highest estimate of smolt equivalents emigrating from Lostine River rearing areas during spring was 35,341 during MY 2011, and for smolt equivalents successfully emigrating to Lower Granite Dam was 20,567 during MY 2010 (Appendix Table A-7). Access to Lostine River trap site was denied during MY 2004, precluding estimates of migrant abundance, survival to Lower Granite Dam, and smolt equivalents.

An estimated 52,396 smolt equivalents emigrated from Minam River rearing areas during spring MY 2011, of which 31,437 successfully emigrated to Lower Granite Dam (Appendix Table A-7); both estimates are within previously reported ranges from MY 2001-2011. Lowest estimates occurred during MY 2007, when an estimated 22,589 smolt equivalents emigrated from Minam River rearing areas during spring, and 13,599 successfully emigrated to Lower Granite Dam. Highest estimates occurred during MY 2005, when an estimated 88,766 smolt equivalents emigrated from Minam River rearing areas during spring, and an estimated 49,265 successfully emigrated to Lower Granite Dam (Appendix Table A-7).

An estimated 19,474 smolt equivalents emigrated from upper Grande Ronde River rearing areas during spring MY 2011, of which 8,763 successfully emigrated to Lower Granite Dam (Appendix Table A-7); both estimates are within previously reported ranges from MY 2001-2011. For years 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 and at Lower Granite Dam occurred during MY 1995 (35,685 and 21,732, respectively). 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 and 2001 (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***). During previous years, steelhead less than 115 mm (FL) were not tagged during spring because fish from this size range were detected at Snake or Columbia River dams during subsequent years. Although this criterion targeted only seaward migrating steelhead for the spring tag group, it failed to characterize migration behavior of all steelhead emigrating from natal rearing areas during spring. Beginning in MY 2004, all steelhead were tagged to fully document all life history strategies. 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 2010 and 28 January 2011. Spring tag groups represent fish that migrate downstream of trap sites between 29 January and 30 June 2011 (late migrants). During summer 2006, our goal was to PIT-tag 500 Catherine Creek and Little Catherine Creek steelhead each. At each trap site during MY 2011, our goal was to PIT-tag 600 steelhead during fall and spring to assess migration timing of early and 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 three 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 (2011) were used to calculate probability of surviving and migrating to Lower Granite Dam. Survival probabilities were calculated using program SURPH2.2b (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 2010 were compared to fork lengths of those subsequently detected at dams in 2011 using the Mann–Whitney rank-sum test. Fork lengths of all steelhead tagged during fall 2009 were compared to that of those subsequently detected in 2010 and 2011 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 2011 were compared to that of those subsequently detected at dams during spring 2011 using a Mann–Whitney rank-sum test. Age structure of steelhead PIT-tagged at the traps and subset detected at the dams during spring 2011 were 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 159 d between 13 September 2010 and 14 June 2011 (Table 7). Systematic subsampling comprised 10 of 120 d the trap was operated during the late migration period. Distinct early and late migrations were exhibited by juvenile steelhead at this trap site (Figure 11). Median emigration date for early migrants was 27 October 2010, while median emigration date for late migrants was 24 April 2011. Both median migration dates were within ranges previously reported for this study (Appendix Table B-1).

We estimated a minimum of 26,947 ± (95% CI, 8,998) juvenile steelhead migrated out of upper rearing areas during MY 2011. Based on total minimum abundance estimate, 8% (2,132 ± 183) migrated early and 92% (24,815 ± 8,996) migrated late. MY 2011 proportion of juvenile steelhead emigrating from upper rearing areas as late migrants (92%) is considerably higher than those proportions previously reported during 1997-2010 (Appendix Table B-1).

Lostine River: The trap fished for 197 d between 9 September 2010 and 16 May 2011 (Table 7). Systematic subsampling comprised 5 of 106 d the trap was operated 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 17 November 2010, and median emigration date for late migrants was 24 April 2011. Both median migration dates were within ranges previously reported during this study (Appendix Table B-1).

We estimated a minimum of 10,922 ± 655 steelhead emigrated during MY 2011. Based on total minimum abundance estimate, 66% (7,251 ± 512) of juvenile steelhead migrated early and 34% (3,671 ± 408) migrated late.

Middle Grande Ronde River: The middle Grande Ronde River trap fished for 64 d between 18 March 2011 and 23 June 2011 (Table 7). Insufficient trap efficiency precluded estimates for abundance and migration timing.

Minam River: The trap fished for 147 d between 16 September 2010 and 16 May 2011 (Table 7). Distinct early and late migrations were evident at this trap site (Figure 11). Median emigration date for early migrants was 31 October 2010, and median emigration date for late migrants was 7 May 2011. Median emigration date for early migrants was within ranges previously reported, while median emigration date for late migrants was the latest reported for this multiyear study (Appendix Table B-1).

We estimated a minimum of 29,925 ± 19,424 juvenile steelhead emigrated during MY 2011. Based on total minimum abundance estimate, 8% (2,361 ± 1,377) migrated early and 92% (27,564 ± 19,375) migrated late. MY 2011 proportion of juvenile steelhead emigrating as late migrants is consistent with proportions from previous years (Appendix Table B-1).

Upper Grande Ronde River: The trap fished for 131 d between 14 September 2010 and 6 June 2011 (Table 7). Systematic subsampling comprised 9 of 90 d the trap was operated 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 30 October 2010, and median emigration date for late migrants was 15 April 2011. Both median migration dates were within ranges previously reported during this study (Appendix Table B-1).

We estimated a minimum of 22,644 ± 5,184 juvenile steelhead emigrated from upper rearing areas of upper Grande Ronde River during MY 2011, which is within estimates from previous migratory years (Appendix Table B-1). Based on total minimum abundance estimate, 10% (2,233 ± 217) were early migrants and 90% (20,411 ± 5,180) were late migrants. Predominant late migration of juvenile steelhead in upper Grande Ronde River is consistent for all migratory years studied to date (Appendix Table B-1).

Age of Migrants at Traps: Summer steelhead collected at trap sites during MY 2011 comprised five age-groups. Early migrants ranged from 0 to 4 years of age, while late migrants ranged from 1 to 4 years of age (Table 8). Majority of Catherine Creek (48.5%), Minam (62.8%), and upper Grande Ronde river (57.3%) early migrants were age 1, while majority of Lostine River (52.3%) early migrants were age 0. Majority of Catherine Creek (51.0%) and upper Grande Ronde River (48.6%) late migrants were age 2, while majority of Lostine (57.9%) and middle Grande Ronde river (53.2%) late migrants were age 1, and majority of Minam River (42.3%) late migrants were age 3 (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 3 May and 10 May, respectively (Figure 12). Median arrival dates for Lostine River fall and spring tag groups were 17 May and 15 May, respectively (Figure 13). Median arrival dates for the middle Grande Ronde River spring tag group was 15 May (Figure 14). Median arrival dates for Minam River fall and spring tag groups were 12 May (Figure 15). Median arrival dates for upper Grande Ronde River fall and spring tag groups were 11 May and 15 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 75 d with a median of 29.7 d. Travel time to Lower Granite Dam for the Lostine River spring tag group ranged from 3 to 92 d with a median of 7.9 d. Travel time to Lower Granite Dam for the middle Grande Ronde River spring tag group ranged from 4 to 56 d with a median of 15.6 d. Travel time to Lower Granite Dam for the Minam River spring tag group ranged from 4 to 66 d with a median of 6.6 d. Travel time to Lower Granite Dam for the upper Grande Ronde River spring tag group ranged from 4 to 92 d with a median of 27.9 d.

Survival Probabilities: Probability of surviving and migrating, during migration year of tagging, to Lower Granite Dam for steelhead tagged in fall 2010 ranged from 0.134 to 0.450 for all four spawning tributaries (Table 10). Probabilities of migration and survival, for larger steelhead (FL ≥ 115 mm) tagged during spring 2011, ranged from 0.492 to 0.802 for all five populations studied (Table 10). Generally, probabilities of migration and survival, during spring 2011, were moderate to relatively high for all five populations studied compared to previous years (Appendix Table B-3).

Length and Age Characterization of Smolt Detections: Of all early migrating steelhead tagged at Catherine Creek and Lostine and upper Grande Ronde river traps during fall 2010, predominantly larger individuals were detected at dams during 2011 (Mann–Whitney, $P < 0.05$, Figure 17). However, no significant difference in length was observed between Minam River fish tagged during fall 2010 and those detected at dams during spring 2011 (Mann-Whitney, $P = 0.255$, Figure 17). Of all early migrating steelhead tagged from Lostine, Minam, and upper Grande Ronde rivers during fall 2009, predominately smaller individuals tended to be detected at dams during 2011 (Kruskal–Wallis, $P < 0.05$, Figure 18). However, no significant difference in length was observed between Catherine Creek fish that were tagged during spring 2009 and those detected at dams in 2010 and 2011 (Kruskal-Wallis, $P = 0.090$, Figure 18). MY 2011 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 115 early migrating age-0 fish tagged during MY11, 2 were observed at dams the following spring, while 69 of 279 age-1 and 20 of 81 age-2 early migrants were observed the following spring at dams. As in past years, age-2 smolts (age-1 early migrants) made up the highest weighted percentage of all MY11 observations (Table 11). Generally, late migrant smolts primarily consisted of age 1 to 4 years during 2011, with the majority consisting of 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 initial 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 2009 juvenile spring Chinook salmon, which ranged from 1 August 2009 (spawning) to 30 June 2011 (the end of MY 2011).

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 preceding and following three days ($n = 7$). Water temperature data was 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), Lostine River (USGS station 13330300; rkm 1.6), Minam River (USGS station 13331500; rkm 0.4), and upper Grande Ronde River (USGS station 13317850; rkm 321.9) 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.

Results and Discussion

Stream Temperature and Flow

Catherine Creek: Water temperatures, during in-basin occupancy of BY 2009 Chinook salmon, ranged from a low of 0.0°C to 23.8°C. During the period egg deposition typically occurs (i.e., spawning; August 2009), daily mean water temperature exceeded DEQ standard of 17.8°C for 7 d. During parr rearing (1 June to 14 August 2010), daily mean water temperatures exceeded 17.8°C for 10 d. During early dispersal (15 August to 30 September 2010), daily mean water temperatures exceeding 17.8°C did not occur. Water temperatures were within the range preferred by juvenile Chinook salmon (10–15.6°C; OPSW 1999) for 106 of 699 (15%) days logged. DEQ lethal limit of 25°C was not exceeded during 699 days 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 101 days (11 November 2009–25 February 2010) during incubation and emergence, and 107 days (17 November 2010–3 March 2011) during dispersal and spring migration. Moving mean temperatures exceeded 18.9°C on 31 days (1 August 2008–3 September 2009) during spawning and 39 days (17 July 2010–24 August 2010) during parr rearing and early dispersal.

Average daily discharge during in-basin life history of the 2009 cohort ranged from 0.7 to 34.8 m^3/s (Figure 21). Discharge was greater than 2.0 m^3/s from early-April through late-July 2010, during incubation, emergence, and parr rearing, and mid-January through spring migration in 2011, excluding 9 days in late-February to early-march. Annual peak flows occurred on 4 June 2010 and 15 May 2011, at 34.8 m^3/s and 32.9 m^3/s, respectively. Discharge was less than 2.0 m^3/s from August 2009 through early-April in 2010, during spawning, incubation and emergence, and late-July 2010 through mid-January 2011, during parr rearing and early and late dispersal. In addition to typical spring freshets, stream discharge exceeded 2.0 m^3/s for 7 days during mid-December 2009, 5 days during early-January 2010, 2 days in late-March 2010, 2 days in mid-November 2010, and 4 days in mid-December 2010.

Lostine River: Water temperatures, during the majority of in-basin occupancy of BY 2009 Chinook salmon, ranged from 0.0°C to 19.2°C. We were unable to characterize an 18 day period during late dispersal and spring migration (10 April 2010–27 April 2010). During egg deposition (i.e., spawning; August 2009), daily mean water temperatures exceeding DEQ standard of 17.8°C did not occur. During parr rearing (1 June-14 August 2010), daily mean water temperatures exceeding 17.8°C did not occur. During early dispersal (15 August–30 September 2010), daily mean water temperatures exceeding 17.8°C did not occur. Water temperatures were within the range preferred by juvenile Chinook salmon (10–15.6°C; OPSW 1999) for 139 of 681 (20%) days logged. DEQ lethal limit of 25°C was not exceeded during 681 days 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 healthy growth water temperature range (Figure 20). Moving mean temperatures were less than 4.4°C for 80 days (12 November 2009–1 February 2010) during incubation and emergence, and 103 days (20 November 2010–2 March 2011) during parr rearing, early dispersal, and spring migration. Moving mean temperatures did not exceed 18.9°C during spawning.

Average daily discharge during in-basin life history of the 2009 cohort ranged from 0.7 to 64.6 m^3/s (Figure 21). Discharge was greater than 7.5 m^3/s from mid-May through mid-July 2010, during incubation, emergence, and parr rearing periods, and mid-May through June 2011, during spring migration. Annual peak flows occurred on 4 June 2010 and 23 June 2011, and were 64.6 m^3/s and 45.3 m^3/s, respectively. Discharge was less than 7.5 m^3/s from August 2009 through mid-May 2010, during spawning, incubation, and emergence, and mid-July 2010 through mid-May 2011, during parr rearing, early and late dispersal, and spring migration. In addition to typical spring freshets, stream discharge exceeded 7.5 m^3/s for 2 days during mid-January 2011.

Middle Grande Ronde River: Water temperatures, during in-basin occupancy of BY 2009 Chinook salmon, ranged from 3.7°C to 25.0°C. We were unable to characterize a 596 day period during spawning, parr rearing and early dispersal (1 August 2009-19 March 2011). During the period egg deposition typically occurs (i.e., spawning; August 2009), daily mean water temperatures exceeding DEQ standard of 17.8°C did not occur. During parr rearing (1 June-14 August 2010), daily mean water temperatures exceeding 17.8°C did not occur. During early dispersal (15 August–30 September 2010), daily mean water temperatures exceeding 17.8°C did not occur. Water temperatures were within the range preferred by juvenile Chinook salmon (10–15.6°C; OPSW 1999) for 29 of 103 (28%) days logged. DEQ lethal limit of 25°C was not exceeded during 103 days temperature was logged. The seven-day moving mean of maximum temperature revealed that water temperatures above, but not below the range expected to support healthy growth (4.4–18.9°C; OPSW 1999) were encountered during the logged period (Figure 20). Moving mean temperatures exceeded 18.9°C on 7 days during parr rearing and early dispersal (24 June 2011–30 June 2011).

Average daily discharge during in-basin life history of the 2009 cohort ranged from 1.3 to 224.6 m^3/s (Figure 21). Discharge was typically greater than 12.0 m^3/s from late-March through early-July 2010, during incubation, emergence, and parr rearing and from mid-January 2011 through June 2011, during late dispersal and spring migration. Annual peak flows occurred on 3 June 2010 and 16 May 2011, and were 154.3 m^3/s and 224.6 m^3/s, respectively. Discharge was less than 12.0 m^3/s from August 2009 through early-April 2010, during spawning, incubation, and emergence, and from early-July 2010 through mid-January 2011, during parr rearing, early and late dispersal and spring migration. In addition to typical spring freshets, stream discharge exceeded 12 m^3/s for a 2 day period in mid-December 2010

Minam River: Water temperatures, during in-basin occupancy of BY 2009 Chinook salmon, ranged from 0.0°C to 25.7°C. During the period egg deposition typically occurs (i.e., spawning; August 2009), daily mean water temperatures exceeded DEQ standard of 17.8°C for 22 d. During parr rearing (1 June-14 August 2010), daily mean water temperatures exceeded 17.8°C for 19 d. During early dispersal (15 August–30 September 2010), daily mean water temperatures exceeded 17.8°C for 6 d. Water temperatures were within the range preferred by juvenile Chinook salmon (10–15.6°C; OPSW 1999) for 76 of 699 (11%) days logged. DEQ lethal limit of 25°C was not exceeded during 699 days 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 on 104 days (10 November 2009–24 February 2010) during incubation and emergence, and 106 days (17 November 2010–2 March 2011) during early and late dispersal and spring migration. Moving mean temperatures exceeded 18.9°C on 50 days (1 August 2009–19 September 2009) during spawning, and 39 days (20 July 2010–27 August 2010) during parr rearing and early dispersal.

Average daily discharge during in-basin life history of the 2009 cohort ranged from 1.0 to 135.9 m^3/s (Figure 21). Discharge was greater than 9.0 m^3/s from mid-April through late-July 2010, during incubation, emergence, and parr rearing, and mid-April through spring migration 2011. Annual peak flows occurred on 4 June 2010 and 23 June 2011, and were 135.9 m^3/s and 117.2 m^3/s, respectively. Discharge was less than 9.0 m^3/s from August 2009 through mid-April 2010, during spawning, incubation, and emergence, and mid-July 2010 through mid-March 2011, during parr rearing, early and late dispersal, and spring migration. In addition to typical spring freshets, stream discharge exceeded 9.0 m^3/s for a 2 day period in mid-December 2010, and a 20 day period in late-January 2011.

Upper Grande Ronde River: Water temperatures, during in-basin occupancy of BY 2009 Chinook salmon, ranged from 0.0°C to 26.8°C. During the period egg deposition typically occurs (i.e., spawning; August 2009), daily mean water temperatures exceeded DEQ standard of 17.8°C for 7 d. During parr rearing (1 June-14 August 2010), daily mean water temperatures exceeding 17.8°C did not occur. During early dispersal (15 August–September 2010), daily mean water temperatures exceeding 17.8°C did not occur. Water temperatures were within the range preferred by juvenile Chinook salmon (10–15.6°C; OPSW 1999) for 140 of 699 (20%) days logged. DEQ lethal limit of 25°C was not exceeded during 699 days temperature was logged. The seven-day moving mean of maximum temperature revealed that water temperatures above and below the range expected to support healthy growth (4.4–18.9°C; OPSW 1999) were encountered (Figure 20). Moving mean temperatures were less than 4.4°C on 134 days (30 October 2009–14 March 2010), and on 2 additional days (2 April 2010-3 April 2010) during incubation and emergence, and 131 days (10 November 2010–20 March 2011) during early dispersal and spring migration. Moving mean temperatures exceeded 18.9°C on 34 days during parr rearing and early dispersal (1 August 2009–3 September 2009).

Average daily discharge during in-basin life history of the 2009 cohort ranged from 0.09 to 11.1 m^3/s (Figure 21). Discharge was greater than 1.0 m^3/s from mid-April through mid-July 2010, and on one additional occasion, 8 August 2009, during incubation, emergence, and parr rearing, and from a four day period in mid-April and from early-May through June 2011, during late dispersal and spring migration. Annual peak flows occurred on 4 June 2010 and 15 June 2011, and were 11.1 m^3/s and 10.9 m^3/s, respectively. Discharge was less than 1.0 m^3/s from August 2009 through mid-April 2010, during spawning, incubation, and emergence, and from mid-July 2010 through April 2011 (excluding 8 days in April), during parr rearing, early and late dispersal, and spring migration.

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.

REFERENCES

Burck, W. A. 1993. Life history of spring Chinook salmon in Lookingglass Creek, Oregon. Oregon Department of Fish and Wildlife, Information Reports 94-1, Portland.

Efron, B., and R. Tibshirani. 1986. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. Statistical Science 1: 54–77.

Giorgi, A. E., G. A. Swan, W. S. Zaugg, T. C. Corley and T. Y. Barila. 1988. The susceptibility of Chinook salmon smolts to bypass systems at hydroelectric dams. North American Journal of Fisheries Management 8:25–29.

Hesse, J., J. Harbeck, and R. W. Carmichael. 2006. Monitoring and evaluation plan for northeast Oregon hatchery Imnaha and Grande Ronde Subbasin spring Chinook salmon. Technical Report 198805301. Bonneville Power Administration, Portland, OR.

Johnson, G. E., R. L. Johnson, E. Kucera, and C. Sullivan. 1997. Fixed-location hydroacoustic evaluation of the prototype surface bypass and collector at Lower Granite Dam in 1996. Final Report. U.S. Army Corps of Engineers, Walla Walla, WA.

Jonasson, B. C., J. V. Tranquilli, M. Keefe, and R. W. Carmichael. 1997. Investigations into the early life history of naturally produced spring Chinook salmon in the Grande Ronde River basin. Annual Progress Report 1997. Bonneville Power Administration, Portland, OR.

Jonasson, B. C., A. G. Reischauer, F. R. Monzyk, E. S. Van Dyke, and R. W. Carmichael. 2006. Investigations into the early life history of naturally produced spring Chinook salmon in the Grande Ronde River basin. Annual Progress Report 2002. Bonneville Power Administration, Portland, OR.

Keefe, M., R. W. Carmichael, B. C. Jonasson, R. T. Messmer, and T. A. Whitesel. 1994. Investigations into the life history of spring Chinook salmon in the Grande Ronde River basin. Annual Progress Report 1994. Bonneville Power Administration, Portland, OR.

Keefe, M., D. J. Anderson, R. W. Carmichael, and B. C. Jonasson. 1995. Early life history study of Grande Ronde River basin Chinook salmon. Annual Progress Report 1995. Bonneville Power Administration, Portland, OR.

Kuehl, S. 1986. Hydroacoustic evaluation of fish collection efficiency at Lower Granite Dam in spring 1985. Final Report to U.S. Army Corps of Engineers, Walla Walla, WA.

Lady, J., P. Westhagen, and J. R. Skalski. 2001. SURPH.2 User Manual, SURPH 2.2b, SURvival under Proportional Hazards. School of Aquatic and Fisheries Sciences, University of Washington, Seattle, WA. Available: http://www.cbr.washington.edu/paramEst/SURPH (January 2008).

Matthews, G. M., J. R. Harmon, S. Achord, O. W. Johnson, and L. A. Kubin. 1990. Evaluation of transportation of juvenile salmonids and related research on the Columbia and Snake rivers, 1989. Report of the U.S. Army Corps of Engineers, Contract DACW68-84-H0034. National Marine Fisheries Service, Seattle.

Matthews, G. M., and eight coauthors. 1992. Evaluation of transportation of juvenile salmonids and related research on the Columbia and Snake rivers, 1990. Report of the U.S. Army Corps of Engineers, Contract DACW68-84-H0034. National Marine Fisheries Service, Seattle.

Nowak, M. C., lead writer. 2004. Grande Ronde Subbasin Plan. Northwest Power and Conservation Council, Portland. Available: http://www.nwcouncil.org/fw/subbasinplanning/granderonde/plan/ (January 2008).

NWPPC (Northwest Power Planning Council). 1992. Strategy for salmon, Volume VII.

ODFW (Oregon Department of Fish and Wildlife). 1990. Grande Ronde River Subbasin Salmon and Steelhead Production Plan. Oregon Department of Fish and Wildlife, Portland, OR.

OPSW (The Oregon Plan for Salmon and Watersheds). 1999. Water Quality Monitoring Technical Guide Book: version 2.0. Available: http://www.oregon.gov/OWEB/docs/pubs/wq_mon_guide.pdf (January 2008).

Prentice, E. F., T. A. Flagg, C. S. McCutcheon, D. F. Brastow, and D. C. Cross. 1990. Equipment, methods, and an automated data-entry station for PIT tagging. American Fisheries Society Symposium 7: 335–340.

Prentice, E. F., D. L. Park, T. A. Flagg, and S. McCutcheon. 1986. A study to determine the biological feasibility of a new fish tagging system, 1985–1986. Annual Progress Report. Bonneville Power Administration, Portland OR.

Peven, C. M., R. R. Whitney, and K. R. Williams. 1994. Age and length of steelhead smolts from the mid-Columbia river basin, Washington. North American Journal of Fisheries Management 14:77–86

Reischauer, A. G., F. R. Monzyk, E. S. Van Dyke, B. C. Jonasson, and R. W. Carmichael. 2003. Investigations into the early life history of naturally produced spring Chinook salmon in the Grande Ronde River basin. Annual Progress Report 2001. Bonneville Power Administration, Portland, OR.

Snake River Recovery Team. 1993. Draft Snake River salmon recovery plan recommendations. National Marine Fisheries Service, Portland, OR.

Swan, G. A., R. F. Krcma, and F. J. Ossiander. 1986. Continuing studies to improve and evaluate juvenile collection at Lower Granite Dam, 1985. Report to U.S. Army Corps of Engineers, Portland, OR.

Thedinga, J. F., M. L. Murphy, S. W. Johnson, J. M. Lorenz, and K. V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 14: 837–851.

TRT (Interior Columbia Basin Technical Recovery Team). 2003. Independent Populations of Chinook, Steelhead, and Sockeye for Listed Evolutionarily Significant Units within the Interior Columbia River Domain.

Van Dyke, E. S., M. Keefe, B. C. Jonasson, and R. W. Carmichael. 2001. Aspects of life history and production of juvenile *Oncorhynchus mykiss* in the Grande Ronde River Basin, northeast Oregon. Summary Report. Bonneville Power Administration, Portland, OR.

Ward, B. R., and P. A. Slaney. 1988. Life history and smolt-to-adult survival of Keogh River steelhead trout (*Salmo gairdneri*) and the relationship to smolt size. Canadian Journal of Fish and Aquatic Science 45: 1110–1122.

Table 1. Dates of tagging and number of spring Chinook salmon parr PIT-tagged in various northeast Oregon streams during summer 2010 and 2011.

Migration year and stream	Dates of collection and tagging	Number PIT-tagged and released	Distance to Lower Granite Dam (km)
2011 (*Summer 2010*)			
Catherine Creek	2 Aug–4 Aug	992	363–383
Imnaha River	23 Aug–26 Aug	997	221–233
Lostine River	11 Aug–30 Aug	997	271–308
Minam River	16 Aug–19 Aug	999	276–290
Upper Grande Ronde	9 Aug–31 Aug	993	418–428
2012 (*Summer 2011*)			
Catherine Creek	15 Aug–17 Aug	998	363–383
Imnaha River	22 Aug–25 Aug	998	221–233
Lostine River	6 Sept–8 Sept	1000	271–308
Minam River	29 Aug–1 Sept	999	276–290
Upper Grande Ronde	12 Sept–14 Sept	1000	418–428

Table 2. Juvenile spring Chinook salmon catch at five general trap locations in Grande Ronde River Subbasin during MY 2011. Early migration period starts 1 July 2010 and ends 28 January 2011. Late migration period starts 29 January and ends 30 June 2011. 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 / days operated	Trap catch
Catherine Creek	Early	13 Sept 10 – 22 Nov10	69/71 (97)	5,258
	Late	15 Feb 11 – 14 Jun 11	80/120 (67)	852[a]
		30 Mar 11 – 16 Apr 11	10/18 (56)	122[b]
Lostine River	Early	9 Sept 10 – 28 Jan 11	99/142 (70)	9,183
	Late	29 Jan 11 – 16 May 11	93/106 (88)	6,464[a]
		9 Apr 11 – 21 Apr 11	5/13 (38)	369[b]
Middle Grande Ronde River	Late	18 Mar 11 – 23 Jun 11	64/98 (65)	76
Minam River (rkm 1)	Early	16 Sept 10 – 28 Jan 11	61/68 (90)	6,791
	Late	29 Jan 11 – 16 May 11	86/108 (80)	1,434
Minam River (rkm 3)	Late	29 Mar 11 – 12 May 11	43/45 (96)	759
Upper Grande Ronde River	Early	14 Sept 10 – 19 Nov 10	56/67 (84)	3,950
	Late	9 Mar 11 – 6 Jun 11	66/90 (73)	2,711[a]
		25 Mar 11 – 16 Apr 11	9/23 (39)	325[b]

[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 2011. Early and late migrants were captured with a rotary screw trap on each study stream. Winter tag group fish were captured with dip nets 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										
Early migrants	1,139	83.6	0.23	59	107	499	83.1	0.30	59	102
Winter	496	83.6	0.37	57	105	496	83.6	0.37	57	105
Late migrants	810	90.8	0.35	56	120	429	88.2	0.40	67	120
Lostine River										
Early migrants	1,874	87.2	0.20	58	121	1,098	88.2	0.25	59	121
Winter	500	77.6	0.34	56	103	500	77.6	0.34	56	103
Late migrants	2,050	90.2	0.19	64	137	1,752	90.5	0.20	64	137
Middle Grande Ronde River										
Spring emigrants	71	92.5	1.13	71	115	71	92.5	1.13	71	115
Minam River										
Early migrants	1,075	81.1	0.69	52	120	931	81.2	0.27	58	120
Late migrants	1,729	88.4	0.18	65	120	1,081	88.1	0.23	65	120
Upper Grande Ronde River										
Early migrants	888	82.1	0.25	55	107	498	83.3	0.34	55	107
Winter	431	72.0	0.34	55	98	431	72.0	0.34	55	98
Late migrants	960	85.2	0.29	56	115	668	85.0	0.33	63	110

Table 4. Weights of juvenile spring Chinook salmon collected from study streams during MY 2011. Early and late migrants were captured with a rotary screw trap on each study stream. Winter tag group fish were captured with dip nets 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										
Early migrants	1,138	6.6	0.06	2.2	13.3	499	6.4	0.07	2.2	12.1
Winter	496	6.5	0.08	2.2	12.9	496	6.5	0.08	2.2	12.9
Late migrants	806	8.4	0.10	1.8	19.4	429	7.6	0.11	3.2	19.4
Lostine River										
Early migrants	1,852	7.4	0.05	2.1	20.7	1,095	7.8	0.07	2.4	20.7
Winter	435	5.3	0.07	1.8	10.6	435	5.3	0.07	1.8	10.6
Late migrants	2,045	8.1	0.05	3.1	27.5	1,748	8.1	0.06	3.1	27.5
Middle Grande Ronde River										
Spring emigrants	71	8.4	0.35	4.0	17.0	71	8.4	0.35	4.0	17.0
Minam River										
Early migrants	1,070	5.9	0.06	1.6	19.3	926	6.0	0.06	1.6	19.3
Late migrants	1,720	7.6	0.05	2.9	19.9	1,080	7.6	0.06	2.9	19.9
Upper Grande Ronde River										
Early migrants	871	5.8	0.06	1.6	12.8	490	6.1	0.07	1.6	12.8
Winter	431	4.2	0.06	1.5	10.0	431	4.2	0.06	1.5	10.0
Late migrants	945	6.4	0.07	1.7	17.1	663	6.3	0.08	2.3	14.6

Table 5. Survival probability to Lower Granite Dam of juvenile spring Chinook salmon tagged during summer 2010 and detected at Columbia and Snake river dams during 2011.

Stream	Number PIT-tagged and released	Survival probability (95% CI)
Catherine Creek	992	0.128 (0.104–0.158)
Imnaha River	997	0.172 (0.145–0.204)
Lostine River	997	0.139 (0.115–0.168)
Minam River	999	0.127 (0.102–0.158)
Upper Grande Ronde River	993	0.125 (0.101–0.156)

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 2010 to spring 2011 and detected at dams during 2011.

Stream and tag group	Number PIT-tagged and released	Survival probability (95% CI)
Catherine Creek		
Fall (trap)	499	0.156 (0.120–0.207)
Winter (above trap)	497	0.174 (0.135–0.227)
Spring (trap)	430	0.422 (0.347–0.535)
Lostine River		
Fall (trap)	1100	0.251 (0.221–0.286)
Winter (above trap)	500	0.196 (0.158–0.242)
Spring (trap)	1751	0.583 (0.549–0.621)
Middle Grande Ronde River		
Spring (trap)	71	0.726 (0.575–0.920)
Minam River		
Fall (trap)	932	0.286 (0.254–0.320)
Spring (trap)	1092	0.595 (0.542–0.659)
Upper Grande Ronde River		
Fall (trap)	499	0.225 (0.184–0.273)
Winter (above trap)	431	0.124 (0.094–0.160)
Spring (trap)	672	0.447 (0.392–0.512)

Table 7. Juvenile steelhead catch at five general trap locations in Grande Ronde River Subbasin during MY 2011. Early migration period starts 1 July 2010 and ends 28 January 2011. Late migration period starts 29 January and ends 30 June 2011. 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 / days operated	Trap catch
Catherine Creek	Early	13 Sept 10 – 22 Nov10	69/71 (97)	759
	Late	15 Feb 11 – 14 Jun 11	80/120 (67)	884[a]
		30 Mar 11 – 16 Apr 11	10/18 (56)	208[b]
Lostine River	Early	9 Sept 10 – 28 Jan 11	99/142 (70)	1,401
	Late	29 Jan 11 – 16 May 11	93/106 (88)	1,004[a]
		9 Apr 11 – 21 Apr 11	5/13 (38)	36[b]
Middle Grande Ronde River	Early	—	—	—
	Late	18 Mar 11 – 23 Jun 11	64/98 (65)	203
Minam River (rkm 1)	Early	16 Sept 10 – 28 Jan 11	61/68 (90)	43
	Late	29 Jan 11 – 16 May 11	86/108 (80)	502
Minam River (rkm 3)	Late	29 Mar 11 – 12 May 11	43/45 (96)	575
Upper Grande Ronde River	Early	14 Sept 10 – 19 Nov 10	56/67 (84)	617
	Late	9 Mar 11 – 6 Jun 11	66/90 (73)	1,596[a]
		25 Mar 11 – 16 Apr 11	9/23 (39)	212[b]

[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 2011. 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	39.5	48.5	11.6	0.5	0.0
Lostine River	52.3	40.4	6.7	0.6	0.1
Minam River	23.3	62.8	11.6	2.3	0.0
Upper Grande Ronde River	35.3	57.3	6.8	0.7	0.0
Mean	43.2	47.9	8.3	0.6	0.0
CV (%)	27.7	20.6	33.9	147.9	123.0
Late					
Catherine Creek	0.0	22.8	51.0	25.8	0.4
Lostine River	0.0	57.9	25.7	15.5	1.0
Minam River	0.0	17.7	38.8	42.3	1.2
Upper Grande Ronde River	0.0	27.4	48.6	23.0	1.0
Mean	0.0	32.1	42.8	24.3	0.8
CV (%)	0.0	56.3	26.9	46.6	40.2
Early and Late[a]					
Middle Grande Ronde River	0.0	53.2	32.3	13.3	1.3

[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 2011 and subsequently arriving at Lower Granite Dam (LGD) during spring 2011.

Stream	Distance to LGD (km)	Number detected	Travel time (d) Median	Min	Max
Catherine Creek	362	107	29.7	7	75
Lostine River	274	60	7.9	3	92
Middle Grande Ronde River	258	20	15.6	4	56
Minam River	245	169	6.6	4	66
Upper Grande Ronde River	397	108	27.9	4	92

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 2010 and spring 2011 (MY 2011). 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	589	32	0.185 (0.137–0.273)
Lostine River	589	32	0.183 (0.143–0.245)
Minam River	43	6	0.450 (0.245–1.181)
Upper Grande Ronde River	562	33	0.134 (0.106–0.169)
Spring (FL ≥ 115 mm)			
Catherine Creek	629	107	0.492 (0.439–0.557)
Lostine River	243	60	0.736 (0.652–0.845)
Middle Grande Ronde River	81	20	0.657 (0.503–0.899)
Minam River	520	168	0.802 (0.735–0.883)
Upper Grande Ronde River	487	108	0.631 (0.566–0.708)

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 2011. 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	159	26	53	20	1
Lostine River	151	22	60	17	1
Minam River	40	23	63	13	3
Upper Grande Ronde River	134	24	60	13	3
Mean		23.8	57.6	16.5	1.7
CV (%)		7.3	7.1	22.4	65.1
PIT tagged fish detected at dams (%)					
Catherine Creek	28	0	71	29	0
Lostine River	31	6	65	26	3
Minam River	13	0	85	15	0
Upper Grande Ronde River	21	0	86	10	5
Mean		2.2	74.2	21.5	2.2
CV (%)		150.0	13.9	41.4	111.1

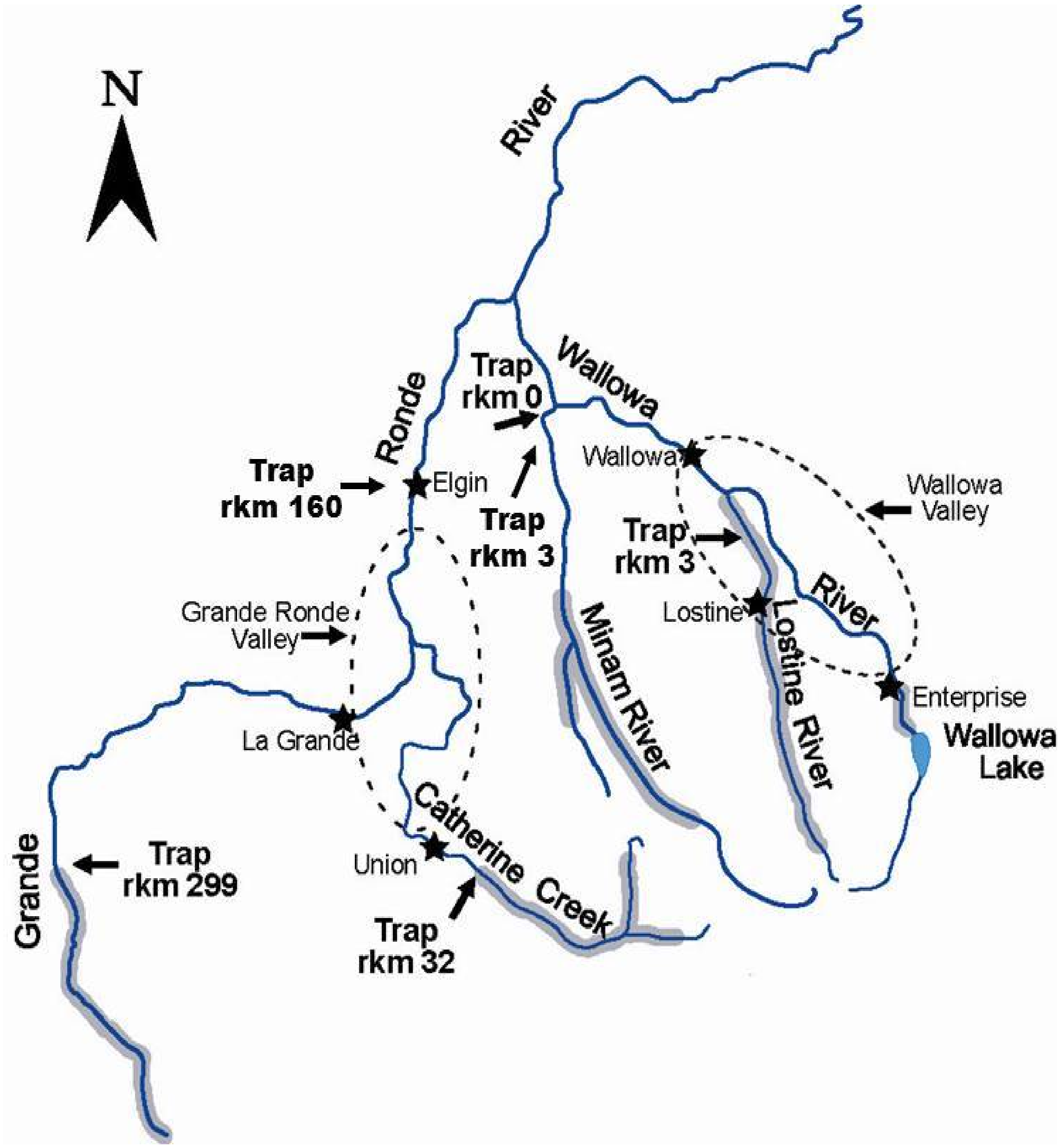

Figure 1. Locations of fish traps in Grande Ronde River Subbasin during the study period. Shaded areas delineate spring Chinook salmon spawning and upper rearing areas. Dashed lines indicate Grande Ronde and Wallowa river valleys.

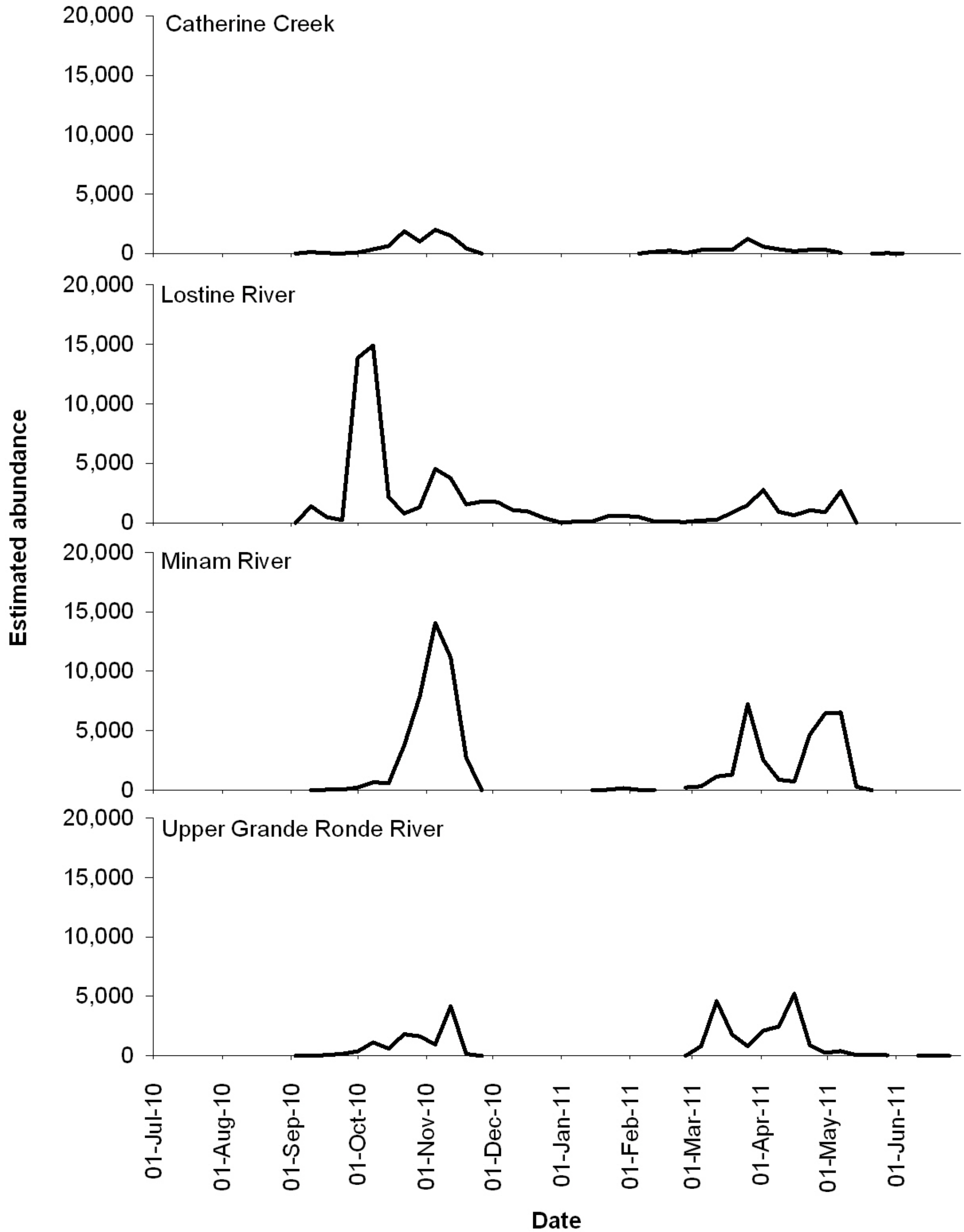

Figure 2. Estimated migration timing and abundance for juvenile spring Chinook salmon migrants sampled by rotary screw traps during MY 2011. Traps were located at rkm 32 on Catherine Creek, rkm 3 on Lostine River, rkm 0 on Minam River, and rkm 299 on upper Grande Ronde River.

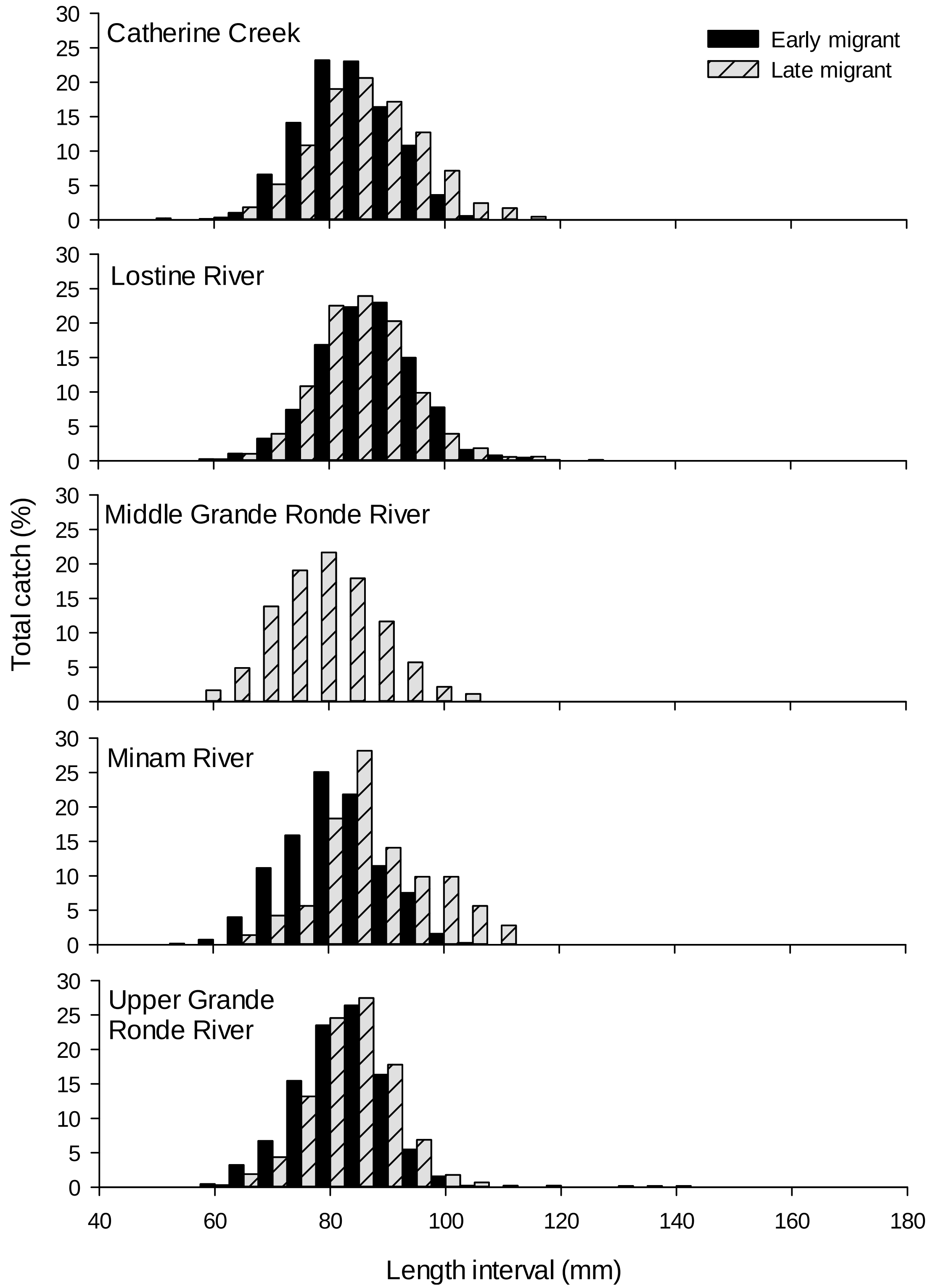

Figure 3. Length frequency distribution (fork length) of early and late migrating juvenile spring Chinook salmon captured at Catherine Creek (rkm 32), Lostine (rkm 3), middle Grande Ronde (rkm 160), Minam (rkm 0), and upper Grande Ronde (rkm 299) river traps during MY 2011.

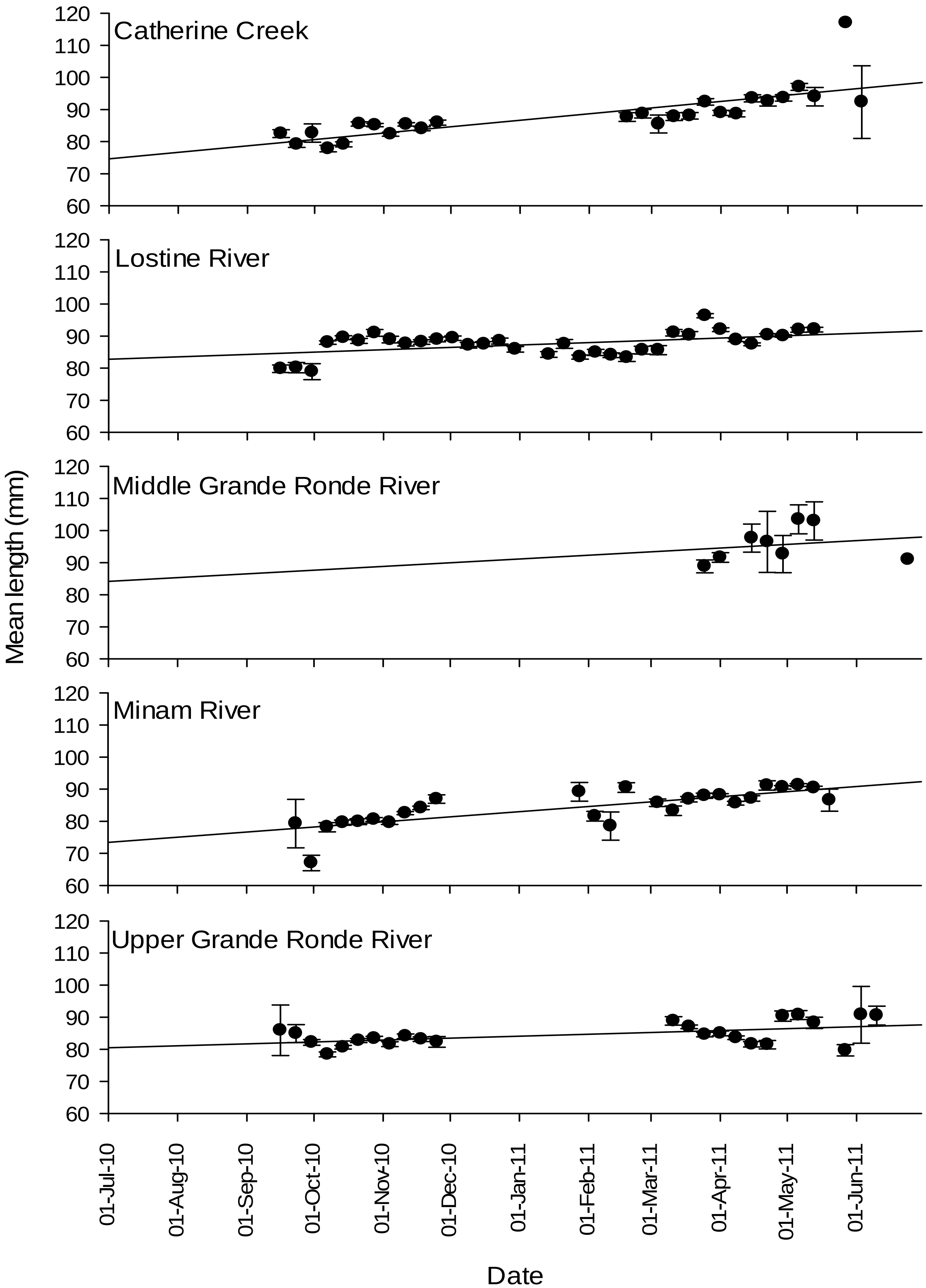

Figure 4. Weekly mean fork lengths and associated standard error for spring Chinook salmon captured by rotary screw traps in Grande Ronde River Subbasin during MY 2011.

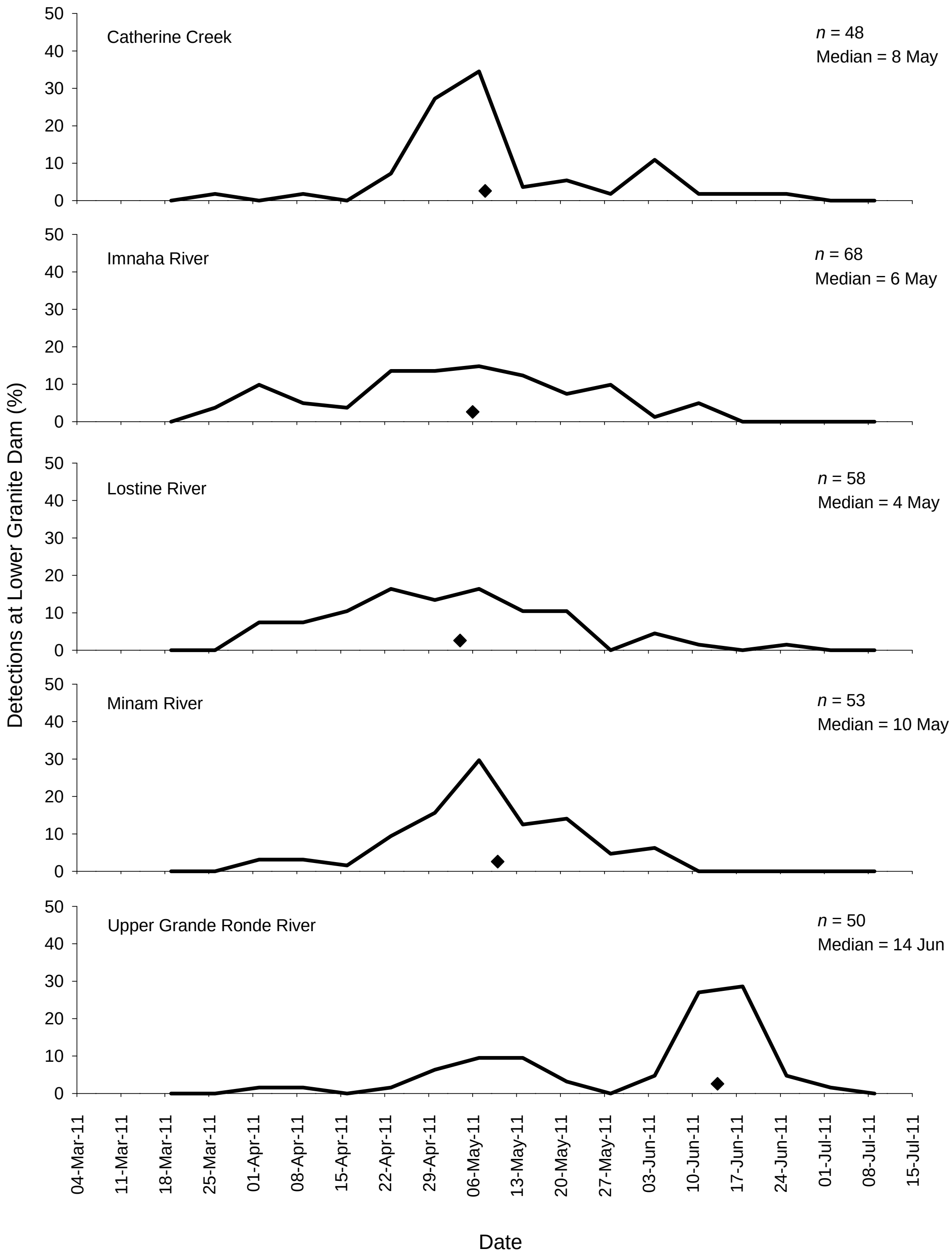

Figure 5. Dates of arrival, during 2011 at Lower Granite Dam, of spring Chinook salmon PIT-tagged as parr in Catherine Creek and Imnaha, Lostine, Minam, and upper Grande Ronde rivers during summer 2010. Data was summarized by week and expressed as percentage of total detected. Detections were expanded for spillway flow. ♦ = median arrival date.

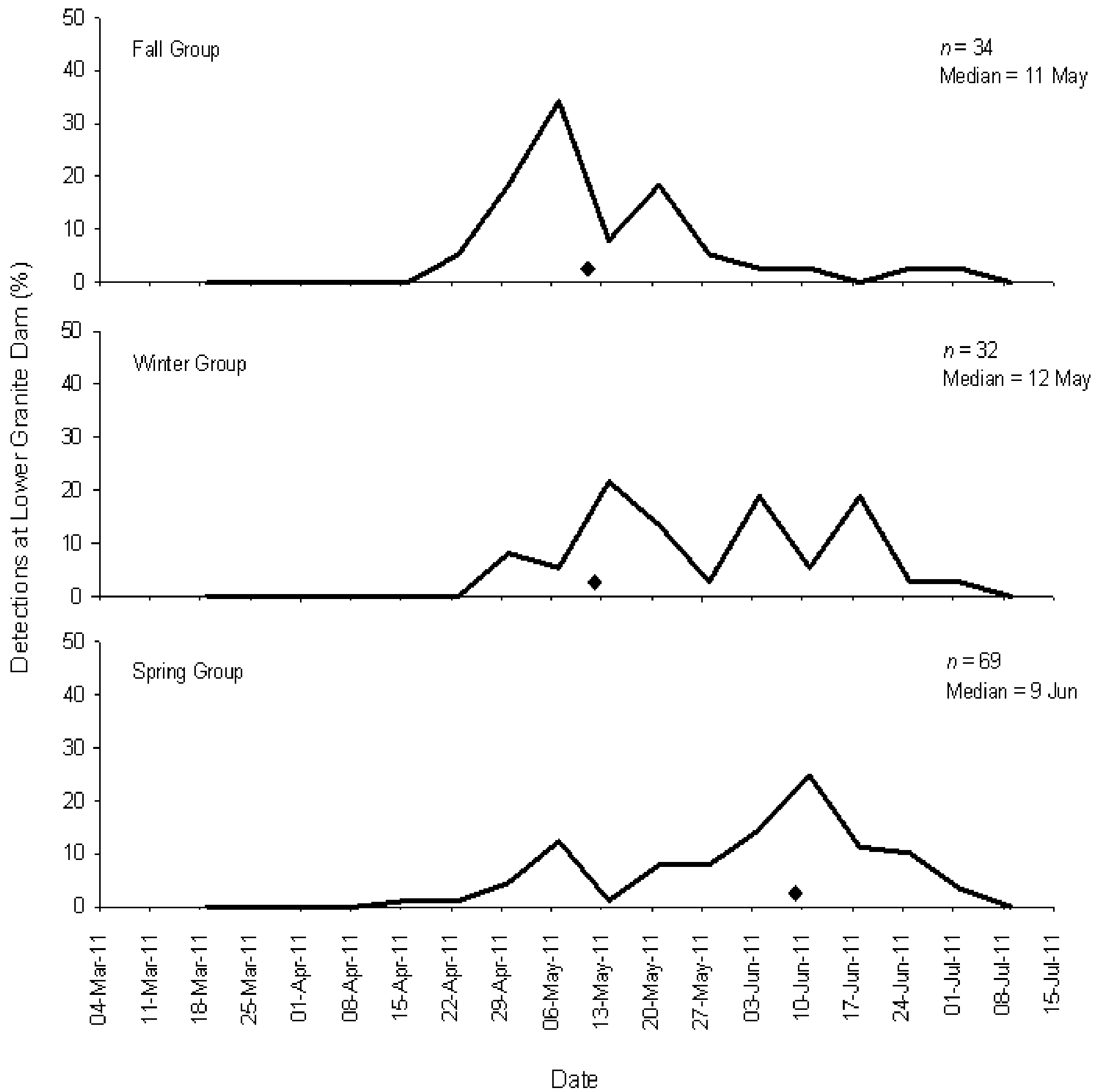

Figure 6. Dates of arrival, during 2011 at Lower Granite dam, for fall, winter, and spring tag groups of juvenile spring Chinook salmon PIT-tagged from Catherine Creek. Data was summarized by week and expressed as percentage of total detected. Detections were expanded for spillway flow. ◆ = median arrival date.

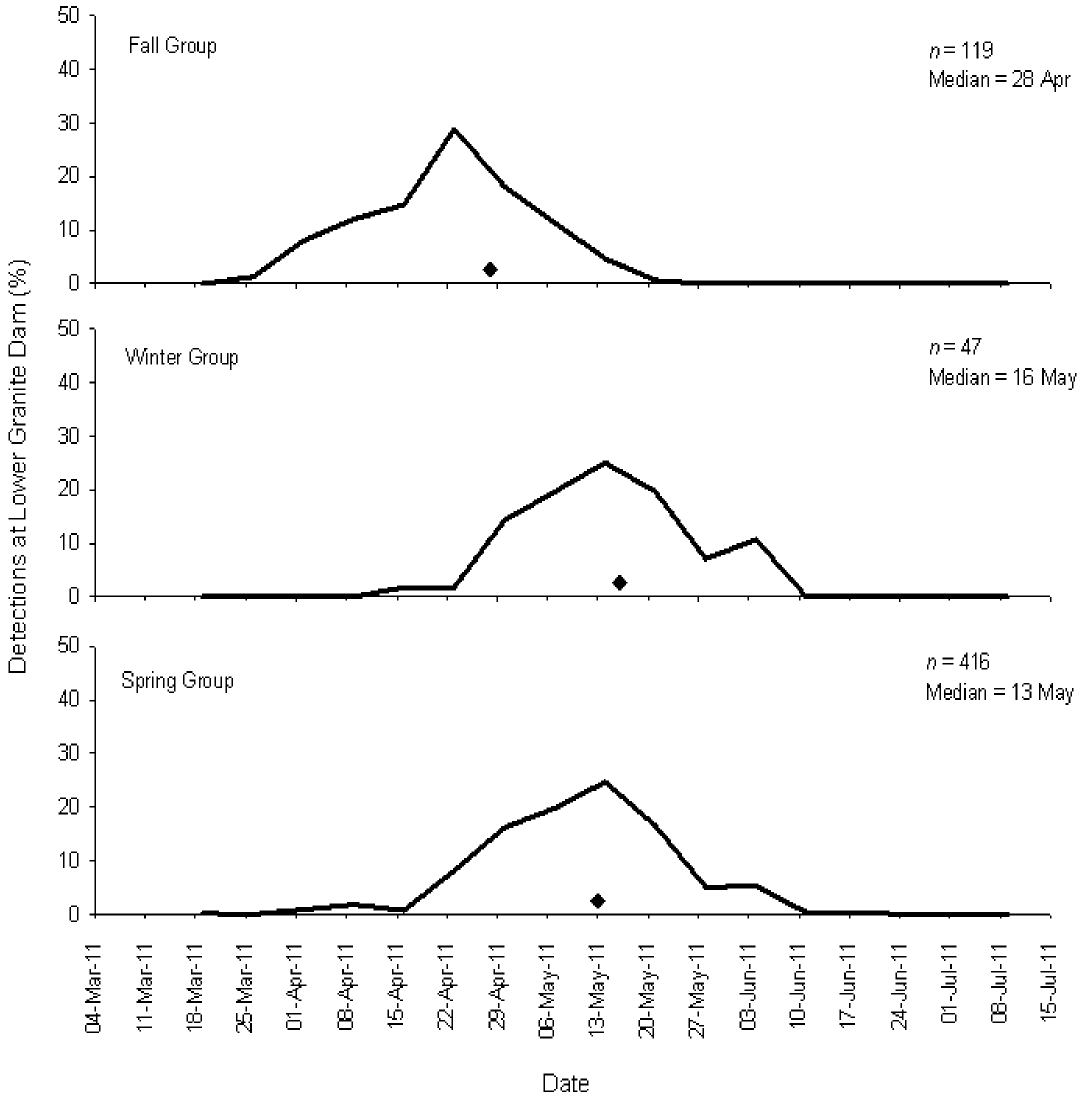

Figure 7. Dates of arrival, during 2011 at Lower Granite dam, for fall, winter, and spring tag groups of juvenile spring Chinook salmon PIT-tagged from Lostine River. Data was summarized by week and expressed as percentage of total detected. Detections were expanded for spillway flow. ◆ = median arrival date.

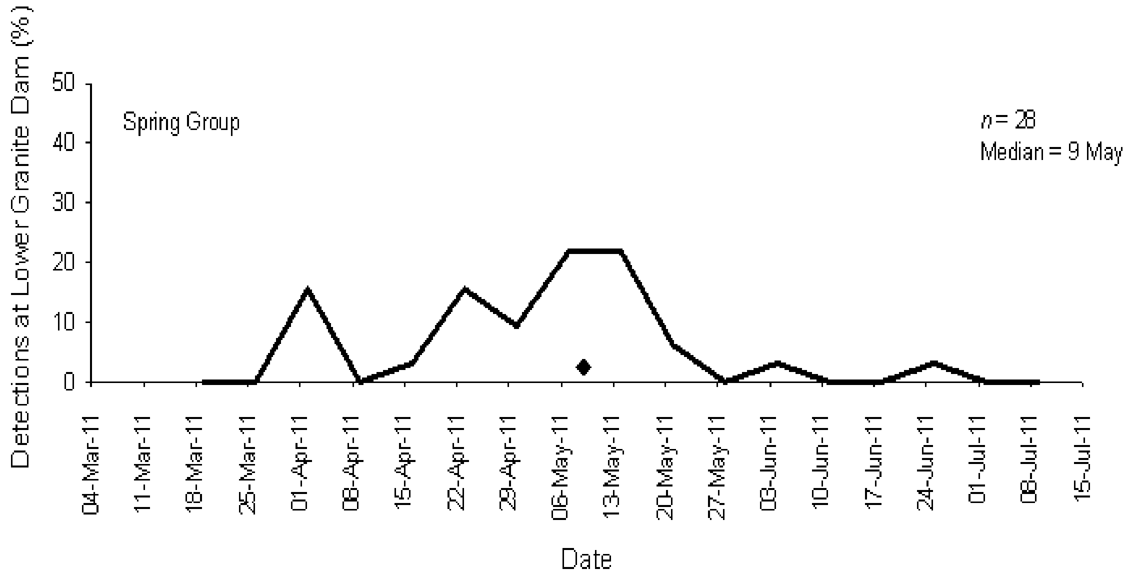

Figure 8. Dates of arrival, during 2011 at Lower Granite dam, for the spring tag group of juvenile spring Chinook salmon PIT-tagged from middle Grande Ronde River. Data was summarized by week and expressed as percentage of total detected. Detections were expanded for spillway flow. ♦ = median arrival date.

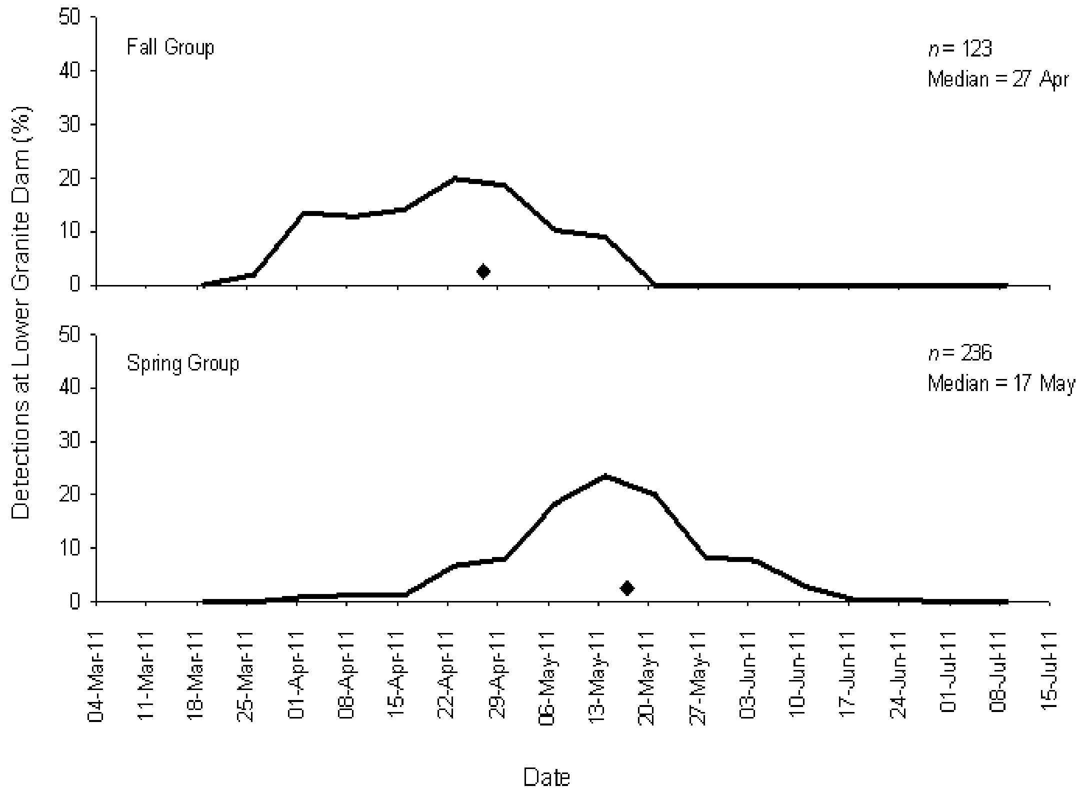

Figure 9. Dates of arrival, during 2011 at Lower Granite dam, for fall and spring tag groups of juvenile spring Chinook salmon PIT-tagged from Minam River. Data was summarized by week and expressed as percentage of total detected. Detections were expanded for spillway flow. ◆= median arrival date.

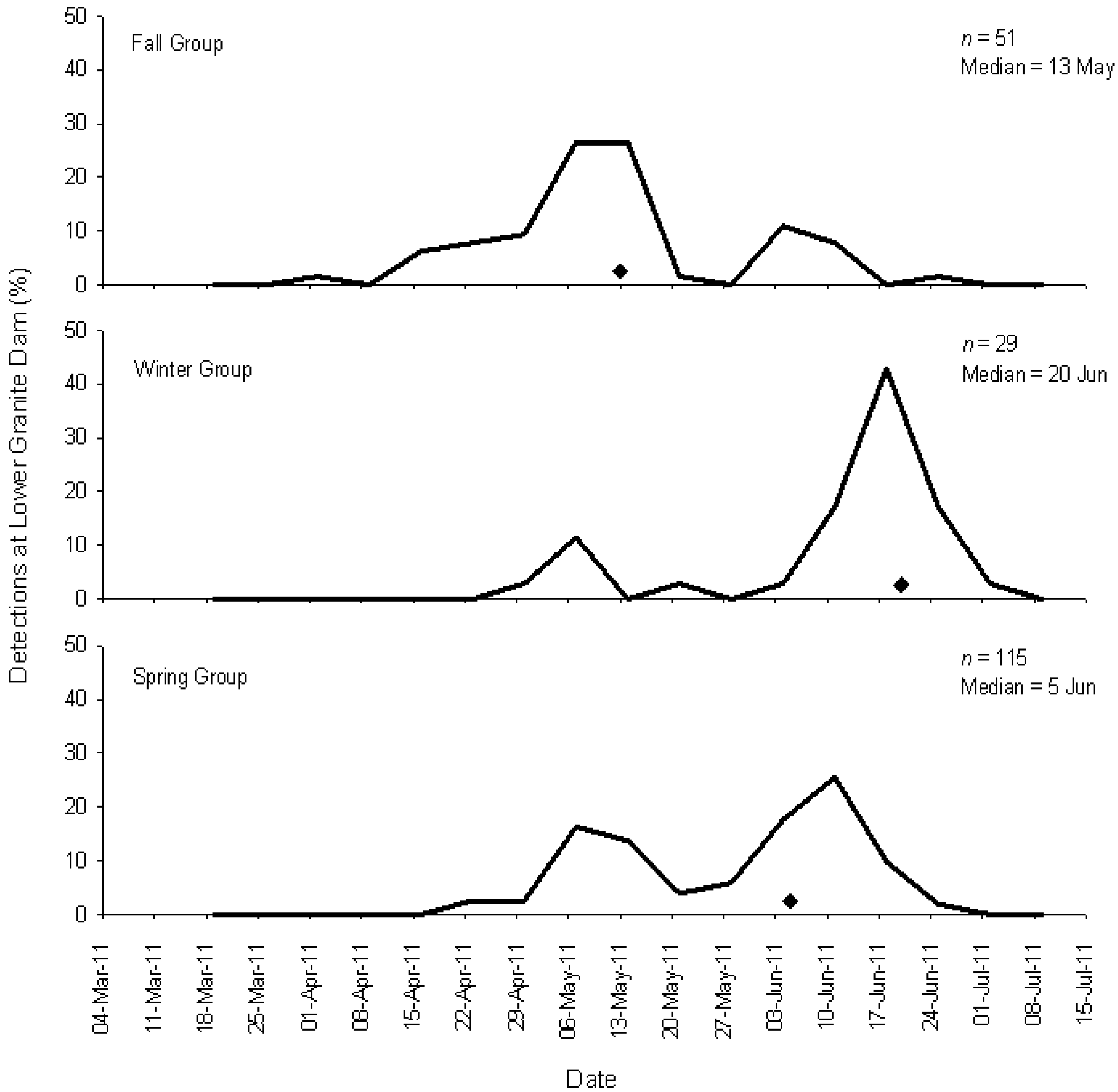

Figure 10. Dates of arrival, during 2011 at Lower Granite dam, for fall, winter, and spring tag groups of juvenile spring Chinook salmon PIT-tagged from upper Grande Ronde River. Data was summarized by week and expressed as percentage of total detected. Detections were expanded for spillway flow. ◆ = median arrival date.

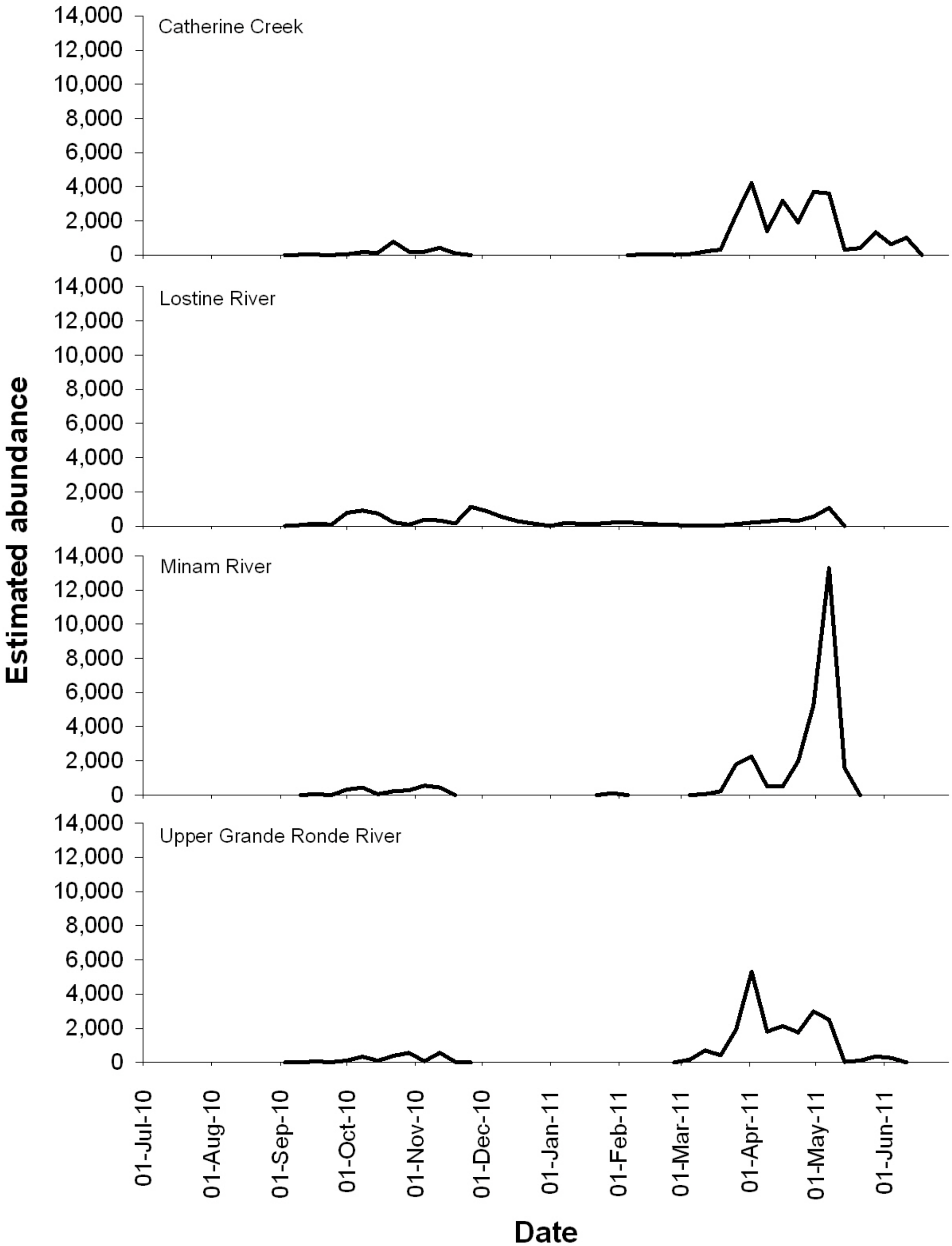

Figure 11. Estimated migration timing and abundance of juvenile summer steelhead migrants captured by rotary screw trap during MY 2011. Traps were operated at rkm 32 on Catherine Creek, rkm 3 on Lostine River, rkm 0 on Minam River, and rkm 299 on upper Grande Ronde River.

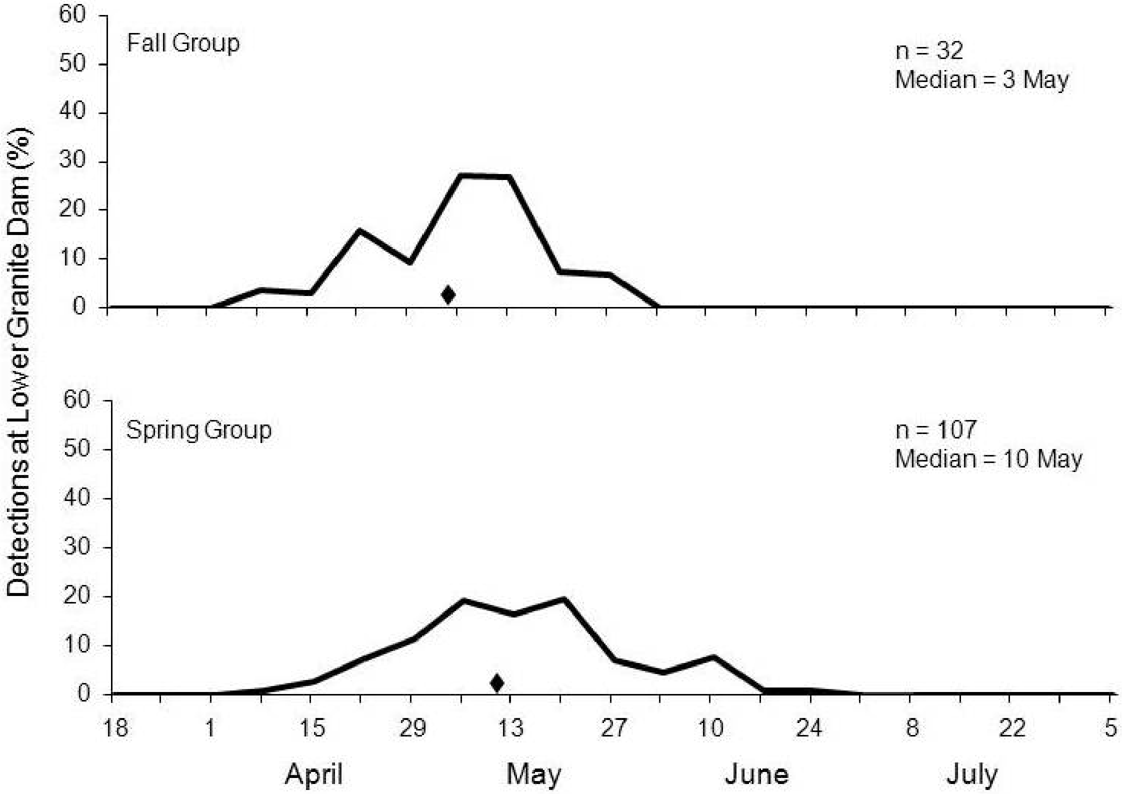

Figure 12. Dates of arrival, in 2011, at Lower Granite Dam for fall and spring tag groups of steelhead PIT-tagged from Catherine Creek, and expressed as a percentage of total detected for each group. Detections were expanded for spillway flow. ♦ = median arrival date.

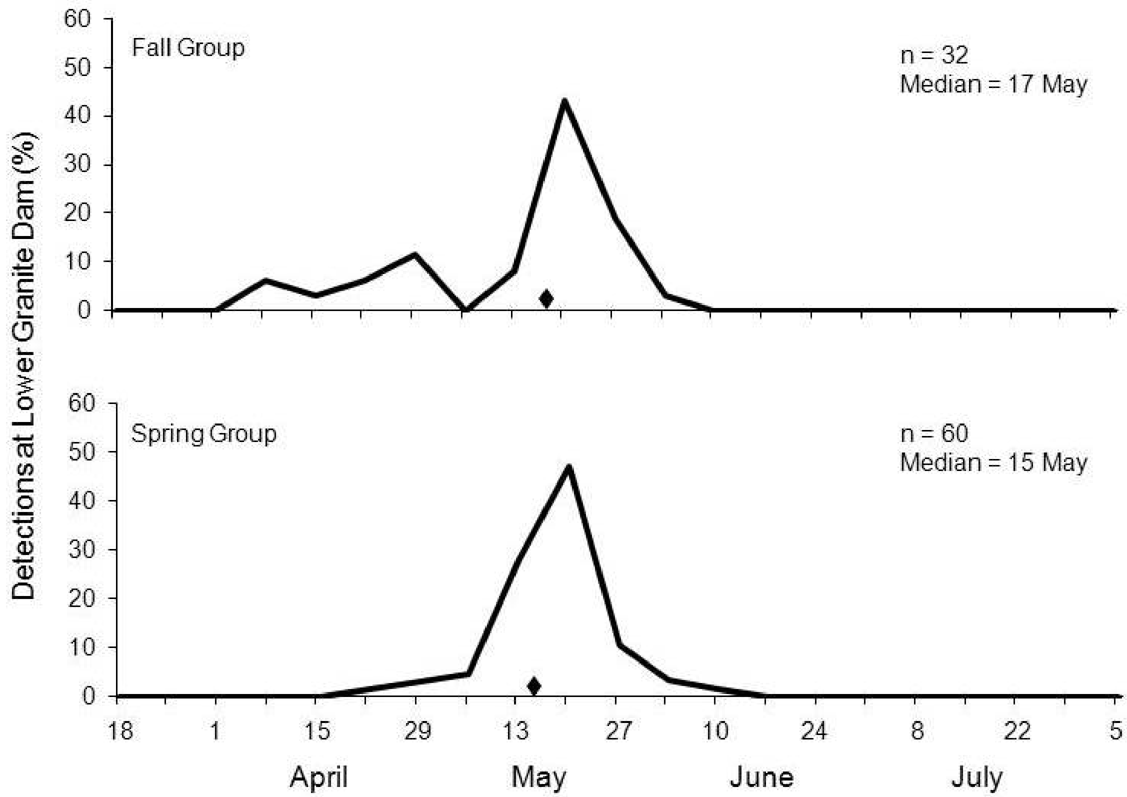

Figure 13. Dates of arrival, in 2011, at Lower Granite Dam for fall and spring tag groups of steelhead PIT-tagged from Lostine River, and expressed as a percentage of total detected for each group. Detections were expanded for spillway flow. ♦ = median arrival date.

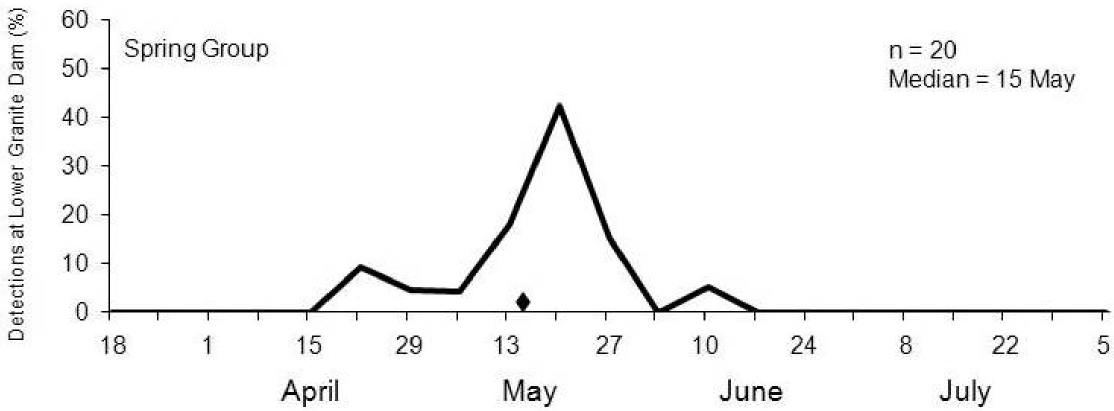

Figure 14. Dates of arrival, in 2011, at Lower Granite Dam for fall and spring tag groups of steelhead PIT-tagged from middle Grande Ronde River, and expressed as a percentage of total detected for each group. Detections were expanded for spillway flow. ♦ = median arrival date.

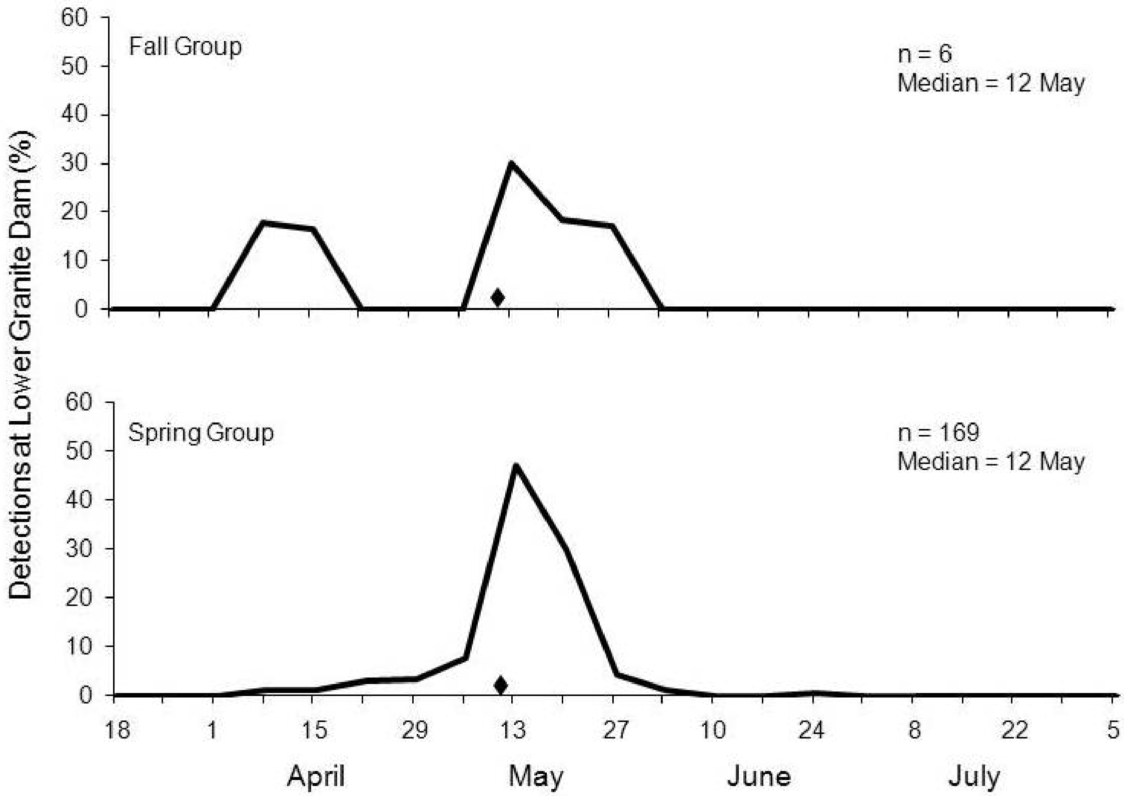

Figure 15. Dates of arrival, in 2011, at Lower Granite Dam for fall and spring tag groups of steelhead PIT-tagged from Minam River, and expressed as a percentage of total detected for each group. Detections were expanded for spillway flow. ♦ = median arrival date.

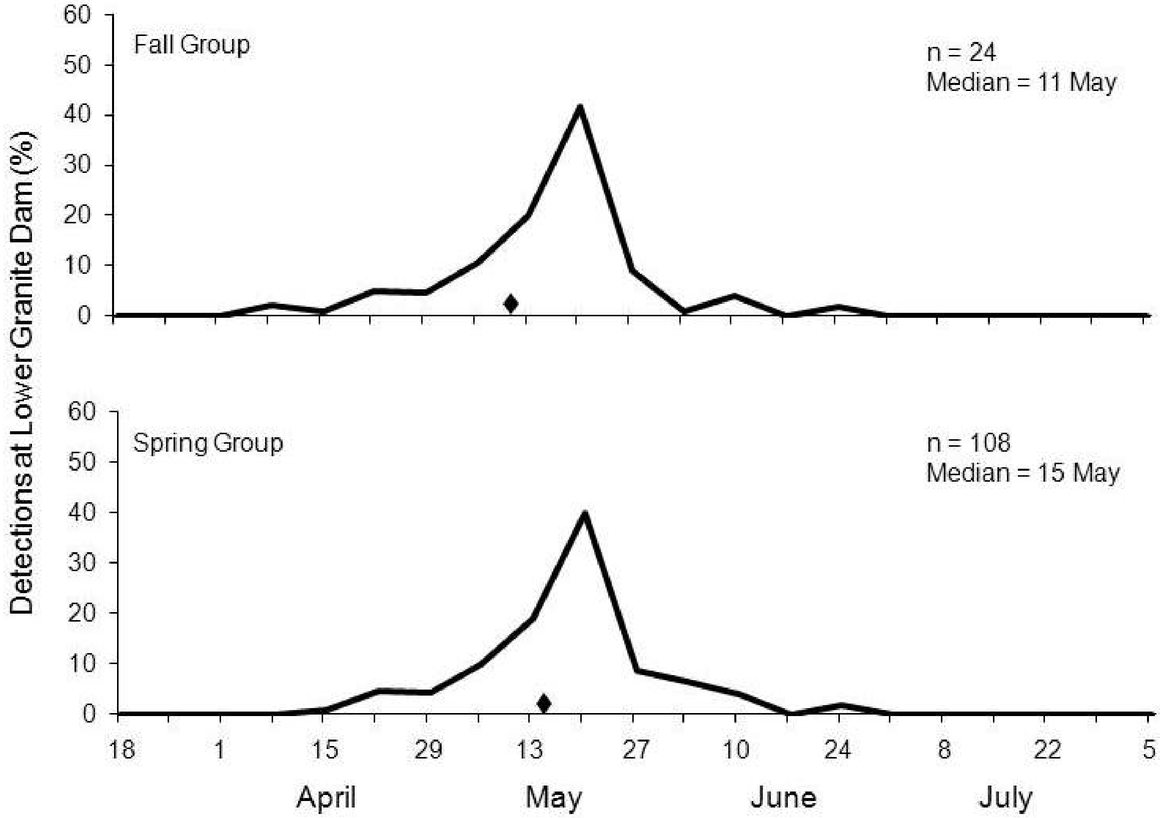

Figure 16. Dates of arrival, in 2011, at Lower Granite Dam for fall and spring tag groups of steelhead PIT-tagged from upper Grande Ronde River, and expressed as a percentage of total detected for each group. Detections were expanded for spillway flow. ♦ = median arrival date.

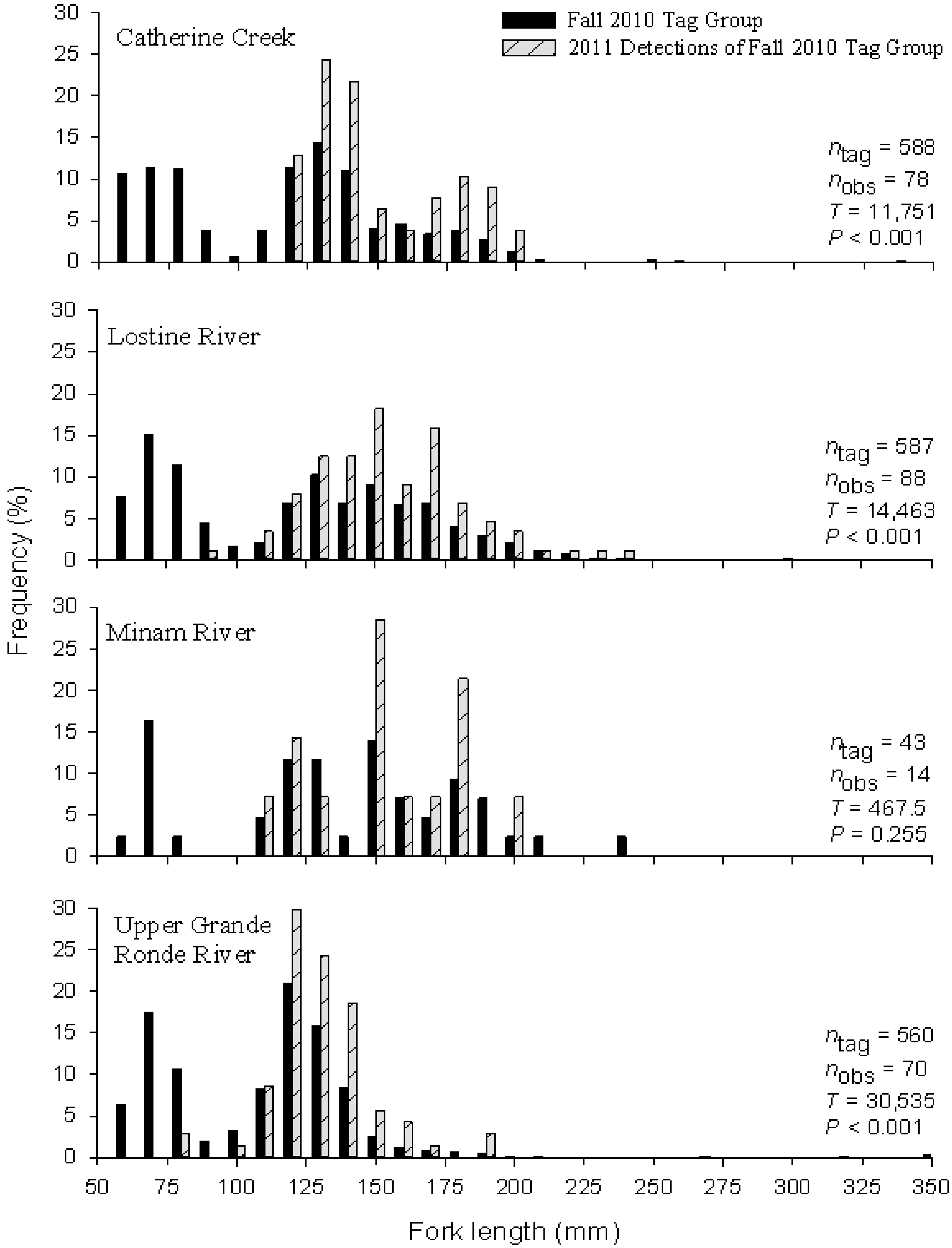

Figure 17. Length frequency distributions for all steelhead PIT-tagged at screw traps during fall 2010 and those subsequently observed at Snake or Columbia river dams during spring 2011. Fork lengths are based on measurements taken at time of tagging. Frequency is expressed as percent of total number tagged (n_{tag}). 'n_{obs}' is number detected.

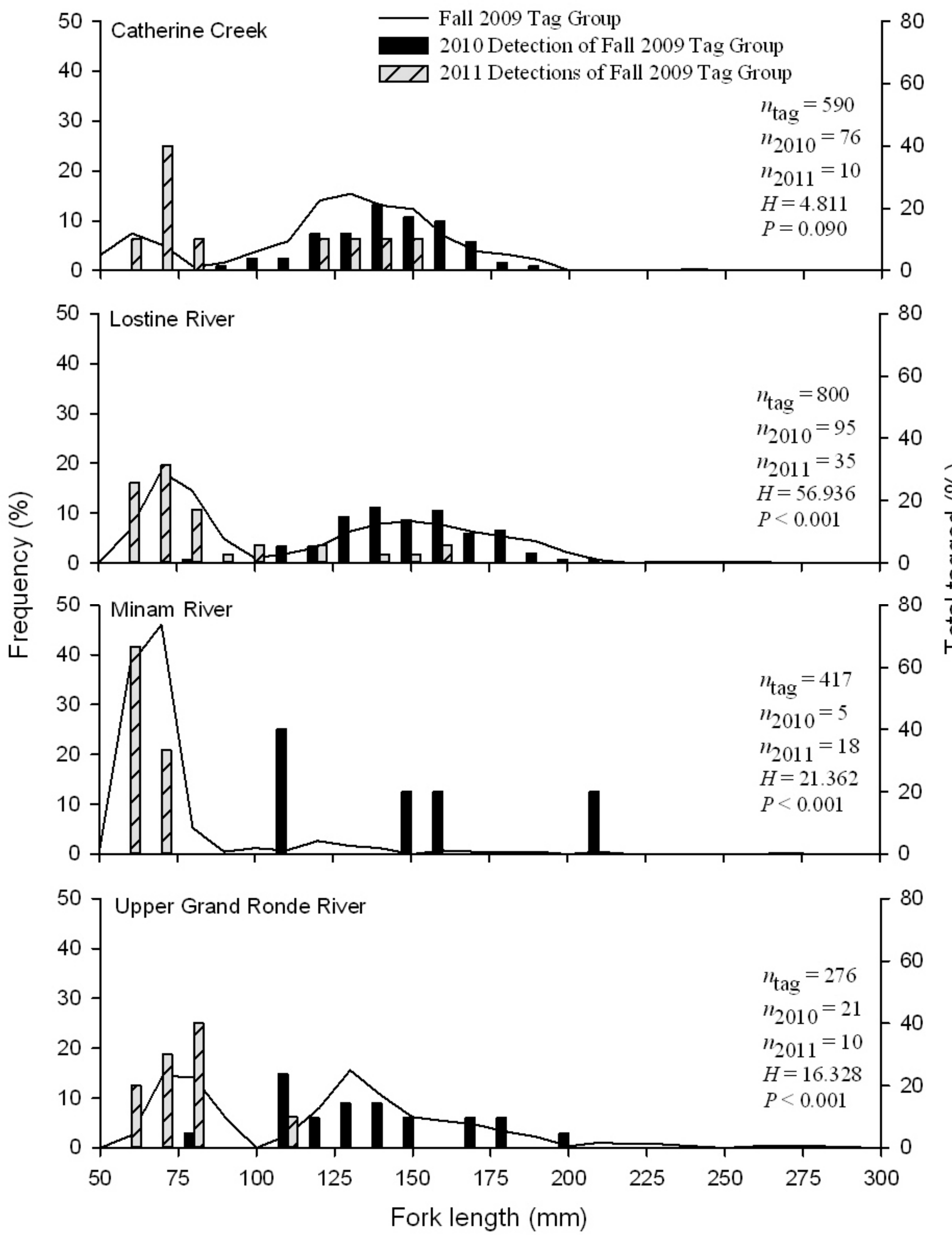

Figure 18. Length frequency distributions for steelhead PIT-tagged at screw traps during fall 2009, and those subsequently observed at Snake or Columbia river dams during 2010 and 2011. Frequency is expressed as percent of total number tagged. 'H' is the test statistic for the Kruskal–Wallis one-way ANOVA on ranks of lengths. Dunn's all pair-wise multiple comparison procedure was employed to compare groups among Catherine Creek, Lostine, and Minam rivers (α = 0.05).

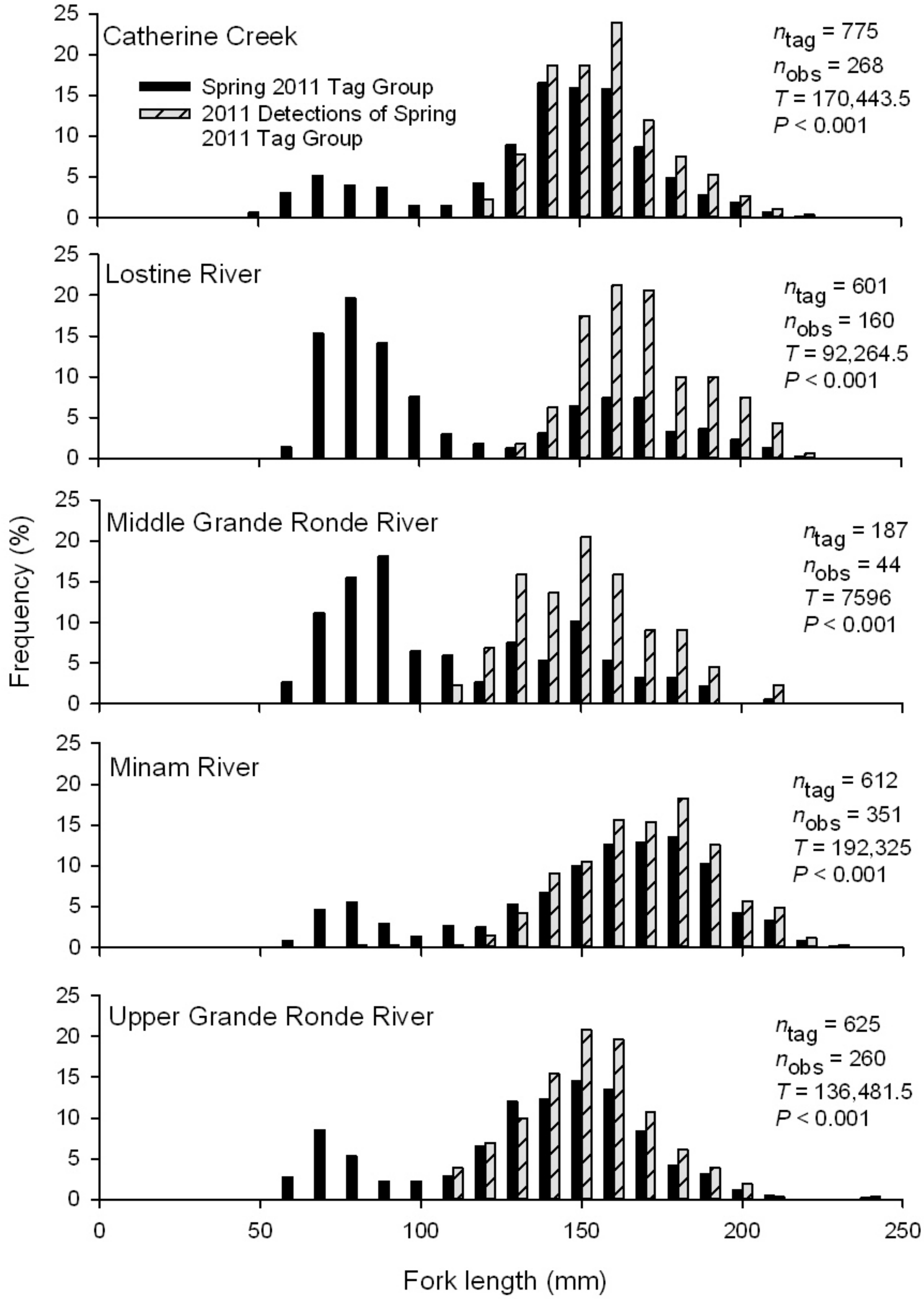

Figure 19. Length frequency distributions for steelhead PIT-tagged at screw traps during spring 2011, and those subsequently observed at Snake or Columbia river dams during spring 2011. Data were compared using the Mann-Whitney rank-sum test. Fork lengths are based on measurements taken at time of tagging. Frequency is expressed as percent of total number tagged (n_{tag}), and 'n_{obs}' represents number detected.

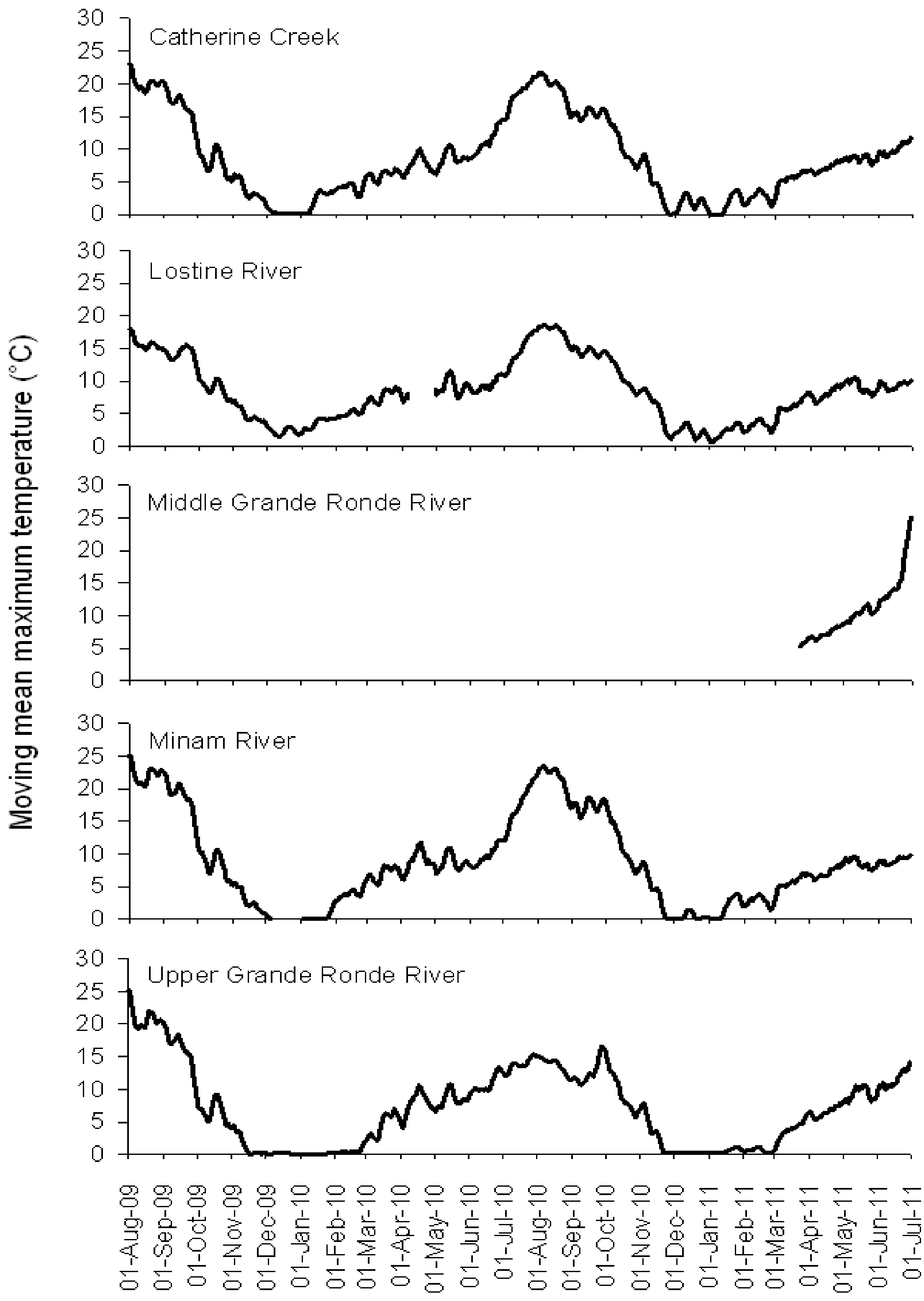

Figure 20. Moving mean of maximum water temperature from four study streams in Grande Ronde River Subbasin during MY 2011. Data corresponds with juvenile spring Chinook salmon in-basin egg-to-emigrant life stages. Missing portions of a trend line represent periods where data were not available.

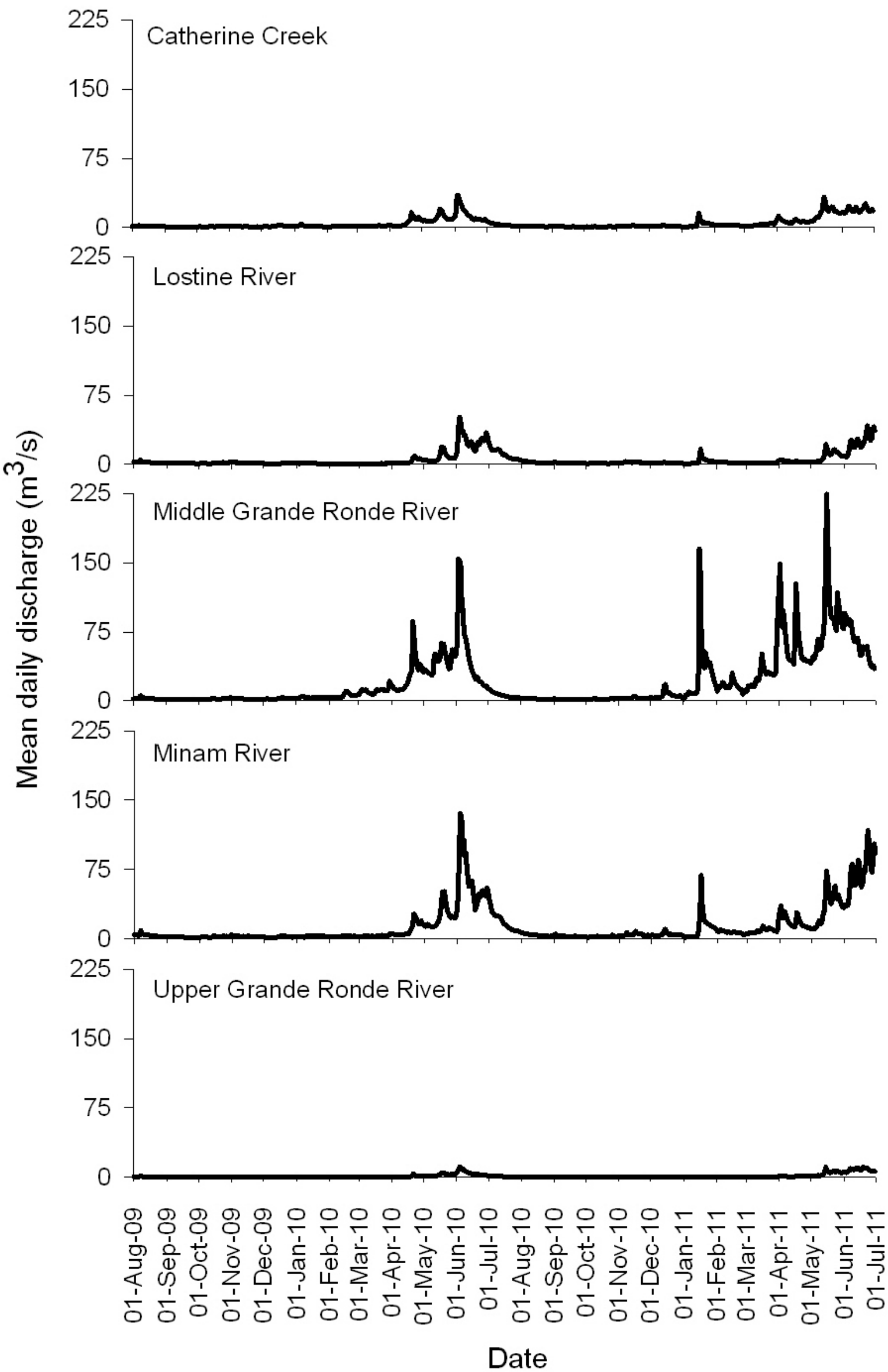

Figure 21. Average daily discharge from four study streams in the Grande Ronde River Subbasin during MY 2011. Data corresponds with juvenile spring Chinook salmon in-basin egg-to-emigrant life stages.

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, 1994–2011. 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	12,594	1,107	3 Nov	31 Mar	36
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
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

[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		Percentage migrating late
			Early migrants	Late migrants	
Lostine River (cont.)					
2011	64,756	10,873	12 Oct	7 Apr	20
Middle Grande Ronde River					
2011	—[e]	—	—	—	—
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
Upper Grande Ronde River					
1994	24,791	3,193	14 Oct[a]	1 Apr	89[a]
1995	38,725	12,690	30 Oct[c]	31 Mar[c]	87[c]
1996	1,118	192	10 Oct[d]	16 Mar	99[d]
1997	82	30	12 Nov	26 Apr[d]	17[d]
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[d]	10 Apr	88[d]
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[d]	29 Mar[d]	76[d]
2010	20,763	1,938	26 Oct	6 Apr	78
2011	25,133	2,313	2 Nov	25 Mar	56

[c] Trap was located at rkm 257.
[d] Median date based on small sample size.
[e] Insufficient trap efficiency to produce an estimate.

Appendix Table A-2. Dates of arrival at Lower Granite Dam (LGD) for spring Chinook salmon smolts PIT-tagged form upper rearing areas during summer and winter, and at screw traps as early and late migrants during migratory years 1993–2011. 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	First	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
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

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.)							
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
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	—[a]	—	—	—	—
	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

[a] No tag group.

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.)							
2001	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 Jun
	Spring	Late	406	61	7 May	15 Apr	11 Jun
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
	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
	Fall	Early	495	29	22 Apr	2 Apr	10 May
	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 May	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	1100	119	28 Apr	28 Mar	22 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.)							
2011	Winter	Late	500	47	16 May	20 Apr	10 Jun
	Spring	Late	1751	421	13 May	25 Mar	20 Jun
Middle Grande Ronde River (rkm 164)							
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
Middle Grande Ronde River (rkm 160)							
2011	Spring	Late	71	28	9 May	3 Apr	27 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
	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

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.)							
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	1092	236	17 May	3 Apr	27 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
	Winter	Late	505	27	29 May	28 Apr	16 Jul
	Spring	Late	573	93	15 May	20 Apr	6 Aug
1995[b]	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 Mar	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

[b] Trap was located at rkm 257.

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.)							
2003	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	534	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
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
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 1993–2011. 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 probability (95% CI)
Summer			
Catherine Creek	1993	1,094	0.178 (0.151–0.212)
	1994	1,000	0.226 (0.186–0.279)
	1995	999	0.154 (0.129–0.184)
	1996	499	0.277 (0.205–0.406)
	1997	583	0.176 (0.139–0.225)
	1998	499	0.211 (0.164–0.276)
	1999	502	0.157 (0.122–0.212)
	2000	497	0.151 (0.109–0.217)
	2001	498	0.087 (0.063–0.115)
	2002	502	0.109 (0.079–0.157)
	2003	501	0.075 (0.052–0.106)
	2004	467	0.072 (0.051–0.098)
	2005	495	0.057 (0.038–0.082)
	2006	523	0.057 (0.033–0.128)
	2007	501	0.042 (SE = 0.009)
	2008	1,000	0.080 (0.053–0.136)
	2009	997	0.147 (0.116–0.178)
	2010	995	0.107 (0.074–0.168)
	2011	992	0.128 (0.104–0.158)
Imnaha River	1993	1,000	0.141 (0.115–0.180)
	1994	998	0.136 (0.109–0.173)
	1995	996	0.083 (0.064–0.108)
	1996	997	0.268 (0.222–0.330)
	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)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Summer			
Imnaha River (cont.)	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)
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)
	2009	988	0.208 (0.176–0.241)
	2010	997	0.114 (0.089–0.152)
	2011	997	0.139 (0.115–0.168)
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)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Summer			
Minam River (cont.)	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)
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)
	2009	0	—
	2010	1,000	0.235 (0.195–0.289)
	2011	993	0.125 (0.101–0.156)
Wenaha/SF Wenaha	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	(a)
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)
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)

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

Appendix Table A-3. Continued

Tag group and stream	MY	Number released	Survival probability (95% CI)
Fall trap			
Lostine River (cont.)	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	1100	0.251 (0.221–0.286)
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)
Upper Grande Ronde River	1994	405	0.348 (0.284–0.432)
	1995	424	0.228 (0.184–0.281)
	1996	5	(a)
	1997	27	(a)
	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	(a)
	2010	485	0.209 (0.162–0.275)
	2011	499	0.225 (0.184–0.273)
Wallowa River	1999	45	(a)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
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)
	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)
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)
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)
	2005	449	0.207 (0.159–0.306)
	2006	464	0.080 (0.052–0.183)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Winter			
Upper Grande Ronde River (cont.)	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)
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)
Lostine River	1997	475	0.769 (0.630–1.009)
	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	1751	0.583 (0.549–0.621)
Middle Grande Ronde River	2001	4	(a)
	2002	167	0.776 (0.624–1.073)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Spring trap			
Middle Grande Ronde River (cont.)	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)
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)
	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	1092	0.595 (0.542–0.659)
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	(a)
	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	(a)
	2010	503	0.468 (0.401–0.553)
	2011	672	0.447 (0.392–0.512)

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
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	5	53
2007		109	34.5	6	84
2008		130	20.5	8	64
2009		163	37	11	78
2010		174	33.0	8	78
2011		416	33.1	6	111
Middle Grande Ronde River (rkm 164)	262				
2002		21	6.6	3	22
2003		95	56	20	84

[a] Limited trapping operations.

Appendix Table A-4. Continued.

Stream and MY	Distance to LGD (km)	Number detected	Travel time (d)		
			Median	Min	Max
Middle Grande Ronde River (rkm 164) (cont.)					
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
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
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	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

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

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 $\neq$ 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/fall migrants	0.020
1996	Equivalent	0.766	—	—	—	—
1997	Downstream/fall migrants	0.016	Equivalent	0.133	—	—
1998	Equivalent	0.289	Downstream/fall migrants	0.014	Downstream/fall migrants	<0.001
1999	Upstream/spring migrants	0.025	Downstream/fall migrants	0.014	Downstream/fall migrants	0.002
2000	Downstream/fall migrants	0.031	Equivalent	0.211	Downstream/fall migrants	<0.001
2001	Downstream/fall migrants	0.009	Equivalent	0.090	—	—
2002	Equivalent	0.403	Equivalent	0.350	—	—
2003	Equivalent	0.283	Equivalent	0.263	—	—
2004	Upstream/spring migrants	0.026	—	—	Upstream/spring migrants	0.001
2005	Equivalent	0.733	Downstream/fall migrants	0.021	Upstream/spring migrants	0.030
2006	Equivalent	0.061	Equivalent	0.144	Equivalent	0.070
2007	Downstream/fall migrants	<0.001	Equivalent	0.115	Downstream/fall migrants	0.012
2008	Equivalent	0.800	Equivalent	0.115	Equivalent	0.931
2009	Downstream/fall migrants	0.003	Downstream/fall migrants	0.003	—	—
2010	Equivalent	0.949	Equivalent	0.719	Downstream/fall migrants	0.014
2011	Equivalent	0.655	Downstream/fall migrants	0.031	Downstream/fall 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			Estimated smolt equivalents leaving tributary	Estimated smolt equivalents at LGD
Stream, BY	MY	Migrant abundance estimate	95% CI	Survival to LGD	Migrant abundance estimate	95% CI	Survival to 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	3,189
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

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
Lostine River (cont.)									
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	2004a	—	—	—	—	—	—	—	—
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	20,498
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

[a] Access was denied to the Lostine River trap site during MY 2004.

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 (cont.)									
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	31,437
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	(b)	1,105	192	0.512	(b)	(b)
1995	1997	68	28	(b)	14	11	(b)	(b)	(b)
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
1998	2000	3,839	386	0.341	10,941	2,033	0.560	13,279	7,436
1999	2001	6	9	(b)	45	30	(b)	(b)	(b)
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	(b)	26	10	(b)	(b)	(b)
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	8,763

[b] Small tag group size and low recaptures at LGD precluded estimating survival probabilities and smolt equivalents.

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, 1997–2011 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.

Stream and MY	Population estimate	95% CI	Median migration date: Early migrants	Median migration date: 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	26,947	8,998	27 Oct	24 Apr	92
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
2010	14,764	2,213	6 Oct	26 Apr	31
2011	10,922	655	17 Nov	24 Apr	34
Middle Grande Ronde River					
2011	—[c]	—	—	—	—
Minam River					
2001	28,113	10,537	3 Oct[a]	28 Apr	86[a]

[a] Trap was started late, thereby potentially missing some early migrants.
[b] Limited trapping operations prevented complete population estimates and migration timing.
[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 (%)
Minam River (cont.)					
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	19,424	31 Oct	7 May	92
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
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	22,644	5,184	30 Oct	15 Apr	90

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, 2000–2011. Numbers of fish detected were expanded for spillway flow to calculate median arrival date.

Stream and MY	Tag group	Number tagged	Number detected	Arrival dates Median	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
Lostine River						
2000	Fall	777	116	10 May	26 Mar	16 Jun
	Spring	532	166	6 May	13 Apr	13 Jun

Appendix Table B-2. Continued.

Stream and MY	Tag group	Number tagged	Number detected	Arrival dates Median	First	Last
Lostine River (cont.)						
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	20Apr	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
Middle Grande Ronde River						
2011	Spring	189	20	15 May	16 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	16 May
	Spring	293	29	7 May	3 May	7 Jun
2008	Fall	495	14	13 May	24 Apr	14 Jun

[a] Limited trapping operations during MY 2004.

Appendix Table B-2. Continued.

Stream and MY	Tag group	Number tagged	Number detected	Arrival dates Median	First	Last
Minam River (cont.)						
2008	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[b]	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
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

Appendix Table B-3. 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	MY + 1	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	915	56	11	0	0.085 (0.059–0.143)
	2004	512	53	6	0	0.128 (0.095–0.177)

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

Appendix Table B-3. Continued.

Tag group and stream	MY tagged	Number tagged	Number detected			Probability of surviving and migrating in the first year (95% CI)
			MY	MY + 1	MY + 2	
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	105	4	0	0.259 (0.207–0.336)
	2010	592	77	4	—	0.190 (0.135–0.315)
	2011	589	32	—	—	0.185 (0.137–0.273)
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	998	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	1,000	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	99	14	—	0.168 (0.127–0.245)
	2011	589	32	—	—	0.183 (0.143–0.245)
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	4	0	(a)
	2008	495	33	24	0	0.090 (0.057 = 0.173)
	2009	131	19	2	0	0.165 (0.103–0.258)
	2010	417	5	11	—	(a)
	2011	43	6	—	—	0.450 (0.245–1.181)
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)

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						
Upper Grande Ronde River (cont.)						
	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	3	—	0.098 (0.059–0.171)
	2011	562	33	—	—	0.134 (0.106–0.169)
Spring (FL ≥ 115 mm)						
Catherine Creek						
	2000	305	104	2	0	0.490 (0.392–0.630)
	2001	247	95	2	0	0.400 (0.339–0.465)
	2002	504	213	2	0	0.532 (0.465–0.615)
	2003	359	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	25	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	0	—	0.527 (0.382–0.884)
	2011	629	107	—	—	0.492 (0.439–0.557)
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	447	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	101	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	2	—	0.831 (0.585–1.490)
	2011	243	60	—	—	0.736 (0.652–0.845)
Middle Grande Ronde River						
	2011	81	20	—	—	0.657 (0.503–0.899)
Minam River						
	2001	442	269	8	0	0.632 (0.584–0.680)
	2002	197	109	1	0	0.722 (0.598–0.898)
		500	272	0	0	0.662 (0.590–0.753)

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 (cont.)						
	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)
	2009	204	119	4	0	0.670 (0.577–0.789)
	2010	178	77	0	—	1.039 (0.627–2.396)
	2011	520	168	—	—	0.802 (0.735–0.883)
Upper Grande Ronde River						
	2000	324	100	1	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	578	205	3	0	0.461 (0.393–0.552)
	2004	853	223	2	0	0.492 (0.443–0.542)
	2005	371	186	2	0	0.553 (0.490–0.628)
	2006	342	168	2	0	0.522 (0.454–0.629)
	2007	464	119	3	0	0.315 (0.246–0.453)
	2008	578	263	3	0	0.626 (0.588–0.708)
	2009	533	256	1	0	0.573 (0.513–0.643)
	2010	316	119	0	—	0.547 (0.434–0.728)
	2011	487	108	—	—	0.631 (0.566–0.708)
Spring (FL < 115 mm)						
Catherine Creek						
	2000	189	0	10	1	(a)
	2001	19	1	2	0	(a)
	2002	6	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	0	(a)
	2010	285	2	10	—	(a)
	2011	147	0	—	—	(a)
Lostine River						
	2000	84	0	9	0	(a)
	2001	21	1	1	0	(a)
	2002	0	0	0	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)						
Lostine River (cont.)						
	2003	1	0	0	0	(a)
	2005	142	0	24	0	(a)
	2006	89	1	16	0	(a)
	2007	172	0	26	0	(a)
	2008	345	3	43	0	0.009 (SE=0.005)
	2009	302	0	29	0	(a)
	2010	411	0	14	—	(a)
	2011	359	0	—	—	(a)
Middle Grande Ronde River						
	2011	108	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	172	0	10	0	(a)
	2006	274	0	7	0	(a)
	2007	115	0	14	0	(a)
	2008	300	0	36	1	(a)
	2009	146	0	16	0	(a)
	2010	324	0	12	—	(a)
	2011	95	1	—	—	(a)
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	272	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	0	(a)
	2010	295	0	11	—	(a)
	2011	138	0	—	—	(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 1999–2010, 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
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

[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
Lostine River (cont.)							
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)	1000	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
2010	(a)	587	130	59	81	159	307
	2011	88	156	92	138	175	249
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

[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
Minam River (cont.)							
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
	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
	2011	14	158	113	134	183	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

Appendix Table B-4. Continued.

Stream and year tagged	Year detected	*N*	Length at tagging (mm) Median	Min	Percentile 25th	75th	Max
Upper Grande Ronde River (cont.)							
2007	2008	41	132	112	126	148	199
2008	(a)	109	126	71	118	134	257
	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

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 2000–2011, 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
2011	(a)	775	150	58	132	165	227
	2011	268	160	121	146	172	227

[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
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
	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
Minam River							
2001	(a)	442	160	115	144	177	227
	2001	269	167	124	151	183	227

Appendix Table B-5. Continued.

Stream and year tagged	Year detected	*N*	Length at tagging (mm)				
			Median	Min	Percentile 25th	Percentile 75th	Max
Minam River (cont.)							
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
	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
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
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

Appendix Table B-5. Continued.

Stream and year tagged	Year detected	N	Length at tagging (mm)				
					Percentile		
			Median	Min	25th	75th	Max
Upper Grande Ronde (cont.)							
2002	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

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	*N*	Length at tagging (mm) Median	Min	Percentile 25th	Percentile 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	—	—	—	—	—