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 the status and life history strategies of spring Chinook salmon and summer steelhead in the 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* in four streams during migratory year 2009 (MY09) from 1 July 2008 through 30 June 2009. Similar to previous years of this study, spring Chinook salmon and steelhead exhibited fall and spring movements from natal rearing areas, but did not begin their smolt migration through the Snake and lower Columbia River hydrosystem until spring. In this report, we provide estimates of migrant abundance and migration timing for each study stream, and their survival and timing to Lower Granite Dam. We also document aquatic habitat conditions using water temperature and discharge of four study streams within the subbasin.

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EXECUTIVE SUMMARY

Objectives

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

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

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

4. Document the annual migration patterns for spring Chinook salmon juveniles from four local, natural populations in the Grande Ronde River and Imnaha River subbasins: Catherine Creek, Lostine, Minam, and Imnaha rivers.

5. Document patterns of movement and estimate abundance of juvenile steelhead from tributary populations in Catherine Creek, the upper Grande Ronde, Lostine and the Minam rivers including data on migration timing, and duration.

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

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

Accomplishments

We accomplished all of our objectives for MY 2009.

Findings

Spring Chinook Salmon

We determined migration timing and abundance of juvenile spring Chinook salmon *Oncorhynchus tshawytscha* using rotary screw traps on four streams in the Grande Ronde River Subbasin from 8 September 2008 through 26 June 2009. Based on migration timing and abundance, two distinct life history strategies were identified for juvenile spring Chinook salmon. 'Early' migrants emigrated from upper rearing areas from 8 September 2008 to 26 January 2009 with a peak during fall. 'Late' migrants emigrated from upper rearing areas from 3 February 2009 to 21 May 2009 with a peak during spring. At the upper Grande Ronde River trap, we estimated 34 juvenile spring Chinook salmon migrated from upper rearing areas with approximately 24% leaving as early migrants. At the Catherine Creek trap, we estimated 21,674 juvenile spring Chinook salmon migrated from upper rearing areas with 77% leaving as early migrants. At the Lostine River trap, we estimated 38,935 juvenile spring Chinook salmon migrated from upper rearing areas with 79% leaving as early migrants. At the Minam River trap, we estimated 43,643 juvenile spring Chinook salmon migrated from the river with 62% leaving as early migrants.

Juvenile spring Chinook salmon, that were PIT-tagged in natal rearing areas of Catherine Creek and Imnaha, Lostine, Minam and upper Grande Ronde rivers during the summer of 2008, were detected at Lower Granite Dam between 2 April and 16 June 2009. Median dates of arrival at Lower Granite Dam for Catherine Creek and Imnaha, Lostine and Minam rivers were statistically significantly different during MY 2009 (Kruskal–Wallis, $P < 0.05$). Catherine Creek dates of arrival were the latest of all five groups and were significantly different from the Imnaha and Lostine rivers (Dunn test, $P < 0.05$). Lostine River fish arrived at Lower Granite Dam significantly earlier than all other populations studied (Dunn test, $P < 0.05$). Median arrival dates at Lower Granite Dam, of juvenile spring Chinook salmon from all study streams, ranged from 28 April to 12 May. Survival probabilities to Lower Granite Dam for parr tagged during summer 2008 were 0.147 for Catherine Creek, 0.219 for the Imnaha River, 0.208 for the Lostine River and 0.191 for the Minam River populations.

Chinook salmon tagged at the traps were detected at Lower Granite Dam between 27 March and 25 June 2009. Although there was overlap in arrival dates, median arrival dates for early migrants were before that of late migrants for all four streams. Only one fish was detected at Lower Granite Dam from the upper Grande Ronde River spring (late) migrant tag group, thus no comparison could be made. Early migrant survival probabilities to Lower Granite Dam ranged from 0.269 to 0.387, and late migrants ranged from 0.491 to 0.692. Survival probabilities could not be estimated for upper Grande Ronde River due to insufficient sample sizes; survival probabilities for Catherine Creek and the Lostine and Minam rivers fall within ranges previously observed for all populations. Juvenile spring Chinook salmon of Catherine Creek and Lostine and upper Grande Ronde rivers, that overwintered downstream of trap sites (early migrants), had similar survival probabilities to those that overwintered upstream from trap sites (late migrants).

Summer Steelhead

We determined migration timing and abundance of juvenile steelhead/rainbow trout (*O. mykiss)* using rotary screw traps on four streams in the Grande Ronde River Subbasin during MY 2009. Based on migration timing and abundance, early and late migration patterns were identified, similar to those for spring Chinook salmon. For MY 2009, we estimated 7,471 steelhead migrants emigrated from upper rearing areas of upper Grande Ronde River with 4% migrating as early migrants. We estimated 17,098 steelhead migrants emigrated from upper rearing areas in Catherine Creek with 65% migrating as early migrants. We estimated 14,792 steelhead emigrated from Lostine River, with approximately 74% migrating as early migrants. We estimated 22,940 steelhead emigrated from Minam River with 28% migrating as early migrants.

The steelhead collected at trap sites during MY 2009 were comprised of four age groups. Early migrants ranged from 0 to 3 years of age, while late migrants ranged from 1 to 3 years of age. Smolts detected at Snake River and lower Columbia River dams ranged from 2 to 3 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, Minam and upper Grande Ronde rivers were detected at Lower Granite Dam from 28 March to 18 June 2009. Median arrival dates for early migrants ranged from 28 April to 20 May. Median arrival dates for late migrants ranged from 29 April to 18 May.

Probabilities of surviving and migrating in the first year to Lower Granite Dam for early migrating steelhead ranged from 0.165 (Minam River) to 0.259 (Catherine Creek). Probabilities of surviving and migrating in the first year to Lower Granite Dam for late migrants, greater than 115mm, ranged from 0.573 (upper Grande Ronde River) to 0.670 (Minam River). None of the four groups of smaller late-migrating fish (<115mm) had detections at Lower Granite dam to calculate a probability of migrating and surviving in spring 2009. 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, for all four study streams, during the period 2007 BY spring Chinook salmon were in the Grande Ronde River Subbasin (1 August 2007–30 June 2009). The 2007 BY encountered daily mean water temperatures in excess of DEQ standard 17.8°C for 4 of 624 d for Catherine Creek, 0 of 696 d for Lostine River, 36 of 602 d for Minam River and 0 of 652 d for the upper Grande Ronde River. During the period egg deposition typically occurs (i.e., spawning; August 2007), daily mean water temperatures exceeded 17.8°C in the Minam River for 28 d. Daily mean temperature in the Lostine River did not exceed 17.8°C during egg deposition. During August 2007, water temperature data was not available for the Upper Grande Ronde River and Catherine Creek. During parr rearing (June-August 2008), daily mean water temperatures exceeding 17.8°C did not occur in the Upper Grande Ronde and Lostine rivers, however occurred for 4 d in Catherine Creek and 8 d in the Minam River. During early dispersal (August–September 2008), daily mean water temperatures exceeding 17.8°C did not occur in Catherine Creek, or the upper Grande Ronde and Lostine rivers., Water temperature data for the Minam River was not available during the early dispersal period. Temperatures preferred by juvenile Chinook salmon (10–15.6°C) occurred for 19% of the hours logged for the upper Grande Ronde River, 15% for Catherine Creek, 20% for Lostine River and 13% for Minam River. These optimal temperatures tended to occur April–June and August–October in all four study streams. Water temperatures considered lethal to Chinook salmon (>25° C) were not encountered by juveniles in Catherine Creek, or the upper Grande Ronde and Lostine rivers. In Minam River, daily maximum water temperature exceeded 25° C for a total of 13 h over the course of 4 d during early egg deposition (August 2007). The moving mean of maximum daily water temperature showed that temperatures below the limit for healthy growth (4.4°C) occurred more often than temperature above that limit (18.9°C) in all four study streams.

Stream discharge for Catherine Creek and the upper Grande Ronde and Lostine rivers remained relatively low and stable from August through March. The Minam River, an unregulated system, experienced more variable stream discharges. Spring run-off typically occurred from April through July with peak flows occurring during mid-May for Catherine Creek and the upper Grande Ronde and Minam rivers. Spring run-off initiated later on Lostine River (May–July) with peak flows occurring during early-June.

Management Implications and Recommendations

Rearing of juvenile spring Chinook salmon and summer steelhead in the 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 overwintering 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

The Grande Ronde River originates in the Blue Mountains of northeast Oregon and flows 334 km to its confluence with the Snake River near Rogersburg, Washington. The 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. The upper Grande Ronde River watershed includes the Grande Ronde River and tributaries from headwaters to the confluence with the Wallowa River. The lower Grande Ronde River watershed includes the Grande Ronde River and tributaries, excluding the Wallowa River, from Wallowa River to the confluence with Snake River. The 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 the Wallowa River); Joseph Creek; Wallowa River (includes Minam and Lostine rivers); and Upper Grande Ronde River (includes the 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 the 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 the importance and frequency at which alternative life history strategies are demonstrated by spring Chinook salmon populations in northeast Oregon.

The spring Chinook salmon and summer steelhead smolt migration from the Grande Ronde River Subbasin occurs during spring. Data from Lookingglass Creek (Burck 1993), Catherine Creek, 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 the Grande Ronde River Subbasin. The proportion of the total migrant population these early migrants represent, and their survival to Snake and Columbia River dams varies among years and streams.

Juvenile Chinook salmon that leave upper rearing areas of Catherine Creek and the upper Grande Ronde River during fall, overwinter in the Grande Ronde Valley. Much of the habitat in these mid-reaches of the Grande Ronde River is degraded. Stream conditions in the Grande Ronde River below the city of La Grande consist of both meandering and channeled sections of stream, which run through agricultural land. Riparian vegetation in this area is sparse, and provides minimal shade and instream cover. The river is heavily silted due to extensive erosion associated with agricultural and 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 the limited ability of the habitat to buffer against environmental extremes. The fall migration from upper rearing areas in Catherine Creek constitutes a substantial portion of the juvenile production (Jonasson et al. 2006): therefore, winter rearing habitat quantity and quality in the Grande Ronde Valley may be important factors limiting spring Chinook salmon smolt production in the Grande Ronde River.

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 the areas where steelhead spawn.

Numerous enhancement activities have been undertaken in an effort to recover spring Chinook salmon populations in the Grande Ronde River Subbasin. Supplementation programs have been initiated by the Oregon Department of Fish and Wildlife, the Confederated Tribes of the Umatilla Indian Reservation and the Nez Perce Tribe using endemic broodstock from the upper Grande Ronde River, Catherine Creek and the Lostine River. Information collected by this project will serve as the foundation for assessing the effectiveness of these programs to increase the 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 in which 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 the in-basin migration timing and abundance of juvenile spring Chinook salmon in the upper Grande Ronde River, Catherine Creek, and the Lostine and Minam rivers by operating rotary screw traps during MY 2009. Spring Chinook salmon in each study stream exhibit two migratory life history patterns. Early migrants leave upper rearing areas in fall to overwinter in downstream reaches before continuing their seaward migration out of the subbasin the following spring. Late migrants exhibit another life history strategy whereby they overwinter in the upper rearing areas prior to initiating their seaward migration in spring. Designations of early and late migration periods were based on trends in capture rates at trap sites. A common period of diminished capture rates occurs at all four 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 the Grande Ronde River Subbasin, we operated four rotary screw traps (Figure 1). In the Upper Grande Ronde River Watershed, one rotary screw trap was located downstream of spawning and upper rearing areas in the 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. In the Wallowa River Watershed, one rotary screw trap was located below the majority of spawning and upper rearing areas on the Lostine River near the town of Lostine at rkm 3, and another trap was located on the Minam River below spawning and rearing areas at rkm 0. Although the intent was to operate the traps continuously through the year, there were times when a trap could not be operated due to high or low river flows or freezing conditions. There were also instances when traps were not operating due to debris blockage and mechanical breakdowns. No attempt was made to adjust population estimates for periods when traps were not operating. For this reason, estimates represent a minimum number of migrants.

Sampling and Marking: The rotary screw traps were equipped with live-boxes that safely held hundreds of juvenile spring Chinook salmon trapped over 24–72 h periods. The 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 the 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 each week when possible. 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 daily at each trap location using thermographs or hand held thermometers.

Migrant abundance was estimated by conducting weekly trap efficiency tests throughout the migratory year at each trap site. Chinook salmon fry and sexually mature parr 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, the number of recaptured fish and the number of marked fish released the previous day were subtracted from the weekly totals. Trap efficiency was estimated by

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

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

The weekly abundance of migrants that passed each trap site was estimated by

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

where $\hat{N}_j$ is the estimated number of fish migrating past the trap for week j , U_j is the 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 the 1,000 iterations. Weekly variance estimates were summed to obtain an estimated variance for the total migrant abundance. Confidence intervals for total migrant abundance were calculated by

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

where V is the estimated total variance determined from the bootstrap.

The Catherine Creek and Lostine and upper Grande Ronde River traps were located below hatchery spring Chinook salmon release sites. The magnitude of hatchery spring Chinook salmon releases into these streams during the spring required modifications to methods used for estimating migrant abundance of wild spring Chinook salmon at trap sites. 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 the proportion of total daily catch captured during each sampling interval. This proportion was estimated by fishing the trap over several 24 h periods prior to systematic sampling. Number of fish trapped during the 1 to 4 h sampling interval and number in the remaining interval within each 24 h period were counted. Proportion of total daily catch captured during the sampling interval (i) was estimated by

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

where $\hat{P}_i$ is the 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 the systematic sampling period was estimated by

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

where $\hat{N}_s$ is estimated number of fish migrating past the trap during systematic sampling, U_i is total number of fish captured during interval i, $\hat{P}_i$ is proportion of daily catch from equation (9) 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 the 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. 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 2008 in their 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. Traditional beach seining was employed to a lesser extent. Captured fish were held in aerated, 19-L buckets and transferred periodically to live cages anchored in shaded areas of the stream. The goal was to PIT-tag 1,000 parr from Catherine Creek and Imnaha, Lostine, Minam and upper Grande Ronde rivers for summer tag groups.

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 2008 through 28 January 2009 were designated as fall tag group. 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 500 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 in spring. The winter group was tagged earlier in upper rearing areas (December 2008) than the spring group, which were tagged as migrants (29 January–30 June 2009) at the trap. 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 and upper Grande Ronde river traps. The goal was to PIT-tag 500 fish at each trap throughout the late migration period.

During MY 2009, 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 2009 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.

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. The extent to which results may be biased would depend on overall rates of fish passage via the bypass system and surface bypass collector, and on 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 fish from the tag group that were detected each day by a daily expansion factor calculated using Lower Granite Dam forebay water flow data obtained from the 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 when both trap efficiency estimates and annual peaks in movement vary (random). Therefore, median arrival dates for spring tag groups may be biased on distribution of

PIT tag releases. In an attempt to alleviate this bias, winter tag groups were used to represent late migrant 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: The 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 probability of detection 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. Summer 2007 and 2008 PIT tagged parr from Catherine Creek and Imnaha, Lostine and Minam river populations were used to monitor and compare smolt migration timing to Lower Granite Dam and survival probabilities from tagging to Snake River dams. 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 to Lower Granite Dam, and survival to main stem Snake and Columbia River dams.

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 the fall tag group (early migrants) and winter tag group (late migrants) were the same. Any difference in survival probabilities between these two groups was assumed to be due to differential survival in upstream (used by winter tag group) and downstream (used by fall tag group) overwintering stream reaches. 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

Upper Grande Ronde River: The upper Grande Ronde River trap fished for 139 d between 3 October 2008 and 26 June 2009 (Table 2). Very few migrants were collected at the trap site in MY 2009, nevertheless a distinct early and late migration was exhibited by juvenile spring Chinook salmon at this trap site. Systematic subsampling comprised 13 of 116 d the trap was fished during the late migration period, and a total of 7 juvenile Chinook salmon were caught during this period. During the early migration period, only four individuals were collected resulting in a median emigration date of 24 October 2008. The median emigration date for 12 individuals collected during the late migration period was 29 March 2009 (Appendix Table A-1). Both dates fall within the range of median dates previously recorded for this study.

We estimated a minimum of 34 (95% CI, ± 13) juvenile spring Chinook salmon emigrated from upper Grande Ronde River rearing areas during MY 2009 which is the lowest number reported for this trap for all study years (Appendix Table A-1). Based on the total minimum estimate, 24% (8 ± 9) of the juvenile spring Chinook salmon were early migrants and 76% (26 ± 10) were late migrants. A dominant late migration for upper Grande Ronde River is consistent with most migratory years studied (Appendix Table A-1).

Catherine Creek: The Catherine Creek trap fished for 156 d between 8 September 2008 and 5 June 2009 (Table 2). A distinct early and late migration was exhibited by juvenile spring Chinook salmon at this trap site (Figure 2). Systematic subsampling comprised 12 of 68 d the trap was fished during the late migration period, and a total of 204 juvenile Chinook salmon were caught during this period. The median emigration date for early migrants passing the trap was 15 October 2008, and median emigration date for late migrants was 25 March 2009 (Appendix Table A-1). Both dates fall within the range of median dates previously recorded for this study.

We estimated a minimum of 21,674 ± 3,029 juvenile spring Chinook salmon emigrated from upper Catherine Creek rearing areas during MY 2009. This migrant estimate was within the range of population estimates previously reported during this study (Appendix Table A-1). Based on total minimum estimate, 77% (16,618 ± 2,723) migrated early and 23% (5,056 ± 1,328) migrated late. In contrast to upper Grande Ronde River, principal migration from Catherine Creek has consistently been observed during the early migrant period.

Lostine River: The Lostine River trap fished for 197 d between 8 September 2008 and 17 May 2009 (Table 2). Distinct early and late migrations were evident at this trap site (Figure 2). Systematic subsampling comprised 12 of 95 d the trap was fished during the late migration period, and a total of 343 juvenile Chinook salmon were caught during this period. The median emigration date for early migrants was 15 October 2008, and 30 March 2009 for late migrants (Appendix Table A-1). Both dates fall within the range of median dates previously reported for this study.

We estimated a minimum of 38,935 ± 7,353 juvenile spring Chinook salmon emigrated from Lostine River during MY 2009. Based on the minimum estimate, 79% (30,896 ± 7,261) of juvenile spring Chinook salmon migrated early and 21% (8,039 ± 1,160) 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 the Catherine Creek population in that the largest emigration has been observed during the early migrant period most years (Appendix Table A-1).

Minam River: The Minam River trap fished for 152 d between 8 September 2008 and 19 June 2009 (Table 2). Distinct early and late migrations were evident (Figure 2). The median emigration date of early migrants was 3 November 2008, and the median date for late migrants was 29 March 2009 (Appendix Table A-1). Both dates fall within the range of median dates previously reported for this study.

We estimated a minimum of 43,643 ± 8,936 juvenile spring Chinook salmon emigrated from Minam River during MY 2009. Based on the minimum estimate, 62% (27,167 ± 6,710) of juvenile spring Chinook salmon migrated early and 38% (16,476 ± 5,902) migrated late. Percentage of late migrants is within the range 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 July–September 2008, Chinook salmon parr were PIT-tagged and released in upper summer rearing areas of Catherine Creek and Lostine, Imnaha and Minam rivers (Table 1). Insufficient parr abundance in upper Grande Ronde River prohibited a summer tag group. Information on migration timing and survival of parr PIT-tagged during summer 2009 will be reported in 2010.

Migration Timing: Spring Chinook salmon parr PIT-tagged from Catherine Creek and Imnaha, Lostine and Minam rivers during summer 2008 were detected at Lower Granite Dam from 2 April to 16 June 2009 (Appendix Table A-2). The period of detection at Lower Granite Dam among the four populations ranged from 50 d (Lostine River) to 74 d (Imnaha River). Median date of arrival ranged from 28 April to 12 May (Figure 5). Median dates of arrival to Lower Granite Dam for Catherine Creek and Imnaha, Lostine and Minam rivers were statistically significantly different for MY 2009 (Kruskal–Wallis, $P < 0.05$). Dunn's multiple comparison tests revealed that median dates of arrival for Minam River were not significantly different from those of Catherine Creek and Imnaha River, while median dates of arrival for Catherine Creek were significantly different from those of Imnaha and Lostine rivers. Lostine River differed significantly from all other populations. All populations fell within previously observed ranges of median arrival date at Lower Granite Dam (Appendix Table A-2).

Survival Probabilities: Survival probabilities to Lower Granite Dam for parr tagged during summer 2008 were 0.147 for Catherine Creek, 0.219 for Imnaha River, 0.208 for Lostine River and 0.191 for Minam River populations (Table 5). Generally, survival probabilities for all groups during MY 2009 fell within ranges reported. Survival probabilities for parr tagged in Imnaha river, have increased over the past five years with this year being the highest since 1998 (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 and upper Grande Ronde rivers. Parr were also tagged upstream of screw traps on Catherine Creek and Lostine River during winter. Low abundance of spring Chinook salmon parr prohibited tagging in upper Grande Ronde River during winter 2009. Total number of Chinook salmon parr PIT-tagged for each study stream, per season, is provided in Table 6.

Migration Timing: Median arrival date at Lower Granite Dam for the spring tag group from upper Grande Ronde River was 19 May. Median arrival dates at Lower Granite Dam for fall, winter and spring tag groups of Catherine Creek were 8 May, 19 May and 20 May 2009, respectively (Figure 6). Median arrival dates at Lower Granite Dam for fall, winter, and spring tag groups for Lostine River were 25 April, 31 May and 18 May 2009, respectively (Figure 7). Median arrival dates at Lower Granite Dam for fall and spring tag groups of Minam River were 25 April and 19 May 2009, respectively (Figure 8). Median arrival dates of fall tag groups from all populations were within ranges previously reported; however, Lostine River winter tag group median arrival date was considerably later than previously observed. (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 Catherine Creek and Lostine River (Mann–Whitney rank-sum test, $P < 0.001$). There were no winter tag groups for Minam and upper Grande Ronde rivers to compare to early migrants.

Travel time for the single late migrant detected from upper Grande Ronde River was 55 d from the screw trap to Lower Granite Dam ($n = 1$). Travel time for Catherine Creek late migrants ranged from 17 to 86 d with a median of 57 d ($n = 73$). Travel time for Lostine River late migrants ranged from 11 to 78 d with a median of 37 d ($n = 163$). Travel time for Minam River late migrants ranged from 7 to 79 d with a median of 38 d ($n = 99$). Median travel times during MY 2009 were within previously observed ranges for Catherine Creek and Minam and upper Grande Ronde rivers. Median travel time of Lostine River late migrants was second slowest ever observed during this multiyear study. (Appendix Table A-4).

Survival Probabilities: Catherine Creek fall, winter and spring tag group survival probabilities to Lower Granite Dam were 0.269, 0.110 and 0.491, respectively. Survival probabilities for Lostine River fall, winter and spring tag groups were 0.312, 0.192 and 0.692, respectively. Survival probabilities for Minam River fall and spring tag groups were 0.387 and 0.618, respectively. Survival probabilities, similar to past years, were generally higher for spring tag groups, likely because these fish were not subject to post-tagging overwinter mortality that summer, fall and winter tag groups experienced (Table 6). Survival probabilities to Lower Granite Dam for upper Grande Ronde River were not estimated due to small release and recapture samples sizes.

Overwinter survival of BY 2007 fish in upper rearing areas of Catherine Creek was 22%, and was similar to those previously observed during this multiyear study (Appendix Table A-5). During MY 2009, difference in survival between fish that overwintered upstream and those downstream of the Catherine Creek trap was significant (Maximum Likelihood Ratio test, $P = 0.003$). 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 (8 of 15 migratory years).

Overwinter survival of BY 2007 fish in upper rearing areas of Lostine River was 28% (Appendix Table A-5); this overwinter survival estimate was the second lowest observed during this multiyear study. During MY 2009, overwinter survival between fish that overwintered upstream and those downstream of Lostine River trap was significantly different (Maximum Likelihood Ratio test, $P = 0.003$). For Lostine River, we have generally observed equivalent overwinter survival rates between upstream and downstream overwintering areas (8 of 12 years), while higher survival rates for downstream rearing fish were estimated the remainder of the time (Appendix Table A-6).

Overwinter survival of BY 2007 (MY 2009) fish in upper rearing areas of upper Grande Ronde River were not estimated due to low fish abundances and subsequent winter tag group absence. We previously observed higher survival rates for fish overwintering downstream of the trap during MY 1995, 1998-2000 and 2007 (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: We were unable to estimate MY 2009 upper Grande Ronde River smolt equivalents due to insufficient fall and spring tag group sample sizes. For years an estimate was available, we documented the lowest spring smolt equivalent estimates from rearing reaches of upper Grande Ronde River and at Lower Granite Dam during MY 2003 (4,198 and 1,666, respectively). The 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). Smolt equivalents were also not estimated for MY 1996, 1997 and 2001 as a result of insufficient sample size and subsequent incomplete survival estimates for one or both migrant groups (Appendix Table A-7).

An estimated 14,160 smolt equivalents emigrated from Catherine Creek rearing reaches during the spring of MY 2009, and 6,953 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 1995-2009. 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. The 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 22,009 smolt equivalents emigrated from Lostine River rearing areas during spring 2009, and 15,203 successfully emigrated to Lower Granite Dam (Appendix Table A-7). Both estimates are within previously reported ranges of smolt equivalent estimates from MY 1997-2009. Lowest smolt equivalent estimates emigrated from Lostine River rearing areas during spring and successfully emigrated to Lower Granite Dam during MY 1997 (3,203 and 2,463, respectively). The highest estimate of smolt equivalents emigrating from Lostine River rearing areas during spring was 33,349 during MY 2005, and for smolt equivalents successfully emigrating to Lower Granite Dam was 19,012 during MY 1999 (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 33,488 smolt equivalents emigrated from Minam River rearing areas during spring MY 2009, of which 20,696 successfully emigrated to Lower Granite Dam (Appendix Table A-7); both estimates are within previously reported ranges from MY 2001-2009. 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).

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 year round. 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 not detected at Snake or Columbia River dams until the following year. 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 used by each of the four populations. 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**). The summer tag group represents steelhead occupying upstream spawning and rearing reaches of Catherine Creek during the beginning of a migratory year (July) and has not been conducted since 2006. The fall tag group represents early migrant summer steelhead that relocate downstream of the screw trap site between 1 September 2008 and 28 January 2009. The spring tag group represents fish that migrate downstream of trap sites between 29 January and 30 June 2010 (late migrants). During the summer of 2006, the goal was to PIT-tag 500 steelhead in the main stem of Catherine Creek, and 500 fish in Little Catherine Creek. At each trap site during MY 2009, the goal was to PIT-tag 600 steelhead during the fall and spring to assess migration timing of early and late migrants for each location.

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 the 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 the assumptions of the Cormack-Jolly-Seber model. For this study, only detections during the migration year of tagging (2009) 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 the relationship between size, migration patterns and survival. Fork lengths of all steelhead tagged during fall 2008 were compared to fork lengths of those subsequently detected at the dams in 2009 using the Mann–Whitney rank-sum test. Fork lengths of all steelhead tagged during fall 2007 were compared to that of those subsequently detected in 2008 and 2009 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 2009 were compared to that of those subsequently detected at dams during spring 2009 using a Mann–Whitney rank-sum test. Age structure of steelhead PIT-tagged at the traps and the subset detected at the dams during spring 2009 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 139 d between 8 September 2008 and 5 June 2009 (Table 7). Systematic subsampling comprised 12 of 108 d the trap was operated during the late migration period. There were distinct early and late migrations exhibited by juvenile steelhead at this trap site (Figure 9). Median emigration date for early migrants was 14 October 2008, while median emigration date for late migrants was 10 April 2009. Both median migration dates were within ranges previously reported for this study (Appendix Table B-1).

We estimated a minimum of 17,098 ± 3,198 juvenile steelhead migrated out of upper rearing areas during MY 2009. Based on the total minimum abundance estimate, 65% (11,147 ± 2,839) migrated early and 35% (5,951 ± 1,472) migrated late. MY 2009 proportion of juvenile steelhead emigrating from upper rearing areas as late migrants is consistent with proportions reported for previous years of this study (Appendix Table B-1).

Lostine River: The trap fished for 197 d between 8 September 2008 and 17 May 2009 (Table 7). Systematic subsampling comprised 12 of 106 d the trap was operated during the late migration period. Distinct early and late migrations were evident at this trap site (Figure 9). Median emigration date for early migrants was 14 October 2008, and median emigration date for late migrants was 10 April 2009. Both median migration dates were within ranges previously reported for this study (Appendix Table B-1).

We estimated a minimum of 14,792 ± 5,332 steelhead emigrated during MY 2009. Based on the total minimum abundance estimate, 74% (10,941 ± 5,262) of juvenile steelhead migrated early and 26% (3,851 ± 856) migrated late.

Minam River: The trap fished for 152 d between 8 September 2008 and 19 June 2009 (Table 7). Distinct early and late migrations were evident at this trap site (Figure 9). Median emigration date for early migrants was 13 November 2008, and median emigration date for late migrants was 21 April 2009. Median emigration date for early migrants was the latest reported for this multiyear study, while median emigration date for late migrants was within ranges previously reported (Appendix Table B-1).

We estimated a minimum of 22,940 ± 9,167 juvenile steelhead emigrated during MY 2009. Based on the total minimum abundance estimate, 28% (6,438 ± 3,925) migrated early and 72% (16,502 ± 8,284) migrated late. MY 2009 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 139 d between 3 October 2008 and 26 June 2009 (Table 7). Systematic subsampling comprised 13 of 116 d the trap was operated during the late migration period. A distinct early migration was not as evident at this trap site as most juvenile steelhead emigrated as late migrants during spring months, which is consistent with previous years of this study (Figure 9). Median emigration date for early migrants was 10 November 2008, and median emigration date for late migrants was 20 April 2009. Both median migration dates were within ranges previously reported for this study (Appendix Table B-1).

We estimated a minimum of 7,471 (95% CI, ± 1,678) juvenile steelhead emigrated from upper rearing areas of upper Grande Ronde River during MY 2009, which is within estimates from previous migratory years (Appendix Table B-1). Based on the total minimum abundance estimate, 4% (322 ± 84) were early migrants and 96% (7,149 ± 1,676) were late migrants. The pattern of a dominant 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 2009 comprised four age-groups. Early migrants ranged from 0 to 3 years of age, while late migrants ranged from 1 to 3 years of age (Table 8). Majority of Catherine Creek (88.8%), Lostine River (64.3%) and upper Grande Ronde River (71.8%) early migrants were age 1, while majority of Minam River (56.7%) early migrants were age 0. Majority of Catherine Creek (72.1%), Minam River (46.1%) and upper Grande Ronde River (70.9%) late migrants were age 2, while majority of Lostine River (57.1%) late migrants were age 1 (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. Detections of summer tag group individuals from Catherine Creek and tributaries represented an undetermined combination of the two migrant groups that originated from this drainage.

Migration Timing: Median arrival dates at Lower Granite Dam for fall and spring tag groups of upper Grande Ronde River were 20 May and 9 May, respectively (Figure 10). Median arrival dates for fall and spring tag groups of Catherine Creek were 8 May and 7 May, respectively (Figure 11). Median arrival dates for fall and spring tag groups of Lostine River were 30 April and 18 May, respectively (Figure 12). Median arrival dates for fall and spring tag groups from Minam River were 28 April and 29 April, respectively (Figure 13).

Travel time from the screw trap to Lower Granite Dam for the spring tag group from all four study streams are presented in Table 9**.** Travel time to Lower Granite Dam for the spring tag group from Catherine Creek ranged from 6 to 65 d with a median of 27.3 d. Travel time to Lower Granite Dam for the spring tag group from Lostine River ranged from 3 to 58 d with a median of 6.7 d. Travel time to Lower Granite Dam for the spring tag group from Minam River ranged from 3 to 78 d with a median of 18.5 d. Travel time to Lower Granite Dam for the spring tag group from upper Grande Ronde River ranged from 5 to 68 d with a median of 35.4 d.

Survival Probabilities: Probability of surviving and migrating, during migration year of tagging, to Lower Granite Dam for steelhead tagged in fall 2008 ranged from 0.165 to 0.259 for all four study streams (Table 10). Probabilities of migration and survival for larger steelhead (FL ≥ 115 mm) tagged during spring 2009 ranged from 0.573 to 0.670 for all four populations studied (Table 10). Generally, probabilities of migration and survival, during spring 2009, were moderate to relatively high for all four populations studied compared to pervious years (Appendix Table B-3).

During this study, at least one PIT tagged fish captured and released in North, Middle and South forks of Catherine Creek, Little Catherine Creek and Milk Creek have been detected at Snake or Columbia river dams, indicating the anadromous life history strategy is present in all these tributaries (Appendix Table B-3).

Length and Age Characterization of Smolt Detections: Of all early migrating steelhead tagged at all four traps during fall 2008, predominately larger individuals tended to be detected at the dams during 2009 (Mann–Whitney, P <0.05, Figure 14). This pattern was also observed the previous migratory year for early migrants tagged during fall 2007. Of all early migrating steelhead tagged at all four traps during fall 2007, predominately smaller individuals tended to be detected at the dams during 2009 (Kruskal–Wallis, P <0.05, Figure 15). MY 2009 spring tag groups exhibited a pattern of larger individuals being detected at dams during spring (Mann–Whitney, P <0.05, Figure 16). Fork length summaries, at time of tagging, of all steelhead tag groups and those detected at dams are provided in Appendix Tables B-4, B-5, and B-6. While differences between medians of an entire tag group and those detected at dams could be a result of smaller fish experiencing greater size-dependent mortality, there is evidence that smaller individuals that emigrate from upper rearing reaches delay seaward migration until the subsequent migratory year (Appendix Tables B-4, B-5, and B-6).

Of 57 early migrating age-0 fish tagged in all four study streams, 0 (0%) were observed at dams the following spring, while 57 of 224 age-1 and 26 of 47 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 observations in MY 2009 (Table 11). Late migrant smolts primary consisted of age 1 to 3 years during 2009, but data collected in previous years have indicated steelhead smolts from the Grande Ronde River Subbasin more commonly range in age from 1 to 4 years. 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 the Oregon Water Resources Department (OWRD) La Grande District Water Master. Stream temperature and discharge was characterized for all four study streams constrained by in-basin life history of juvenile spring Chinook salmon from BY 2007, which ranged from 1 August 2007 (spawning) to 1 July 2009 (the end of MY 2009).

Mean daily temperature was generated 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 upper Grande Ronde River (USGS station 13317850; rkm 321.9), Catherine Creek (USGS station 13320000; rkm 38.6), Lostine River (USGS station 13330300; rkm 1.6) and Minam River (USGS station 13331500; rkm 0.4) gaging stations that measured discharge in cubic feet per second (cfs) every 15 minutes. Average daily discharge was converted to cubic meters per second (nearest 0.0001, m^3/s). Each gaging station was situated near the downstream margin of summer rearing distribution.

Results and Discussion

Stream Temperature and Flow

Catherine Creek: Water temperatures, during the majority of in-basin occupancy of BY 2007 spring Chinook salmon, ranged from 0.0 to 21.9°C. We were not able to characterize a 76 d period during summer 2007 (1 August 2007–15 October 2007). Daily mean water temperature exceeded the DEQ standard of 17.8°C on 4 of 624 d. Water temperatures were within the range preferred by juvenile spring Chinook salmon (10–15.6°C; OPSW 1999) for 2,239 of 14,976 (14.9%) hours logged. The DEQ lethal limit of 25°C was not exceeded during 624 d temperature was logged. The seven-day moving mean of maximum temperature revealed that water temperatures below the range expected to support healthy growth (4.4–18.9°C; OPSW 1999) were encountered for a longer duration than those that exceeded healthy growth water temperature range (Figure 17). Moving mean temperatures were less than 4.4°C for 97 d (20 November 2007–24 February 2008) during incubation and emergence, and 113 d (20 November 2008-15 March 2009) during dispersal and spring migration. Moving mean temperatures exceeded 18.9°C for 24 d (26 July 2008-20 August 2008) during summer rearing and dispersal.

Average daily discharge during the entire in-basin life history of the 2007 cohort ranged from 0.510 to 31.715 m^3/s (Figure 18). Discharge was greater than 2.00 m^3/s from mid-April through late-July 2008 and mid-March through spring migration 2009. Annual peak flows occurred on 19 May 2008 and 2009, and were 31.715 and 22.569 m^3/s, respectively. Discharge was less than 2.00 m^3/s from August 2007 through mid-April in 2008 and late-June 2008 through mid-March 2009. In addition to typical spring freshets, stream discharge exceeded 2.00 m^3/s for 24 d from late-November 2007 to mid-February 2008 and 17 d from mid-November 2008 to mid-March 2009.

Lostine River: Water temperatures, during in-basin occupancy of BY 2007 spring Chinook salmon, ranged from 0.0 to 20.7°C. We were unable to characterize a 4 d period during the overwintering period (4 January 2008–7 January 2008). Daily mean water temperature did not exceed the DEQ standard of 17.8°C during the 696 d thermograph. Water temperatures were within the range preferred by juvenile spring Chinook salmon (10–15.6°C; OPSW 1999) for 3,327 of 16,704 (19.9%) h logged. DEQ lethal limit of 25°C was not exceeded during the 696 d temperature was logged. The seven-day moving mean of maximum temperature revealed that water temperatures below the range expected to support healthy growth (4.4–18.9°C; OPSW 1999) were encountered for a longer duration than those that exceeded the healthy growth water temperature range (Figure 17). Moving mean temperatures were less than 4.4°C on 80 d (20 November 2007–11 February 2008) during incubation and emergence, and 90 d (21 November 2008–13 March 2009) during fall dispersal, overwintering and early spring migration. Moving mean temperature exceeded 18.9°C on 1 d during early incubation (1 August 2007) and 5 d (14 August 2008–18 August 2008) during summer rearing.

Average daily discharge during entire in-basin life history of the 2007 cohort ranged from 0.187 to 42.758 m^3/s (Figure 18). Discharge was greater than 7.5 m^3/s from mid-May through mid-July. Annual peak flows occurred on 1 July 2008 and 6 June 2009 and were 42.758 and 38.228 m^3/s, respectively. Discharge was less than 7.5 m^3/s from mid-July through mid-May. In addition to typical spring freshets, stream discharge exceeded 7.5 m^3/s on 8 November 2008.

Minam River: Water temperatures, during in-basin occupancy of BY 2007 spring Chinook salmon, ranged from 0.0 to 26.1°C. We were unable to characterize a 38 d period during summer rearing (16 August 2008–22 September 2008) and 60 d period during overwintering (5 December 2008-2 February 2009). Daily mean water temperature exceeded DEQ standard of 17.8°C on 36 of 602 d. Water temperatures were within the range preferred by juvenile spring Chinook salmon (10–15.6°C; OPSW 1999) for 1,866 of 14,448 (12.9%) h logged. DEQ lethal limit of 25°C was exceeded for 13 h over the course of 4 d during the 600 d temperature was logged. The seven-day moving mean of maximum temperature revealed that water temperatures below the range expected to support healthy growth (4.4–18.9°C; OPSW 1999) were encountered for a longer duration than those that exceeded healthy growth water temperature range (Figure 17). Moving mean temperatures were less than 4.4°C on 99 d (11 November 2007–22 February 2008) during incubation and emergence, and 52 d (17 November 2008–14 March 2009) during fall dispersal and overwinter rearing. Moving mean temperatures exceeded 18.9°C on 46 d (1 August 2007–15 September 2007) during incubation, and 22 d (26 June–1 August 2007) during summer rearing.

Average daily discharge during entire in-basin life history of the 2007 cohort ranged from 1.303 to 99.675 m^3/s (Figure 18). Discharge was greater than 9.0 m^3/s from late-April through late-June 2008, and mid-March through spring migration. Annual peak flows occurred on 19 May 2008 and 30 May 2009 and were 99.675 and 93.162 m^3/s, respectively. Discharge was less than 9.0 m^3/s from early-July through late-April 2008 and late-July through mid-March 2008. In addition to typical spring freshets, stream discharge exceeded 9.0 m^3/s for a 5 d period during mid-November 2008 and an 11 d period during early-January 2009.

Upper Grande Ronde River: Water temperatures, during majority of in-basin occupancy of BY 2007 spring Chinook salmon, ranged from 0.0 to 23.5°C. We were unable to characterize a 48 d period during summer 2007 (2 August 2007–18 September 2007). Daily mean water temperature did not exceed DEQ standard of 17.8°C during the 652 d thermograph. Water temperatures were within the range preferred by juvenile spring Chinook salmon (10–15.6°C; OPSW 1999) for 2,913 of 15,648 (18.6%) h logged. DEQ lethal limit of 25°C was not exceeded during the 652 d temperature was logged. Seven-day moving mean of maximum temperature revealed that water temperatures below and above the range expected to support healthy growth (4.4–18.9°C; OPSW 1999) were encountered by the 2007 cohort (Figure 17). Moving mean maximum stream temperatures were less than 4.4°C on 154 d (30 October 2007–31 March 2008) during incubation and emergence, and 138 d (16 November 2008-2 April 2009) during dispersal and spring migration. Moving mean maximum stream temperature was greater than 18.9°C on 1 d (30 June 2009) during spring migration.

Average daily discharge during entire in-basin life history of the 2007 cohort ranged from 0.119 to 9.514 m^3/s (Figure 18). Discharge was greater than 1.00 m^3/s from late-April through mid-July 2008 and from mid-April through spring migration in 2009. Annual peak flows occurred on 29 May 2008 and 19 May 2009 and were 9.514 and 7.815 m^3/s, respectively. Discharge was less than 1.00 m^3/s from August 2007 through early-May 2008 and from mid-July 2008 through mid-April 2009.

FUTURE DIRECTIONS

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

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Table 1. Dates of tagging and number of spring Chinook salmon parr PIT-tagged in various northeast Oregon streams during summer 2007 and 2008.

Migration year and stream	Dates of collection and tagging	Number PIT-tagged and released	Distance to Lower Granite Dam (km)
2008 (*Summer 2007*)			
Catherine Creek	30 Jul–2 Aug	1,000	363–383
Imnaha River	4 Sep–6 Sep	1,000	221–233
Lostine River	14 Aug–17 Aug	1,000	271–308
Minam River	20 Aug–23 Aug	1,000	276–290
Upper Grande Ronde	27 Aug–29 Aug	1,000	418–428
2009 (*Summer 2008*)			
Catherine Creek	28 Jul–31 Jul	999	363–383
Imnaha River	3 Sep–5 Sep	995	221–233
Lostine River	4 Aug–7 Aug	992	271–308
Minam River	18 Aug–21 Aug	998	276–290
Upper Grande Ronde	NA	0	418–428

Table 2. Catch of juvenile spring Chinook salmon at four trap locations in the Grande Ronde River Subbasin during MY 2009. The early migration period starts 1 July 2008 and ends 28 January 2009. The late migration period starts 29 January and ends 30 June 2009. The period a trap operated was used to identify the total number of days fished with percentage in parentheses during each migration period.

Trap site	Migration period	Period trap operated	Days fished / days operated	Trap catch
Catherine Creek	Early	8 Sept 08–16 Jan 09	88/131 (67)	5,822
	Late	18 Feb 09–5 Jun 09	68/108 (63)	583[a]
		17 Mar 09–15 Apr 09	12/30 (40)	204[b]
Lostine River	Early	8 Sep 08–26 Jan 09	102/142 (72)	3,219
	Late	1 Feb 09–17 May 09	95/106 (90)	2,400[a]
		20 Mar 09–21 Apr 09	12/33 (36)	343[b]
Minam River	Early	8 Sep 08–5 Dec 08	77/89 (87)	3,138
	Late	23 Feb 09–19 Jun 09	75/117 (64)	1,315
Upper Grande Ronde River	Early	3 Oct 08–26 Nov 08	50/55 (91)	4
	Late	3 Mar 09–26 Jun 09	89/116 (77)	5[a]
		25 Mar 09–15 Apr 09	13/22 (59)	7[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 2009. 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	615	86.7	0.30	63	108	500	87.5	0.31	66	108
Winter	504	87.2	0.28	72	107	500	87.1	0.28	72	107
Late migrants	607	90.9	0.30	69	132	498	90.7	0.32	69	132
Lostine River										
Early migrants	1240	84.9	0.31	53	123	501	84.4	0.43	60	117
Winter	494	72.3	0.33	56	114	494	72.3	0.33	56	114
Late migrants	1160	92.0	0.34	66	148	594	91.4	0.45	69	148
Minam River										
Early migrants	870	81.4	0.32	58	124	500	82.5	0.39	58	115
Late migrants	740	88.1	0.29	68	143	415	88.5	0.41	69	143
Upper Grande Ronde River										
Early migrants	4	96.0	3.94	85	103	4	96.0	3.94	85	103
Late migrants	11	100.2	4.31	82	135	10	100.4	4.76	82	135

Table 4. Weights of juvenile spring Chinook salmon collected from the study streams during MY 2009. 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	576	7.2	0.08	2.5	13.1	473	7.3	0.08	3.4	13.1
Winter	504	7.4	0.07	4.0	13.6	500	7.4	0.07	4.0	13.6
Late migrants	607	8.2	0.09	3.4	25.9	498	8.1	0.10	3.4	25.9
Lostine River										
Early migrants	1234	7.0	0.08	1.5	20.9	496	7.0	0.12	2.2	19.7
Winter	492	4.1	0.08	1.6	29.0	492	4.1	0.08	1.6	29.0
Late migrants	1159	8.9	0.11	2.8	35.2	593	8.7	0.15	3.6	35.2
Minam River										
Early migrants	865	6.1	0.08	1.7	24.6	496	6.3	0.09	2.0	16.6
Late migrants	735	7.3	0.09	2.8	34.5	410	7.5	0.14	3.3	34.5
Upper Grande Ronde River										
Early migrants	4	10.1	1.62	6.2	14.1	4	10.1	1.62	6.2	14.1
Late migrants	11	10.5	1.84	5.0	27.5	10	10.6	2.03	5.0	27.5

Table 5. Survival probability to Lower Granite Dam of juvenile spring Chinook salmon tagged during summer 2008 and detected at Columbia and Snake River dams during 2009.

Stream	Number PIT-tagged and released	Survival probability (95% CI)
Catherine Creek	999	0.147 (0.116–0.178)
Imnaha River	995	0.219 (0.187–0.251)
Lostine River	992	0.208 (0.176–0.241)
Minam River	998	0.191 (0.162–0.219)
Upper Grande Ronde River	0	—

Table 6. Juvenile spring Chinook salmon survival probability by location and tag group from time of tagging to Lower Granite Dam. Chinook salmon were tagged from fall 2008 to spring 2009 and detected at the dams during 2009.

Stream and tag group	Number PIT-tagged and released	Survival probability (95% CI)
Catherine Creek		
Fall (trap)	500	0.269 (0.241–0.297)
Winter (above trap)	500	0.110 (0.086–0.134)
Spring (trap)	498	0.491 (0.434–0.548)
Lostine River		
Fall (trap)	501	0.312 (0.284–0.340)
Winter (above trap)	494	0.191 (0.166–0.216)
Spring (trap)	593	0.692 (0.654–0.730)
Minam River		
Fall (trap)	500	0.387 (0.359–0.415)
Spring (trap)	415	0.618 (0.578–0.658)
Upper Grande Ronde River		
Fall (trap)	4	(a)
Winter (above trap)	(b)	(a)
Spring (trap)	10	(a)

[a] Data was insufficient to calculate a survival probability.
[b] There was an insufficient number of Chinook parr to tag a winter group.

Table 7. Catch of juvenile steelhead at four trap locations in the Grande Ronde River Subbasin during MY 2009. The early migration period starts 1 July 2008 and ends 28 January 2009. The late migration period starts 29 January and ends 30 June 2009. The period a trap operated was used to identify the total number of days fished with percentage in parentheses during each migration period.

Trap site	Migration period	Period trap operated	Days fished / days operated	Trap catch
Catherine Creek	Early	8 Sept 08–16 Jan 09	88/131 (67)	998
	Late	18 Feb 09–5 Jun 09	68/108 (63)	395[a]
		17 Mar 09–15 Apr 09	12/30 (40)	64[b]
Lostine River	Early	8 Sep 08–26 Jan 09	102/142 (72)	742
	Late	1 Feb 09–17 May 09	95/106 (90)	690[a]
		20 Mar 09–21 Apr 09	12/33 (36)	76[b]
Minam River	Early	8 Sep 08–5 Dec 08	77/89 (87)	174
	Late	23 Feb 09–19 Jun 09	75/117 (64)	446
Upper Grande Ronde River	Early	3 Oct 08–26 Nov 08	50/55 (91)	110
	Late	3 Mar 09–26 Jun 09	89/116 (77)	1094[a]
		25 Mar 09–15 Apr 09	13/22 (59)	204[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 2009. 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 the frequency distribution of sampled lengths and allocated using an age–length key. Means were weighted by migrant abundance at trap sites.

	Percent				
Migration period and trap site	Age-0	Age-1	Age-2	Age-3	Age-4
Early					
Catherine Creek	3.8	88.8	7.4	0.0	0.0
Lostine River	28.7	64.3	6.9	0.1	0.0
Minam River	56.7	26.2	17.0	0.0	0.0
Upper Grande Ronde River	4.5	71.8	22.7	0.9	0.0
Mean	**20.3**	**70.4**	**9.2**	**0.1**	**0.0**
CV (%)	**123.5**	**37.6**	**84.0**	**324.6**	**0.0**
Late					
Catherine Creek	0.0	24.5	72.1	3.3	0.0
Lostine River	0.0	57.1	38.0	4.9	0.0
Minam River	0.0	40.1	46.1	13.8	0.0
Upper Grande Ronde River	0.0	18.2	70.9	10.9	0.0
Mean	**0.0**	**34.5**	**57.2**	**8.3**	**0.0**
CV (%)	**0.0**	**50.4**	**30.3**	**59.2**	**0.0**

Table 9. Travel time to Lower Granite Dam of wild steelhead PIT tagged at screw traps during spring 2009 and subsequently arriving at Lower Granite Dam (LGD) in 2009.

Stream	Distance to LGD (km)	Number detected	Travel time (d)		
			Median	Min	Max
Catherine Creek	362	64	27.3	6	65
Lostine River	274	65	6.7	3	58
Minam River	245	56	18.5	3	78
Upper Grande Ronde River	397	128	35.4	5	68

Table 10. Probability of surviving and migrating in the first year to Lower Granite Dam of steelhead PIT tagged at screw traps on Catherine Creek and the upper Grande Ronde, Lostine and Minam rivers during fall 2008 and spring 2009 (MY 2009).

Season and location tagged	Number tagged	Number detected	Probability of surviving and migrating in the first year (95% CI)
Fall			
Catherine Creek	517	57	0.259 (0.207–0.336)
Lostine River	584	51	0.167 (0.136–0.204)
Minam River	131	13	0.165 (0.103–0.258)
Upper Grande Ronde River	109	6	0.256 (0.165–0.464)
Spring (FL ≥ 115 mm)			
Catherine Creek	357	64	0.582 (0.495–0.694)
Lostine River	570	65	0.646 (0.563–0.754)
Minam River	350	56	0.670 (0.577–0.789)
Upper Grande Ronde River	612	128	0.573 (0.513–0.643)

Table 11. PIT-tagged early migrating steelhead sampled by screw trap in the Grande Ronde Basin, and the subset subsequently detected at Snake and Columbia River dams the following spring. Italicized headings represent smolt age at the 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	130	8	77	15	0
Lostine River	112	27	66	7	0
Minam River	28	39	46	14	0
Upper Grande Ronde River	59	8	63	27	2
Mean		**20.5**	**63.0**	**15.75**	**0.5**
CV (%)		**72.58**	**20.37**	**51.89**	**100.00**
PIT-tagged fish detected at dams (%)					
Catherine Creek	34	0	74	26	0
Lostine River	25	0	68	32	0
Minam River	4	0	75	25	0
Upper Grande Ronde River	20	0	60	40	0
Mean		**0.0**	**69.3**	**30.8**	**0.0**
CV (%)		**—**	**9.83**	**22.01**	**—**

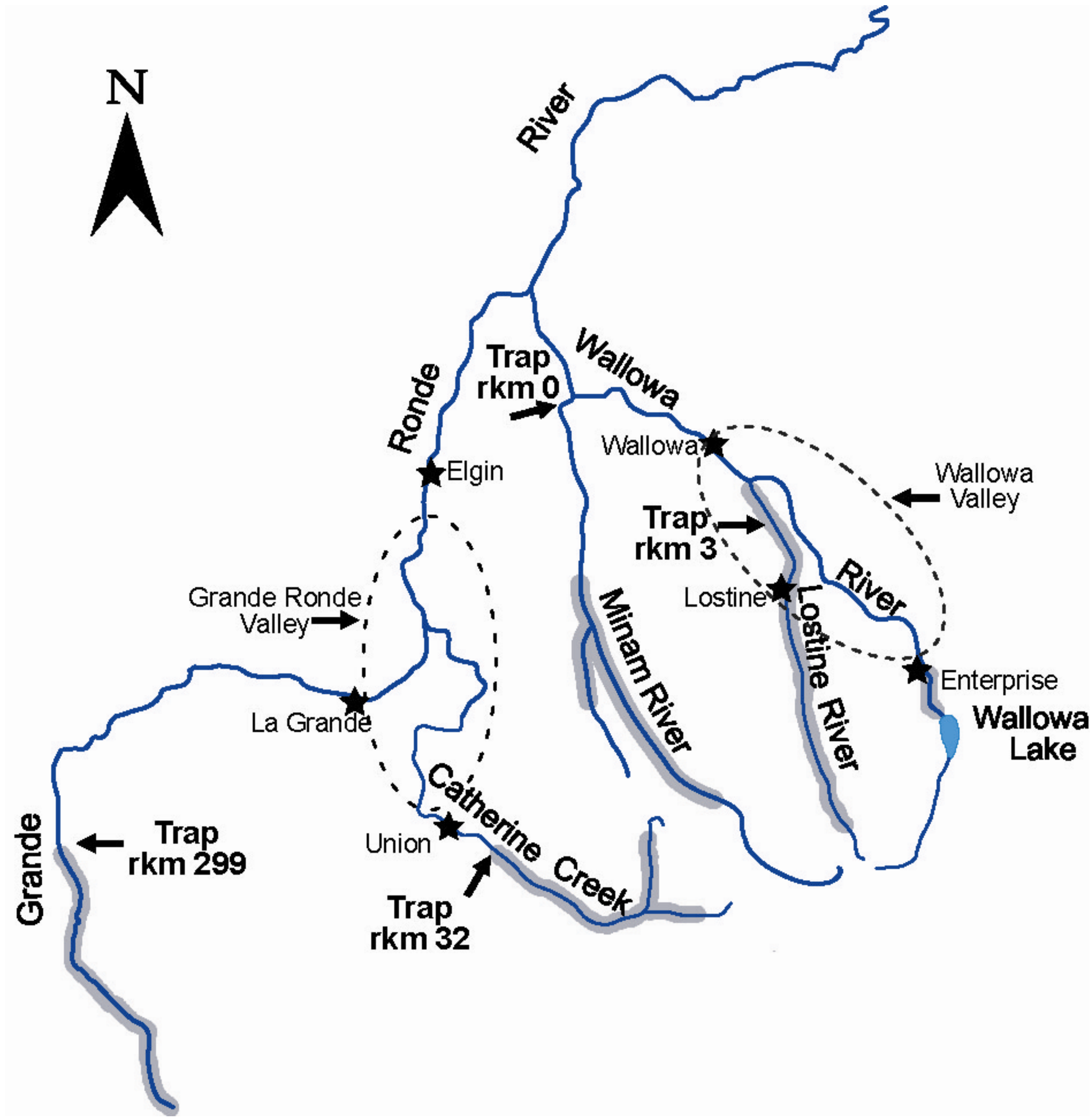

Figure 1. Locations of fish traps in the Grande Ronde River Subbasin during the study period. Shaded areas delineate spring Chinook salmon spawning and upper rearing areas in each study stream. Dashed lines indicate the Grande Ronde River and Wallowa River valleys.

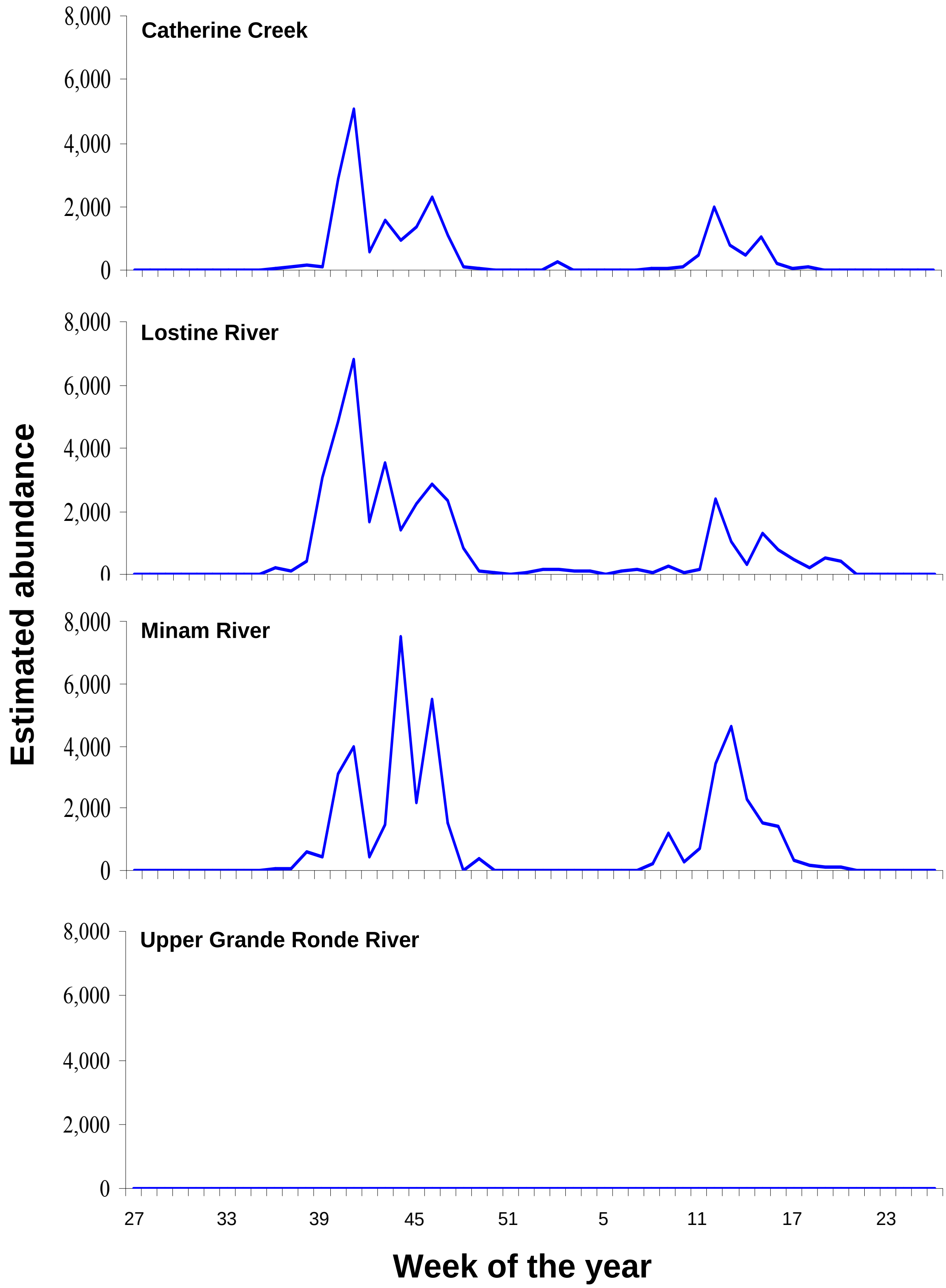

Figure 2. Estimated migration timing and abundance of juvenile spring Chinook salmon migrants captured by rotary screw traps during MY 2009. Traps were located at rkm 32 on Catherine Creek, rkm 3 on Lostine River, rkm 0 on Minam River and rkm 299 on upper Grande Ronde River.

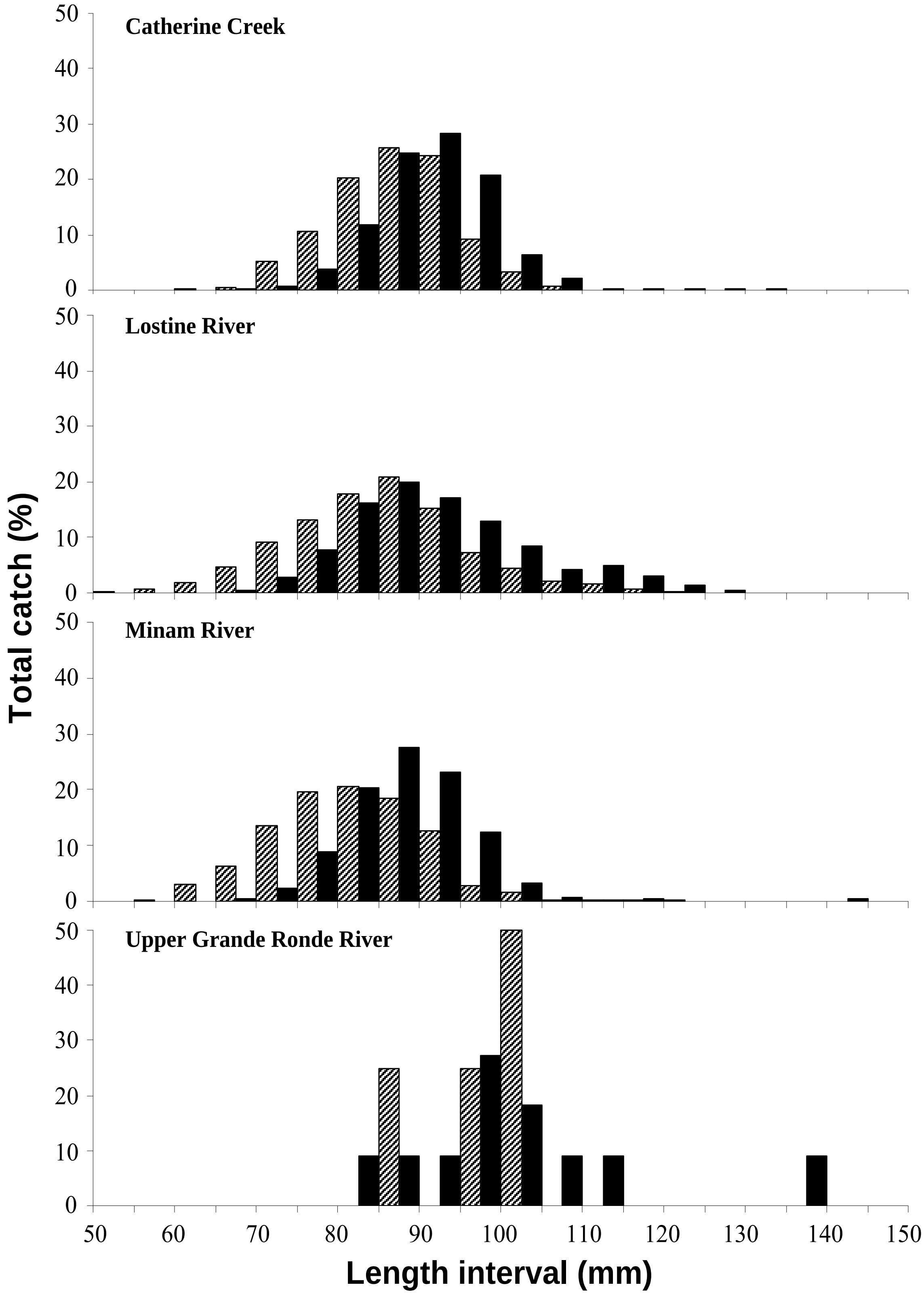

Figure 3. Length frequency distribution (fork length) of early and late migrating juvenile spring Chinook salmon captured at Catherine Creek (rkm 32), Lostine River (rkm 3), Minam River (rkm 0) and upper Grande Ronde River (rkm 299) traps during MY 2009.

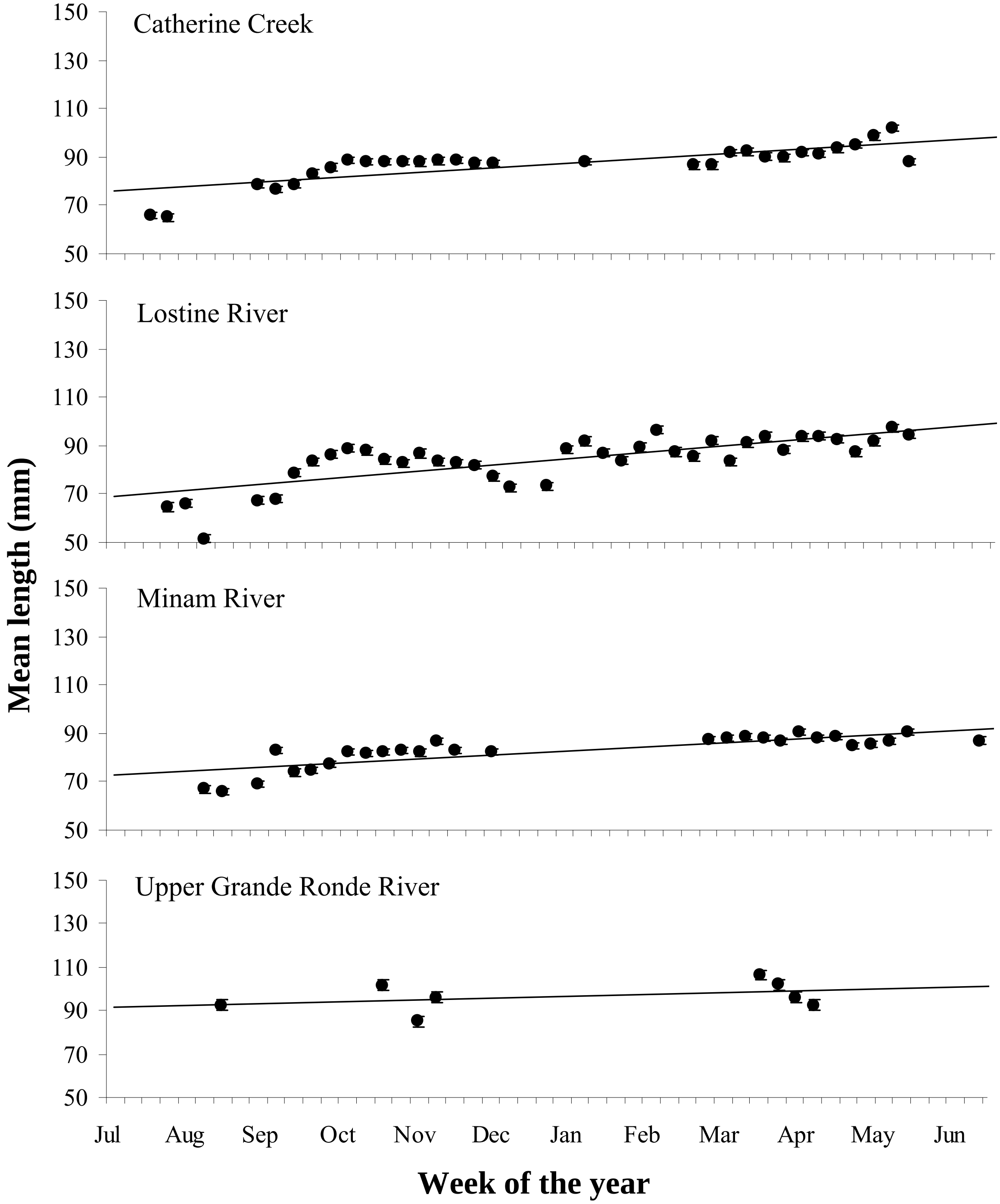

Figure 4. Weekly mean fork lengths (mm) and associated standard error for spring Chinook salmon captured by rotary screw traps in the Grande Ronde River Subbasin during MY 2009.

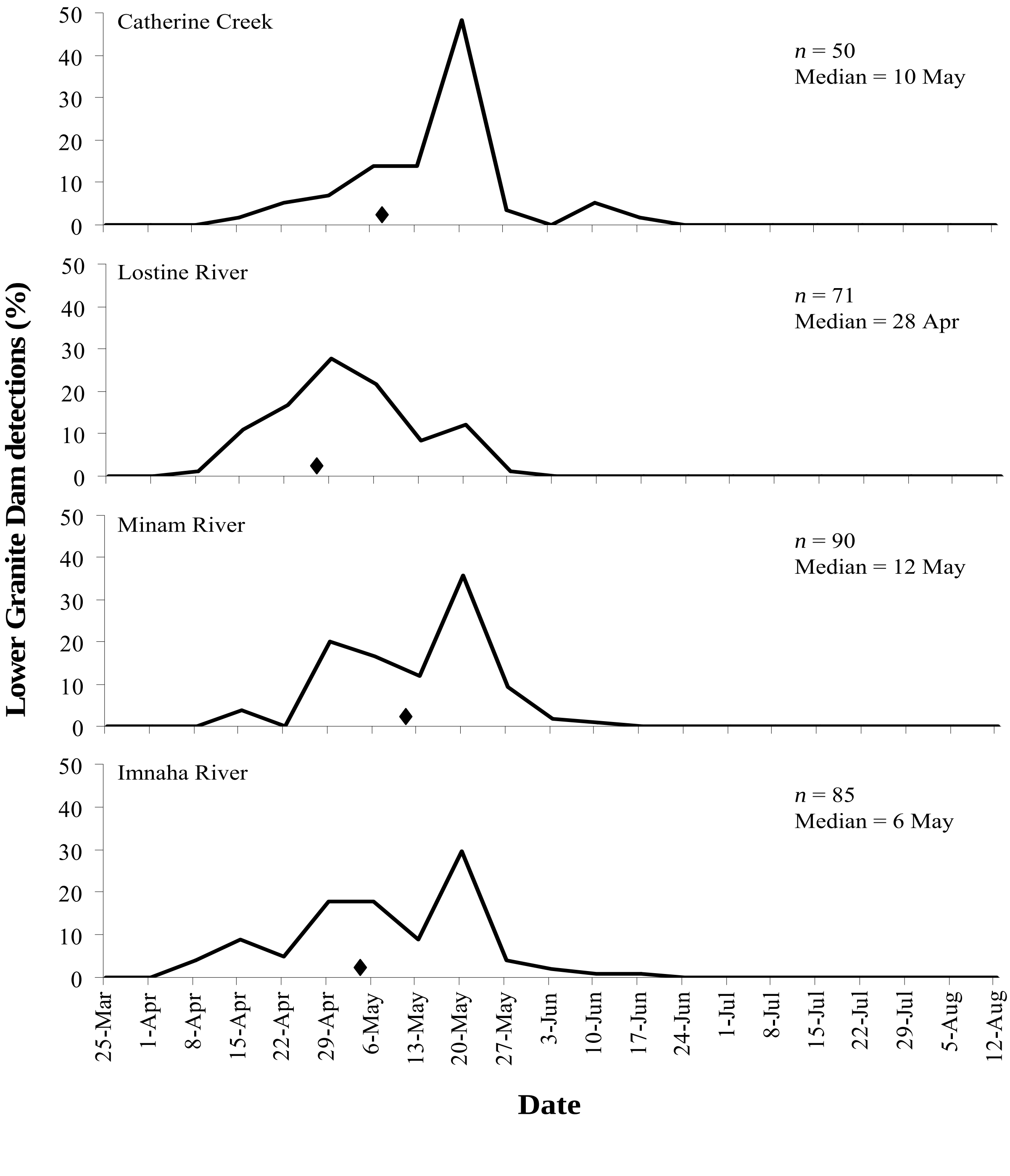

Figure 5. Dates of arrival, in 2009, at Lower Granite Dam of spring Chinook salmon PIT-tagged as parr in Catherine Creek and Lostine, Minam and Imnaha rivers during the summer of 2008. Data summarized by week and expressed as percentage of total detected for each group. ♦ = median arrival date. Detections were expanded for spillway flow.

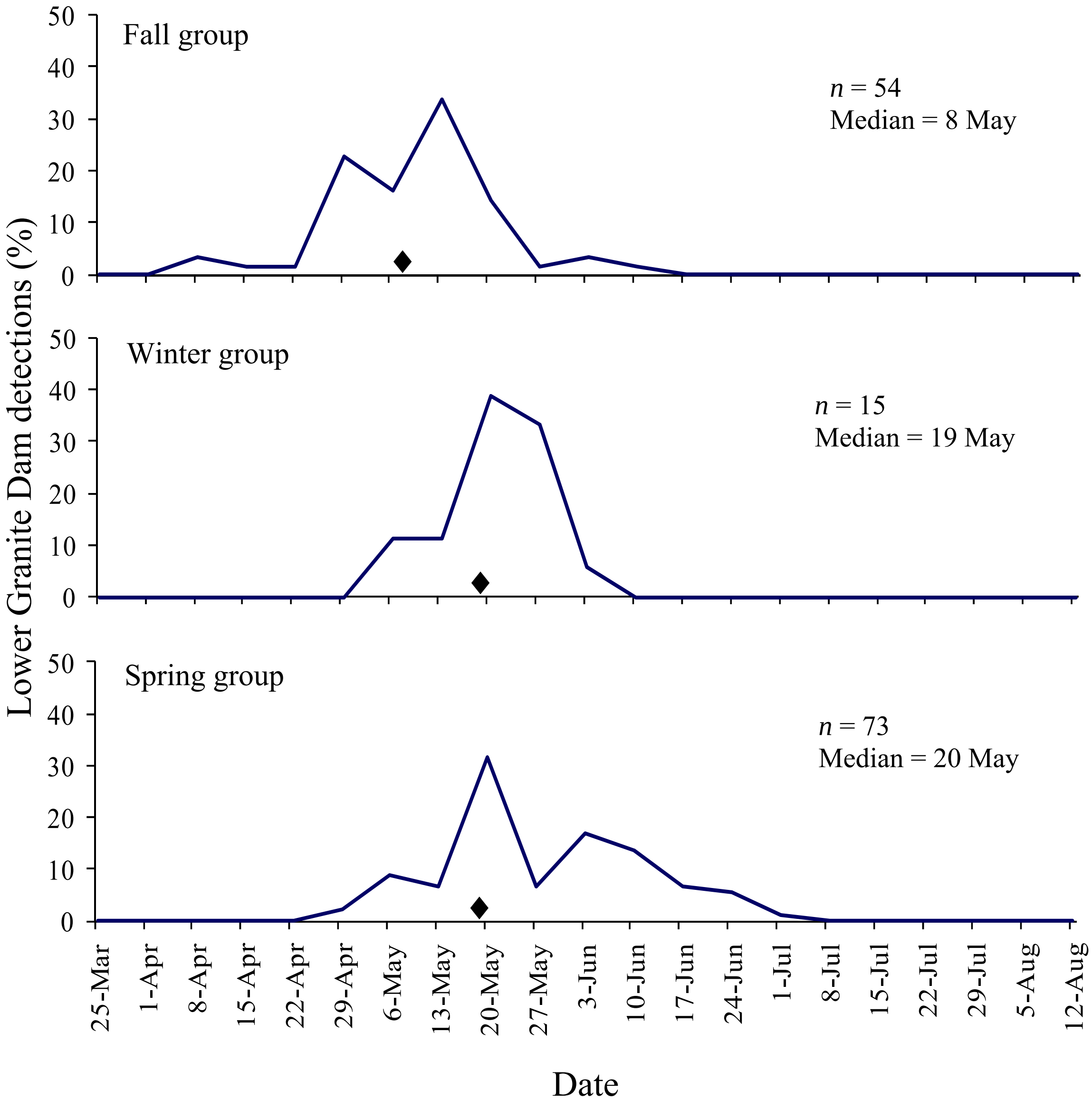

Figure 6. Dates of arrival, in 2009, at Lower Granite dam for fall, winter and spring tag groups of juvenile spring Chinook salmon PIT-tagged from Catherine Creek, expressed as percentage of total detected for each group. ♦ = median arrival date. Detections were expanded for spillway flow.

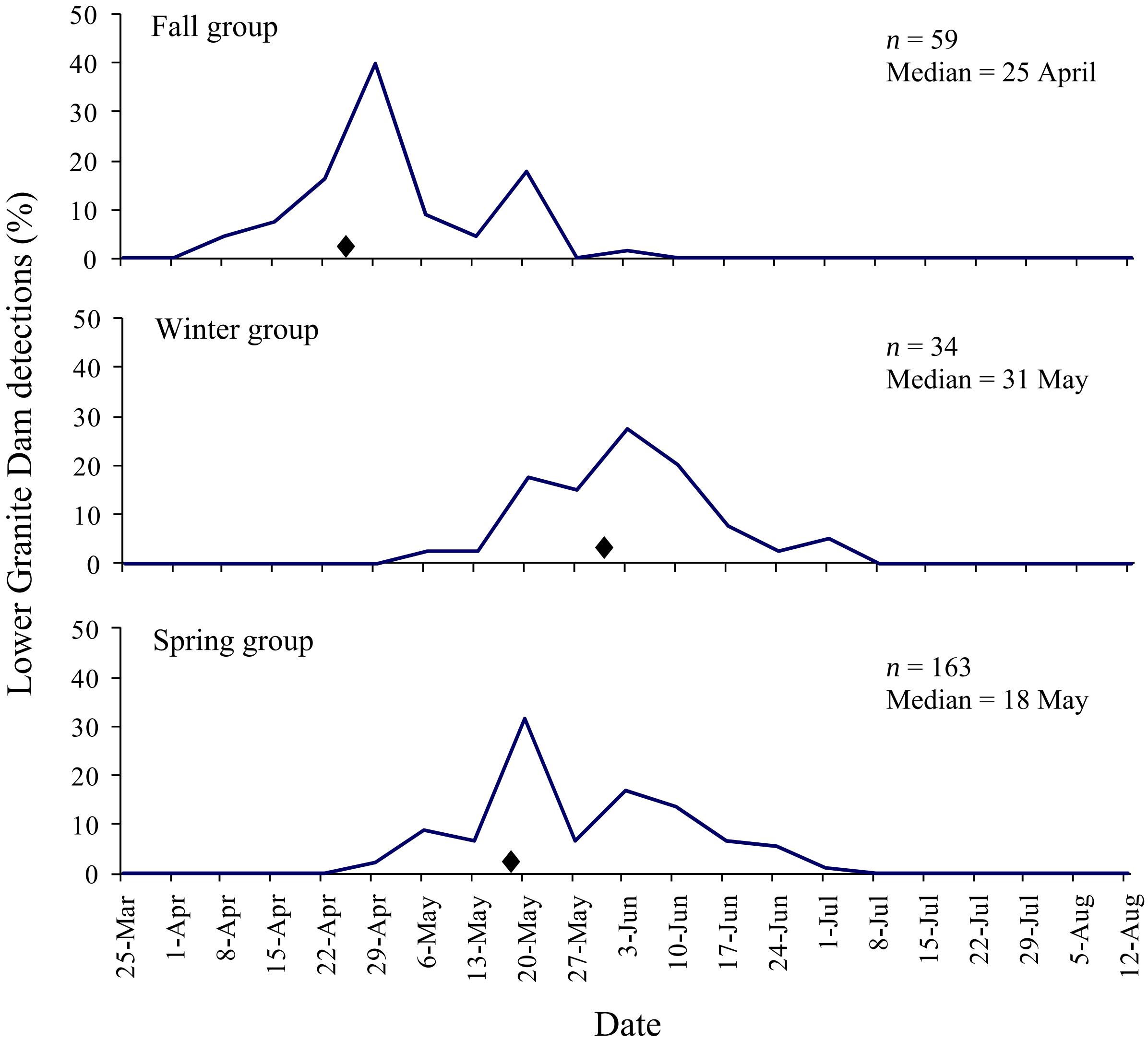

Figure 7. Dates of arrival, in 2009, at Lower Granite dam for fall, winter and spring tag groups of juvenile spring Chinook salmon PIT-tagged from Lostine River, expressed as percentage of total detected for each group. ♦ = median arrival date. Detections were expanded for spillway flow.

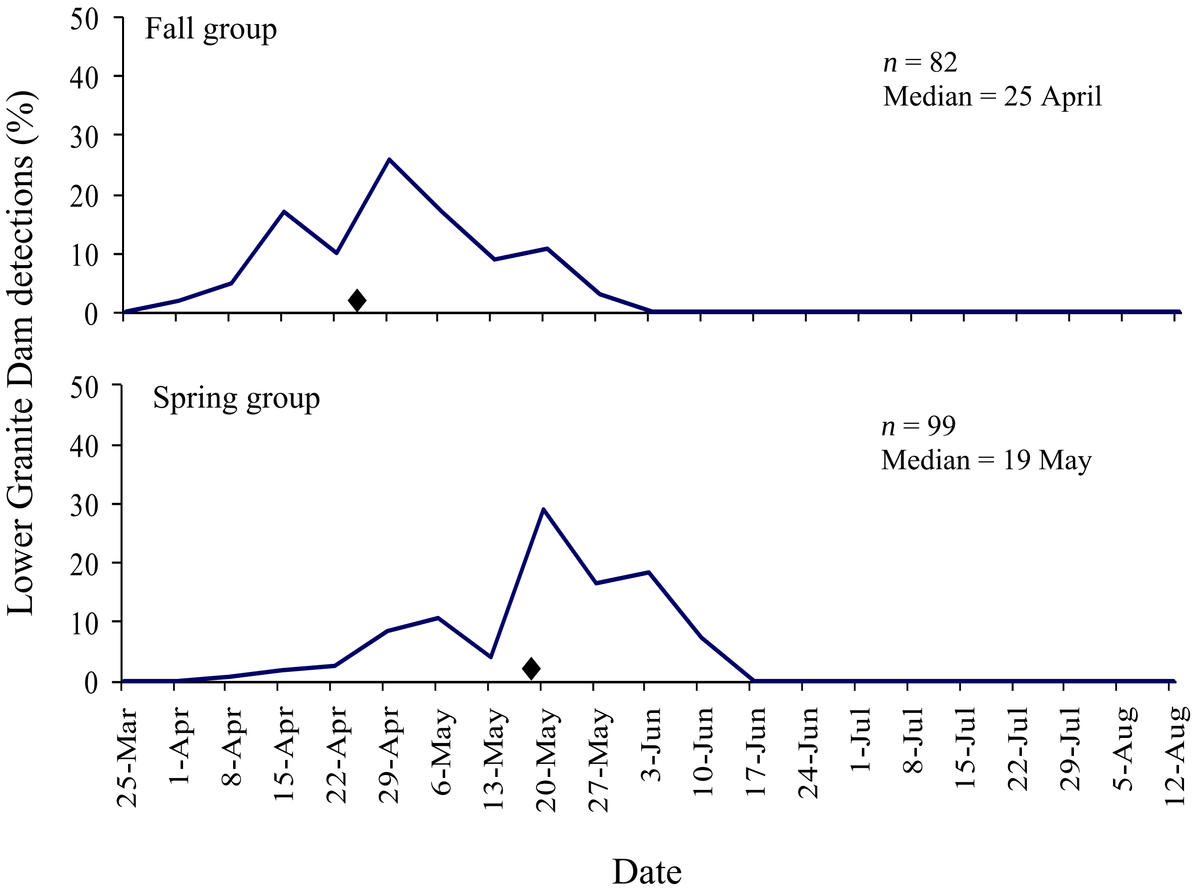

Figure 8. Dates of arrival, in 2009, at Lower Granite dam for fall and spring tag groups of juvenile spring Chinook salmon PIT-tagged from Minam River, expressed as percentage of total detected for each group. ♦ = median arrival date. Detections were expanded for spillway flow.

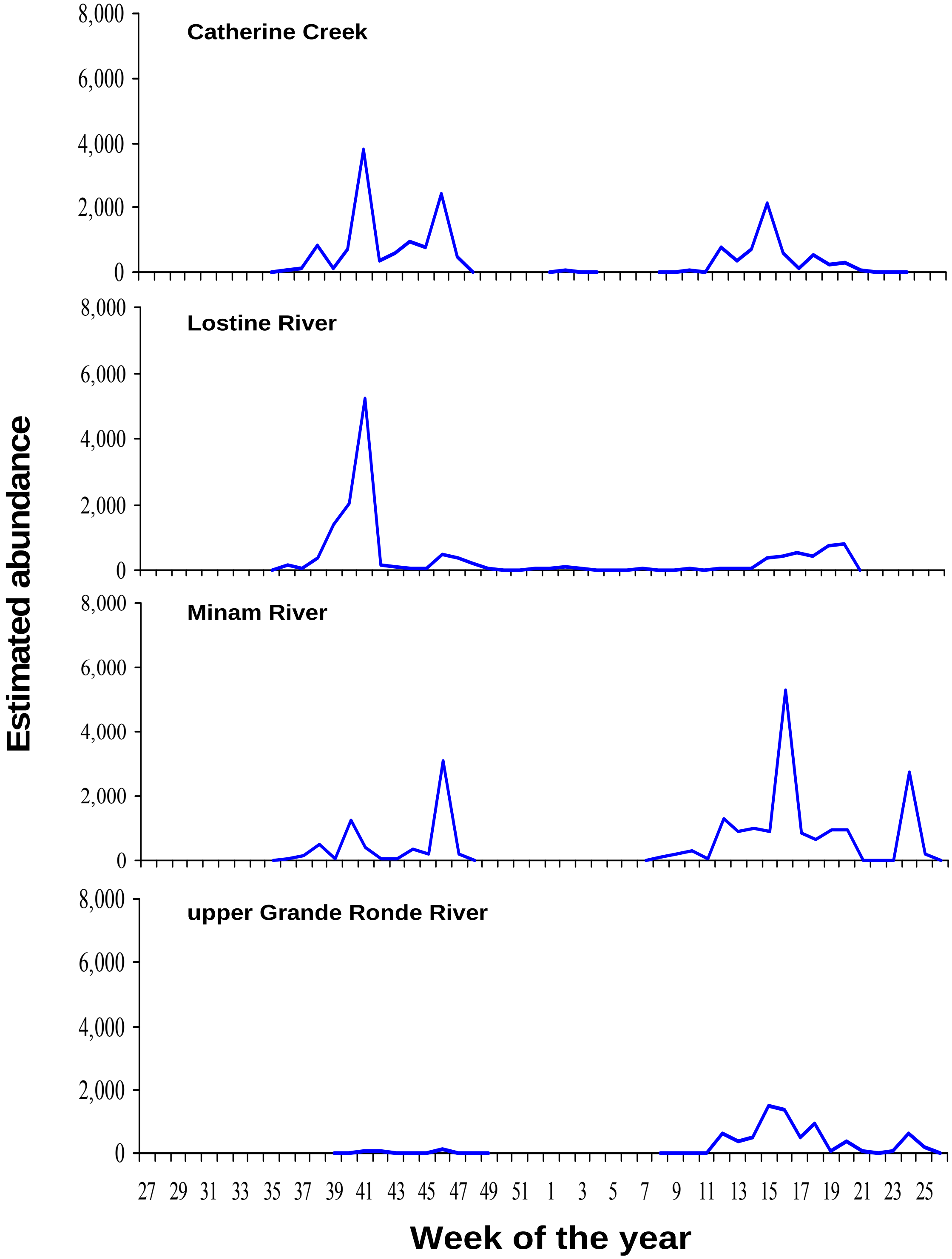

Figure 9. Estimated migration timing and abundance of juvenile summer steelhead migrants captured by rotary screw trap during MY 2009. Traps were operated at rkm 32 on Catherine Creek, rkm 3 on Lostine River, rkm 0 on Minam River and rkm 299 on upper Grande Ronde River.

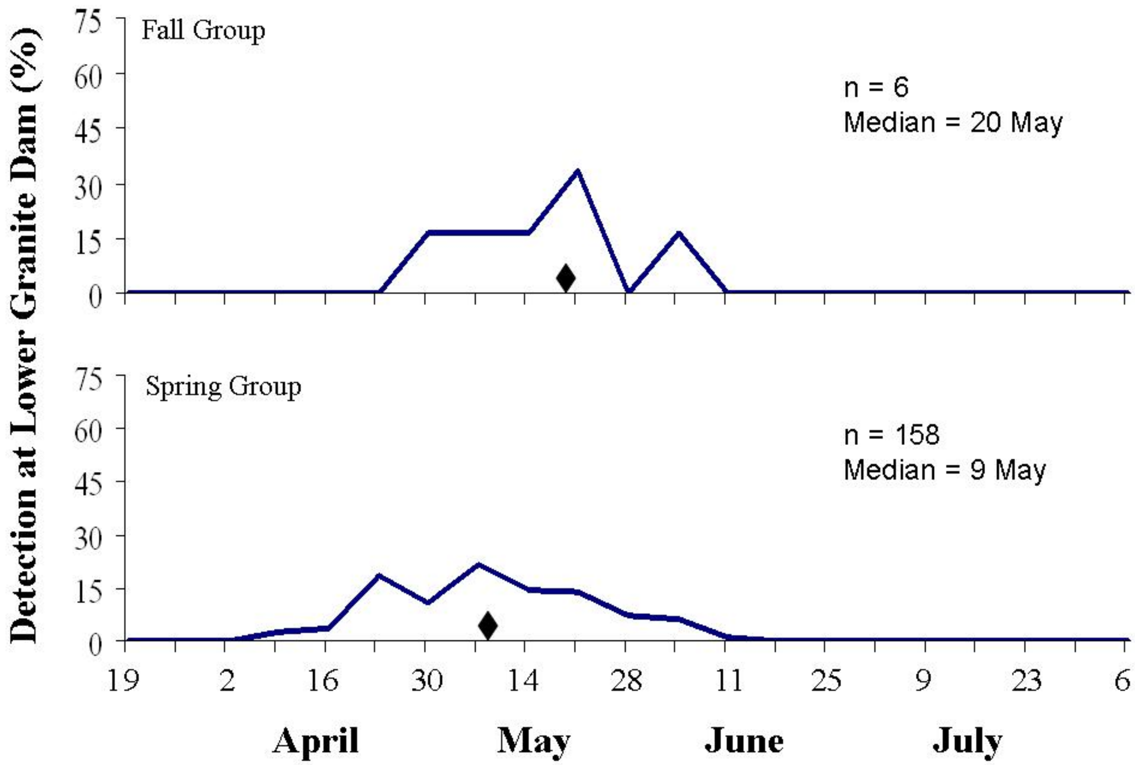

Figure 10. Dates of arrival, in 2009, at Lower Granite Dam for fall and spring tag groups of steelhead PIT-tagged in upper Grande Ronde River, expressed as a percentage of the total detected for each group. ♦ = median arrival date. Detections were expanded for spillway flow.

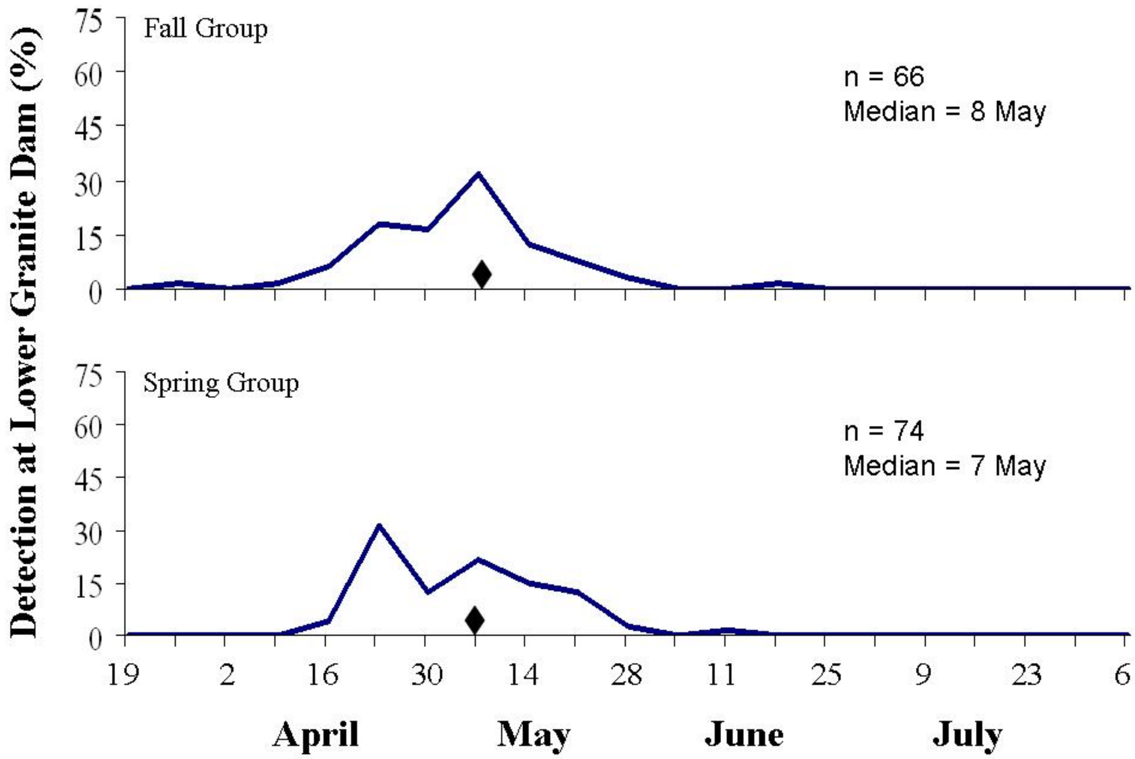

Figure 11. Dates of arrival, in 2009, at Lower Granite Dam for fall and spring tag groups of steelhead PIT-tagged in Catherine Creek, expressed as a percentage of the total detected for each group. ♦ = median arrival date. Detections were expanded for spillway flow.

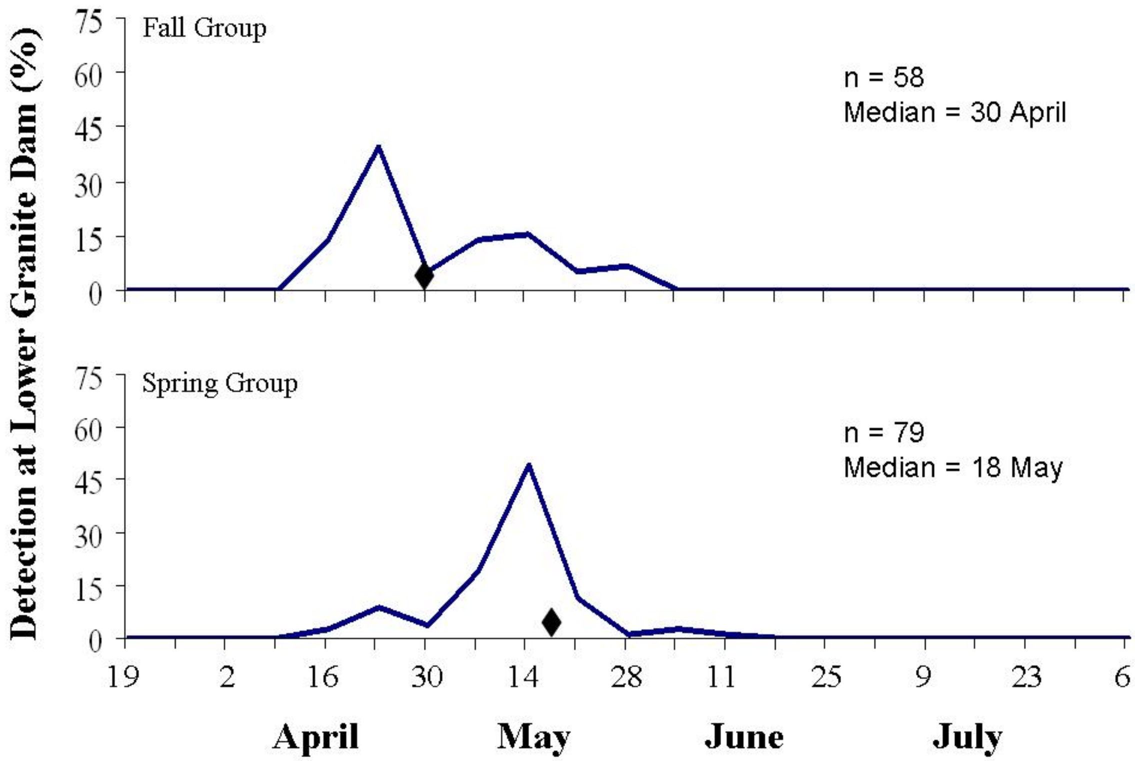

Figure 12. Dates of arrival, in 2009, at Lower Granite Dam for fall and spring tag groups of steelhead PIT-tagged in Lostine River, expressed as a percentage of the total detected for each group. ♦ = median arrival date. Detections were expanded for spillway flow.

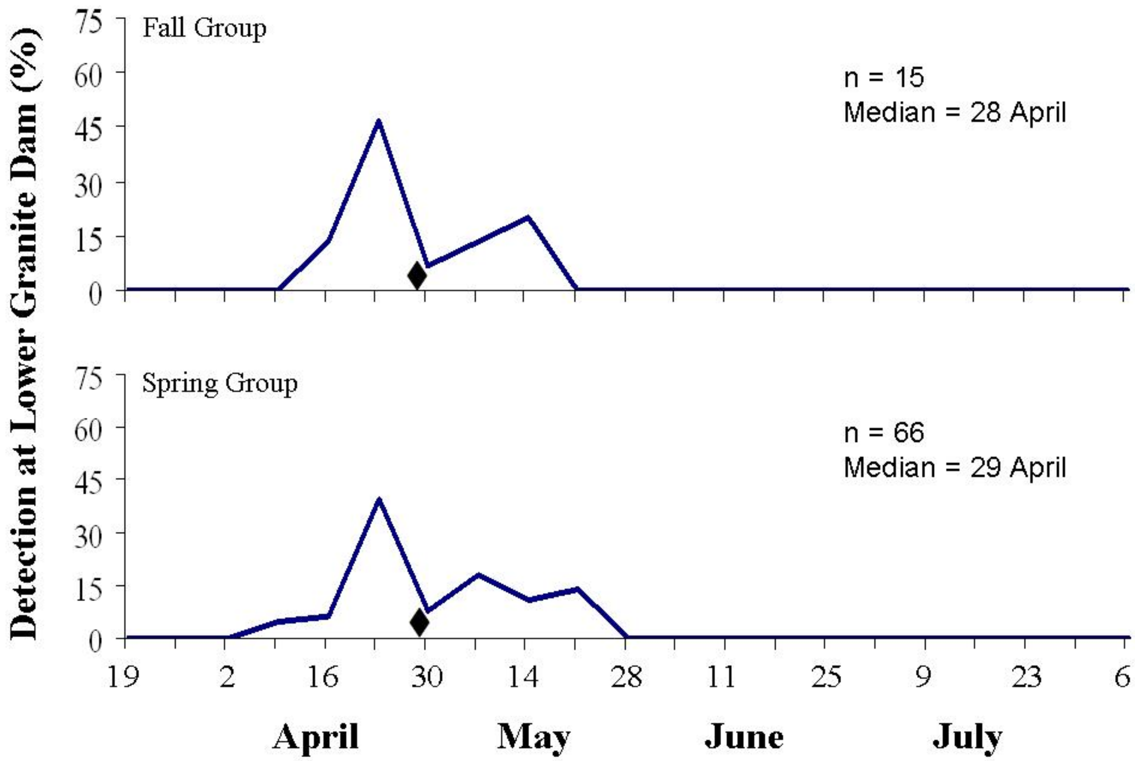

Figure 13. Dates of arrival, in 2009, at Lower Granite Dam for fall and spring tag groups of steelhead PIT-tagged in Minam River, and expressed as a percentage of the total detected for each group. ♦ = median arrival date. Detections were expanded for spillway flow.

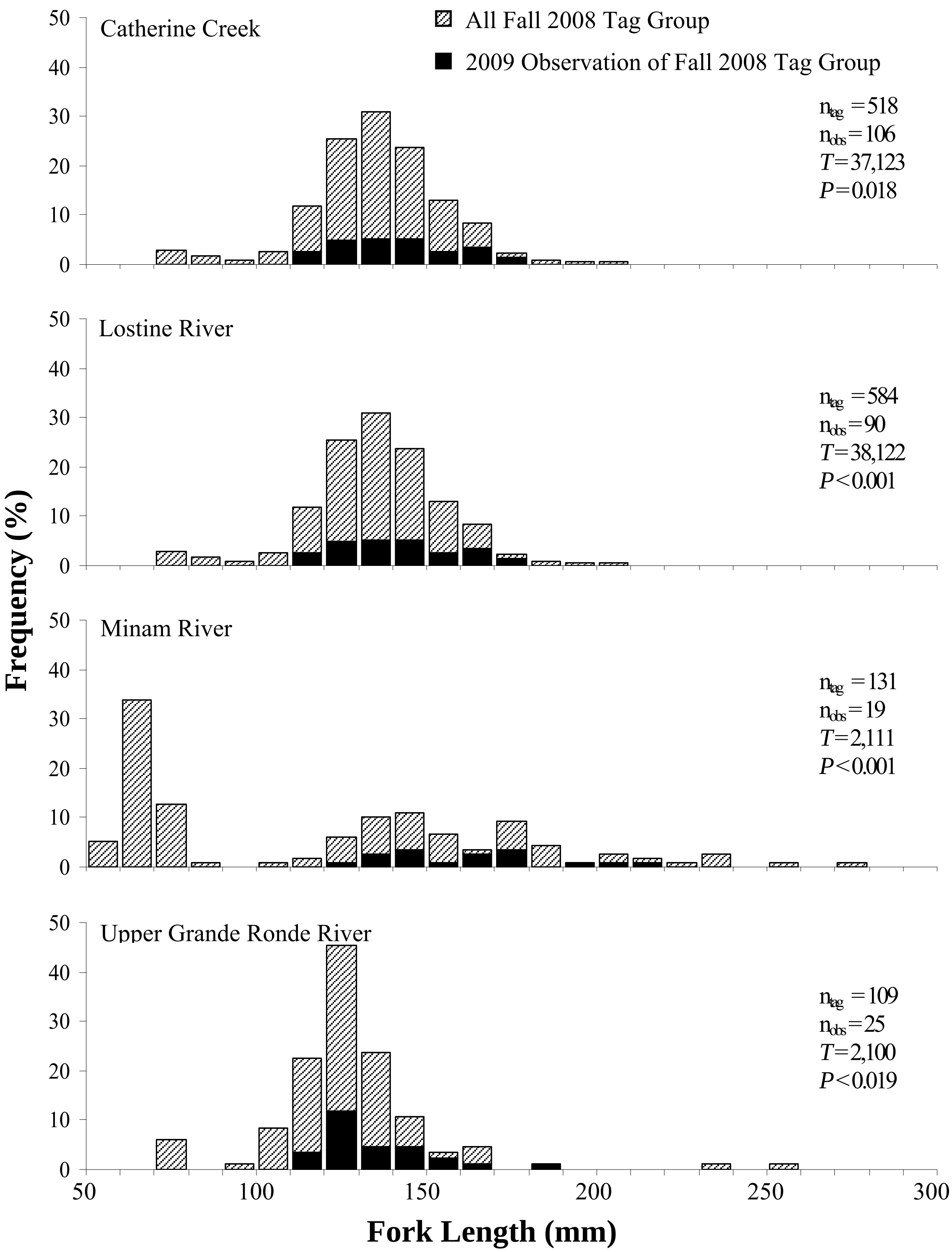

Figure 14. Length frequency distributions for all steelhead PIT-tagged at screw traps during fall 2008 and those subsequently observed at Snake River or Columbia River dams during spring 2009. Fork lengths are based on measurements taken at the time of tagging. Frequency is expressed as the percent of the total number tagged (n_{tag}). 'n_{obs}' is the number detected.

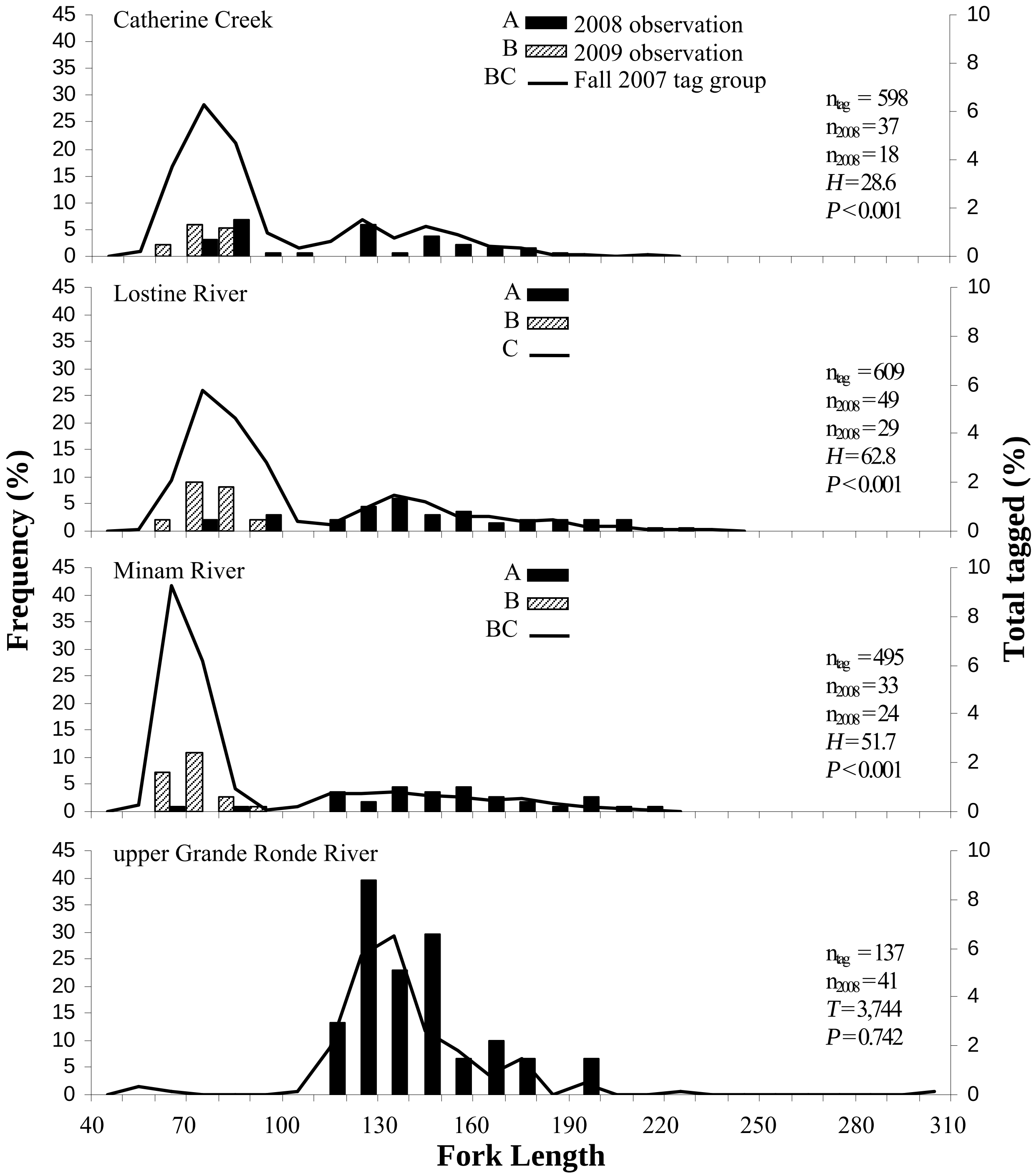

Figure 15. Length frequency distributions for all steelhead PIT-tagged at screw traps during fall 2007, and those subsequently observed at Snake River or Columbia River dams during 2008 and 2009. Frequency is expressed as the percent of the total number tagged. 'H' is the test statistic for the Kruskal–Wallis one-way ANOVA on ranks of the lengths. Dunn's all pair-wise multiple comparison procedure was employed to compare groups among Catherine Creek, Lostine, and Minam rivers (α = 0.05). For the upper Grande Ronde River, fork lengths were compared using the Mann-Whitney rank-sum test due to no spring 2009 detections.

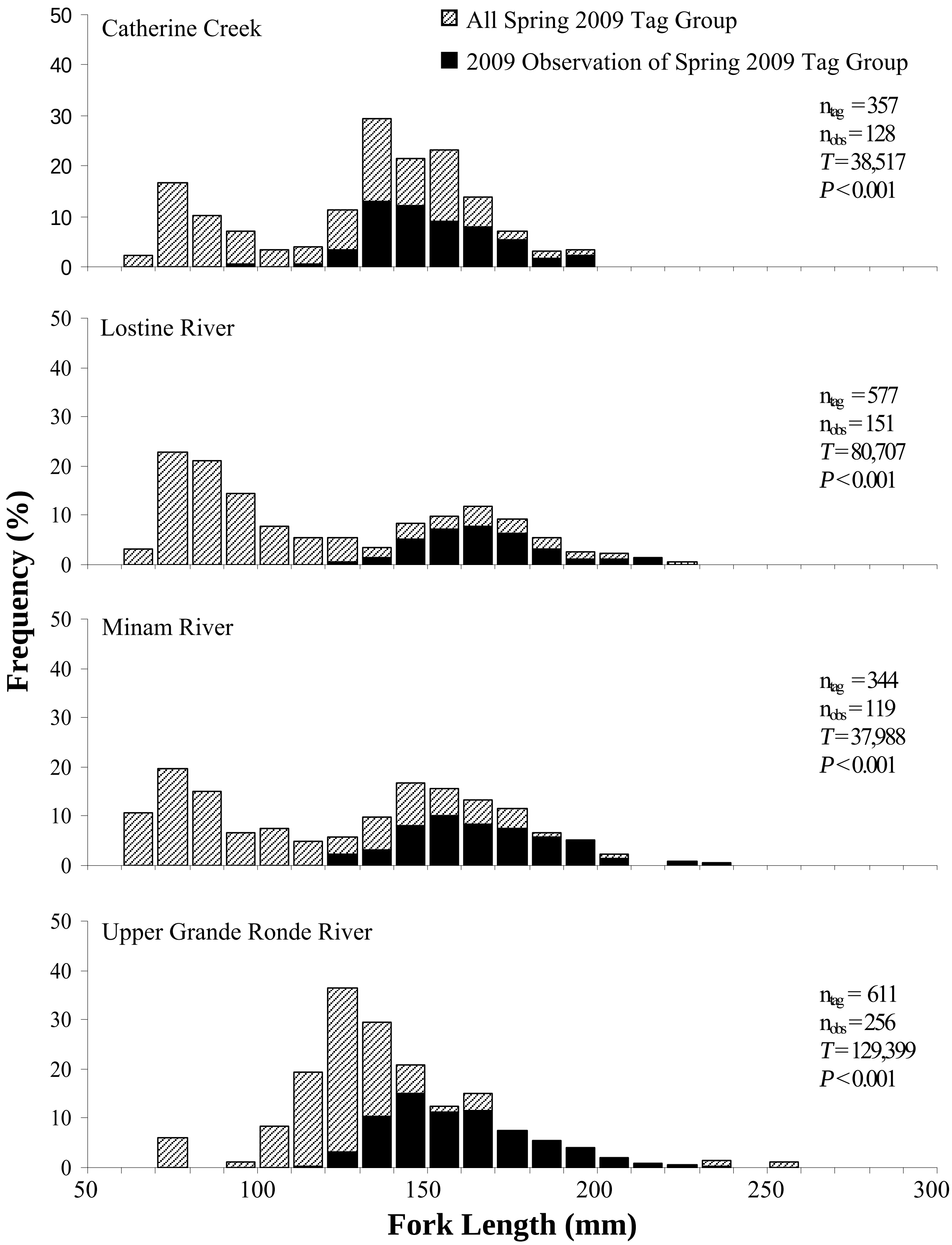

Figure 16. Length frequency distributions for all steelhead PIT-tagged at screw traps during spring 2009, and those subsequently observed at Snake or Columbia River dams during spring 2009 were compared using the Mann-Whitney rank-sum test. Fork lengths are based on measurements taken at the time of tagging. Frequency is expressed as percent of total number tagged (n_{tag}), and 'n_{obs}' represents number detected.

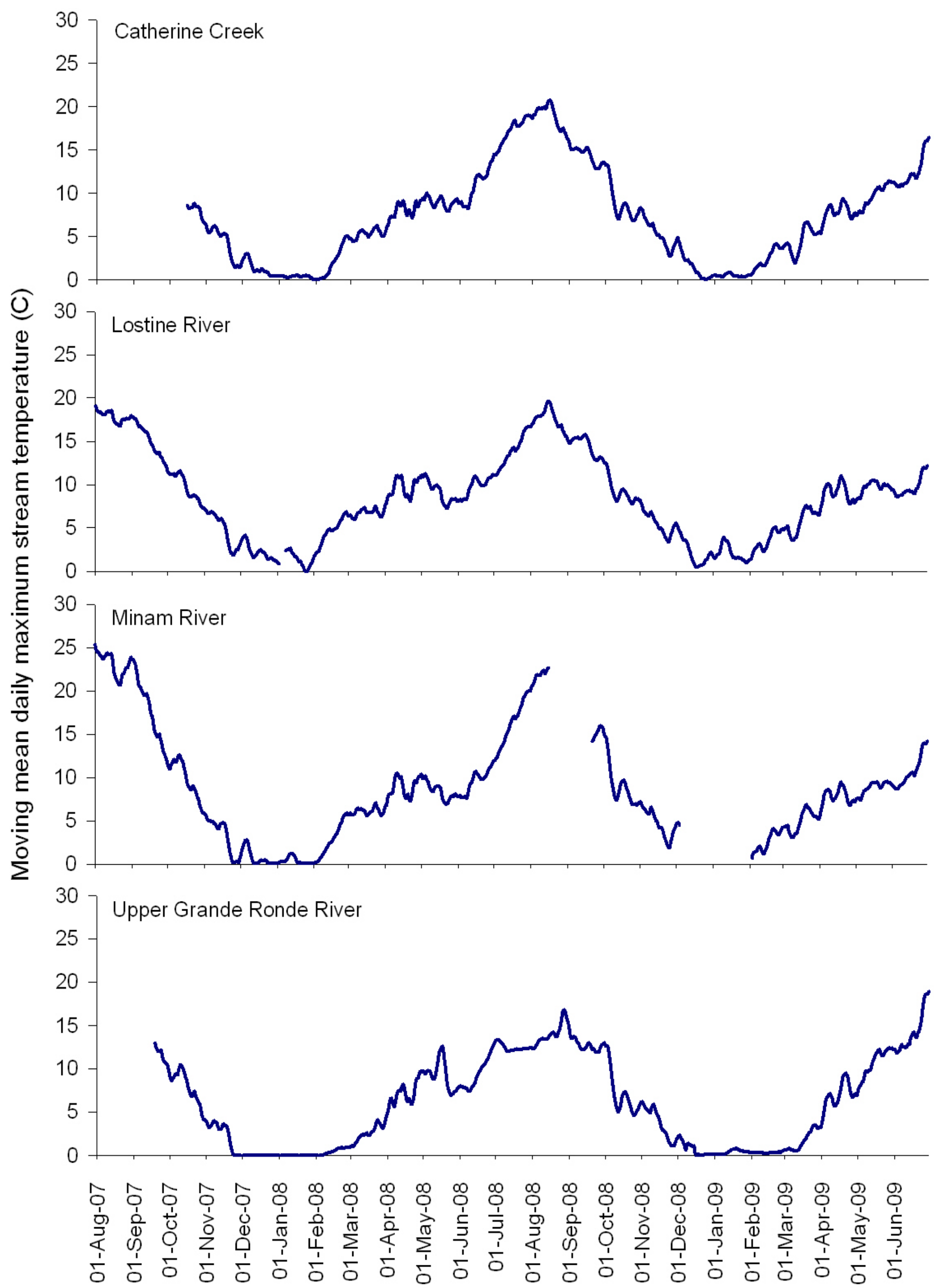

Figure 17. Moving mean of maximum water temperature during the in-basin life stages of egg-to-emigrant for juvenile spring Chinook salmon that migrated from four study streams in the Grande Ronde River basin during migration year 2009. Missing portions of a trend line represent periods where data were not available.

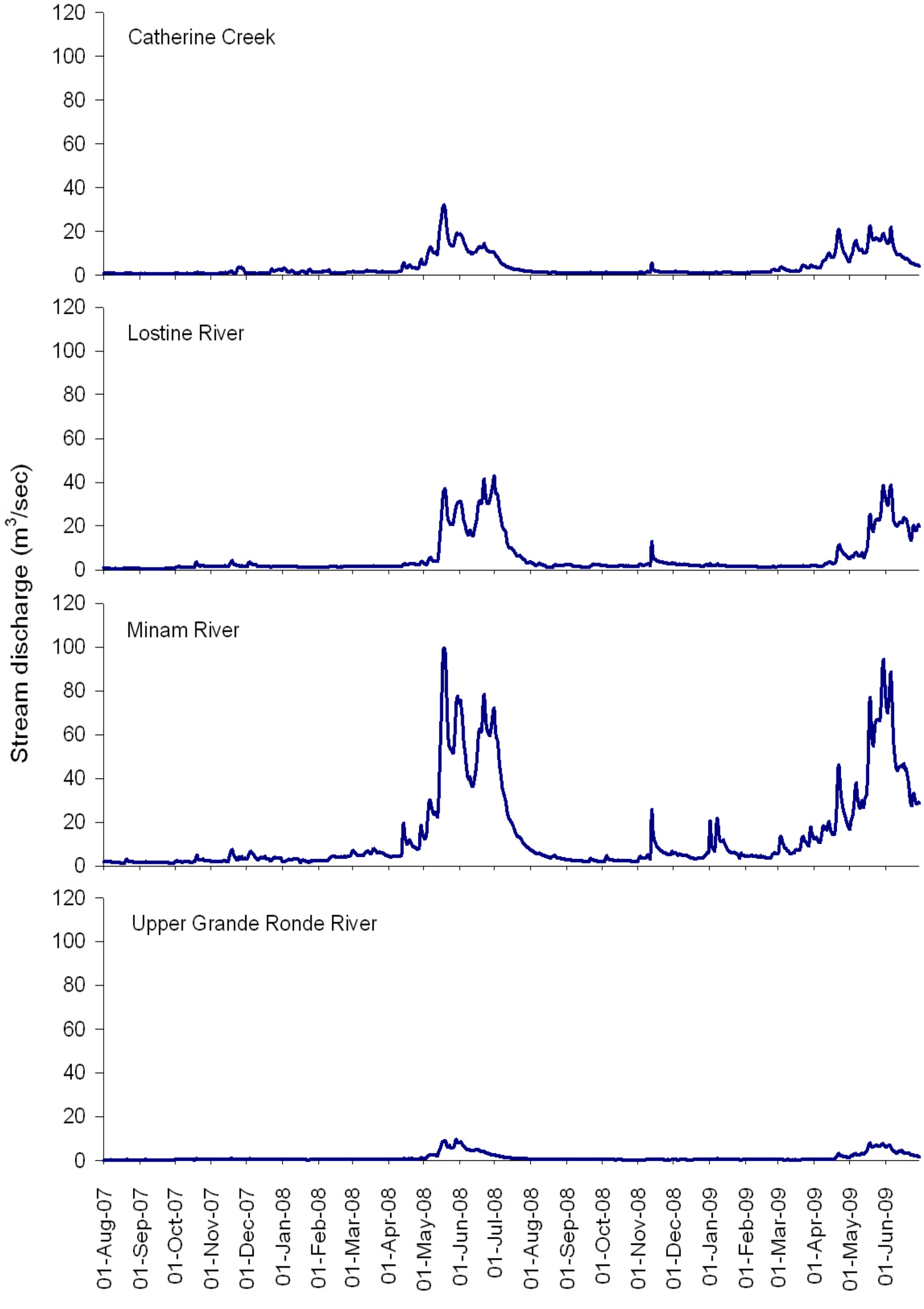

Figure 18. Average daily discharge during the in-basin life stages of egg-to-emigrant for juvenile spring Chinook salmon that migrated from four study streams in the Grande Ronde River basin during migration year 2009.

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 moving as late migrants past trap sites, 1994–2009. The early migratory period begins 1 July and ends 28 January, while the late migratory period begins 29 January and ends 30 June.

Stream, MY	Population estimate	95% CI	Median migration date: Early migrants	Median migration date: 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
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

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

Appendix Table A-1. Continued.

Stream and MY	Population estimate	95% CI	Median migration date: Early migrants	Median migration date: Late migrants	Percentage migrating late
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
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]

[c] Trap was located at rkm 257.
[d] Median date based on small sample size.

Appendix Table A-2. Dates of arrival at Lower Granite Dam (LGD) of spring Chinook salmon smolts PIT-tagged in upper rearing areas during the summer and winter, and at screw traps as early and late migrants during migratory years 1993–2009. Italics indicate that the median may be biased due to when fish were tagged. Numbers of fish detected at Lower Granite Dam were expanded for spillway flow to calculate the median arrival date.

					Arrival dates		
Stream and MY	Tag group	Migration period	Number tagged	Number detected at LGD	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
Imnaha River							
1993	Summer	All	1,000	74	14 May	15 Apr	23 Jun
1994	Summer	All	998	65	8 May	20 Apr	11 Aug
1995	Summer	All	996	41	2 May	10 Apr	7 Jul
1996	Summer	All	997	158	26 Apr	14 Apr	12 Jun
1997	Summer	All	1,017	98	19 Apr	31 Mar	2 Jun
1998	Summer	All	1,009	159	29 Apr	3 Apr	24 May
1999	Summer	All	1,009	41	8 May	17 Apr	3 Jun
2000	Summer	All	982	63	2 May	12 Apr	16 Jun

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.)							
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
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	506	19	15 May	29 Mar	29 May
	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	509	36	8 May	13 Apr	3 Jun
	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	489	87	9 May	10 Apr	12 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	501	23	20 Apr	28 Mar	29 May
	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	509	21	8 May	11 Apr	3 Jun
	Fall	Early	501	37	17 Apr	30 Mar	5 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.)							
	Winter	Late	564	22	7 May	11 Apr	23 Jun
	Spring	Late	406	61	7 May	15 Apr	11 Jun
2003	Summer	All	997	136	4 May	17 Apr	1 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
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

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.)							
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
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
Grande Ronde River (rkm 164)							
2002	Spring	NA	167	21	23 May	17 May	18 Jun
2003	Spring	NA	250	90	16 May	22 Apr	18 Jun
2004	Spring	NA	488	286	5 May	21 Apr	5 Jun
2005	Spring	NA	236	118	3 May	6 Apr	29 May
2006	Spring	NA	400	107	16-May	8-Apr	30-May
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	06 Aug

Appendix Table A-2. Continued.

Stream and MY	Tag group	Migration period	Number tagged	Number detected at LGD	Arrival dates Median	First	Last
Upper Grande Ronde River (rkm 299) (cont.)							
1995[a]	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
	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

[a] 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.)							
2009	Fall	Early	4	0	—	—	—
	Spring	Late	10	1	19 May	19 May	19 May
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. The number of PIT tagged spring Chinook salmon released by tag group and stream, and survival probability to Lower Granite Dam during migratory years 1993–2009. 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)
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)
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)
	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)
Minam River	1993	994	0.187 (0.115–0.230)
	1994	997	0.293 (0.249–0.350)
	1995	996	0.153 (0.124–0.191)
	1996	998	0.208 (0.169–0.264)
	1997	589	0.270 (0.181–0.693)
	1998	992	0.228 (0.199–0.259)
	1999	1,006	0.181 (0.155–0.210)
	2000	998	0.239 (0.199–0.292)
	2001	1,000	0.228 (0.202–0.256)
	2002	994	0.093 (0.074–0.119)
	2003	1,000	0.061 (0.044–0.088)
	2004	996	0.062 (0.047–0.080)
	2005	1,002	0.136 (0.114–0.160)
	2006	1,007	0.145 (0.119–0.178)
	2007	1,000	0.175 (0.147–0.211)
	2008	1,000	0.193 (0.166–0.224)
	2009	995	0.191 (0.162–0.219)
Upper Grande Ronde	1993	918	0.287 (0.237–0.365)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Summer			
Upper Grande Ronde (cont.)	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	—
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)
Lostine River	1997	519	0.312 (0.247–0.465)
	1998	500	0.448 (0.391–0.514)
	1999	501	0.422 (0.349–0.538)
	2000	514	0.317 (0.267–0.380)
	2001	498	0.335 (0.294–0.378)
	2002	500	0.326 (0.258–0.455)
	2003	854	0.287 (0.236–0.365)
	2004	0	—
	2005	500	0.267 (0.227–0.310)
	2006	495	0.269 (0.207–0.406)
	2007	500	0.223 (0.172–0.301)
	2008	499	0.265 (0.221–0.317)
	2009	501	0.312 (0.257–0.367)

[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			
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)
Upper Grande Ronde	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)
Wallowa River	1999	45	(a)
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)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Winter			
Catherine Creek (cont.)	2008	500	0.144 (0.108–0.207)
	2009	500	0.110 (0.063–0.157)
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)
Upper Grande Ronde	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)
	2007	482	0.169 (0.132–0.226)
	2008	83	0.361 (0.124–5.029)
	2009	0	—
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)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Spring trap			
Catherine Creek (cont.)	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)
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)
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)
Grande Ronde (Elgin)	2001	4	(a)
	2002	167	0.776 (0.624–1.073)
	2003	250	0.764 (0.668–0.893)
	2004	488	0.721 (0.677–0.764)
	2005	236	0.698 (0.625–0.776)
	2006	400	0.745 (0.666–0.881)
Upper Grande Ronde	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)

Appendix Table A-3. Continued.

Tag group and stream	MY	Number released	Survival probability (95% CI)
Spring trap			
Upper Grande Ronde (cont.)	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)

Appendix Table A-4. Travel time to Lower Granite Dam (LGD) of juvenile spring Chinook salmon PIT-tagged at screw traps in spring 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	26.6	119.3
2009		73	56.7	17.1	85.6
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	7.7	64.3
2009		163	37	10.5	77.6
Minam River	245				
2001		274	39.5	9	106
2002		42	32.4	5	52

[a] Limited trapping operations

Appendix Table A-4. Continued.

Stream and MY	Distance to LGD (km)	Number detected	Travel time (d)		
			Median	Min	Max
Minam River (cont.)					
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	7.8	74.1
2009		99	37.8	7.4	79.4
Grande Ronde River (rkm 164)	262				
2002		21	6.6	3	22
2003		90	8.6	3	35
2004		286	8.5	4	52
2005		118	20.3	4	51
2006		107	5.8	2	50
Upper Grande Ronde River (rkm 299)	397				
1994		93	45.1	17	130
1995[b]		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	37.4	92.1
2009		1	54.6	—	—

[b] 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 Grande Ronde River at rkm 299, except during MY 1995 when the upper Grande Ronde River trap was at rkm 257. Survival rates were calculated by dividing the 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	—

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 the upper Grande Ronde River, Catherine Creek and the Lostine River. 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 the exception of the 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 the fit of the null model (fall tag group survival = winter tag group survival) to the fit of the full model (fall tag group survival ≠ winter tag group survival).

	Catherine Creek		Lostine River		Upper Grande Ronde River	
MY	Area/life history with higher overwinter survival	*P*-value	Area/life history with higher overwinter survival	*P*-value	Area/life history with higher overwinter survival	*P*-value
1994	—	—	—	—	Equivalent	0.331
1995	Equivalent	0.278	—	—	Downstream/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	—	—

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

		Early migrants			Late migrants				
Stream, brood year	Migration year	Migrant abundance estimate	95% CI	Survival to LGD	Migrant abundance estimate	95% CI	Survival to LGD	Estimated smolt equivalents leaving tributary in spring	Estimated smolt equivalents at LGD
Catherine Creek									
1993	1995	8,966	1,337	0.238	8,667	1,577	0.506	12,884	6,519
1994	1996	4,985	440	0.358	1,872	529	0.591	4,892	2,891
1995	1997	4,029	1,118	0.365	413	103	0.413	3,974	1,641
1996	1998	7,058	1,140	0.238	2,823	403	0.517	6,072	3,139
1997	1999	12,607	2,010	0.202	7,704	1,115	0.448	13,388	5,998
1998	2000	19,769	2,156	0.212	4,222	914	0.452	13,494	6,099
1999	2001	18,996	2,213	0.130	2,940	558	0.376	9,508	3,575
2000	2002	21,183	2,846	0.154	2,179	373	0.527	8,369	4,411
2001	2003	29,763	2,399	0.120	4,860	1,039	0.365	14,645	5,345
2002	2004	53,712	3,796	0.126	10,300	1,804	0.413	26,687	11,022
2003	2005	50,630	6,500	0.122	5,467	1,680	0.445	19,348	8,610
2004	2006	22,823	2,176	0.074	4,365	934	0.367	8,967	3,291
2005	2007	10,936	788	0.203	2,895	677	0.310	10,056	3,117
2006	2008	20,502	1,700	0.153	5,649	1,231	0.380	13,904	5,283
2007	2009	16,618	2,723	0.269	5,056	1,328	0.491	14,160	6,953

Appendix Table A-7, continued.

Stream, brood year	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 in spring	Estimated smolt equivalents at LGD
Lostine River									
1995	1997	2,175	239	0.312	2,321	557	0.769	3,203	2,463
1996	1998	11,381	2,373	0.448	6,158	1,089	0.784	12,661	9,927
1997	1999	20,133	1,966	0.422	14,134	1,749	0.744	25,554	19,012
1998	2000	8,370	835	0.317	3,880	299	0.660	7,900	5,214
1999	2001	10,478	1,246	0.335	3,132	549	0.695	8,183	5,687
2000	2002	15,358	2,371	0.326	2,782	522	0.683	10,112	6,907
2001	2003	19,048	1,459	0.287	9,891	1,161	0.495	20,935	10,363
2002	2004[a]	—	—	—	—	—	—	—	—
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
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

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

Appendix Table A-7, continued.

Stream, brood year	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 in spring	Estimated smolt equivalents at LGD
Minam River (cont.)									
2004	2006	29,492	6,275	0.245	21,467	5,374	0.543	34,774	18,882
2005	2007	25,875	5,517	0.250	11,844	1,680	0.602	22,589	13,599
2006	2008	33,592	5,337	0.283	43,709	10,744	0.623	58,968	36,737
2007	2009	27,167	6,710	0.387	16,476	5,902	0.618	33,488	20,696
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)

[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 moving as late migrants past trap sites, 1997–2009 migratory years. The early migratory period begins 1 July of the preceding year and ends 28 January of the migratory year. The late migratory period begins 29 January and ends 30 June.

			Median migration date		
Stream and MY	Population estimate	95% CI	Early migrants	Late migrants	Late migrants (%)
Catherine Creek					
1997	25,229	4,774	23 Nov[a]	14 Apr	42[a]
1998	20,742	2,076	22 Sep	4 Apr	58
1999	19,628	3,549	2 Nov	15 Apr	75
2000	35,699	6,024	30 Oct	16 Apr	61
2001	20,586	4,082	24 Sep	31 Mar	56
2002	45,799	6,271	12 Oct	1 May	58
2003	29,593	5,095	14 Oct	18 May	59
2004	26,642	4,324	31 Oct	23 Apr	63
2005	27,192	5,686	15 Oct	20 May	66
2006	23,243	8,142	13 Oct	13 Apr	62
2007	13,715	1,704	16 Oct	4 May	27
2008	24,011	9,268	19 Oct	13 Apr	64
2009	17,098	3,198	14 Oct	10 Apr	35
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
Minam River					
2001	28,113	10,537	3 Oct[a]	28 Apr	86[a]
2002	44,872	19,786	24 Oct[a]	25 Apr	82[a]
2003	43,743	20,680	10 Nov[a]	1 May	99[a]
2004	24,846	13,564	29 Oct	28 Apr	97
2005	105,853	75,607	16 Sep	18 Apr	94
2006	103,141	62,607	2 Oct	22 Apr	78
2007	11,831	3,330	1 Oct	30 Apr	72

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

Appendix Table B-1. Continued.

Stream and MY	Population estimate	95% CI	Median migration date: Early migrants	Median migration date: Late migrants	Late migrants (%)
Minam River (cont.)					
2008	62,675	21,725	19 Oct	30 Apr	81
2009	22,940	9,167	13 Nov	21 Apr	72
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

Appendix Table B-2. Dates of arrival at Lower Granite Dam of steelhead PIT tagged upstream of the screw trap in Catherine Creek and tributaries during summer, and at screw traps in the fall and spring during the same migratory year, 2000–2009. The numbers of fish detected were expanded for spillway flow to calculate the 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
Lostine River						
2000	Fall	777	116	10 May	26 Mar	16 Jun
	Spring	532	166	6 May	13 Apr	13 Jun
2001	Fall	421	13	12 May	16 Apr	13 Jun
	Spring	345	164	14 May	13 Apr	18 Aug
2002	Fall	837	40	8 May	10 Apr	24 Jun
	Spring	351	72	23 May	19 Apr	30 Jun

Appendix Table B-2. Continued.

Stream and MY	Tag group	Number tagged	Number detected	Arrival dates Median	First	Last
Lostine River cont.						
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
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
	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
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

[a] Limited trapping operations during MY 2004.

Appendix Table B-2. Continued.

Stream and MY	Tag group	Number tagged	Number detected	Median	Arrival dates First	Last
Upper Grande Ronde River (cont.)						
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	—	—
	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

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

Tag group and stream	MY tagged	Number tagged	Number detected: MY	Number detected: MY + 1	Number detected: MY + 2	Probability of surviving and migrating in the first year (95% CI)
Summer						
Catherine Creek						
	2001	413	22	7	0	0.056 (0.012–0.083)
	2002	838	65	9	0	0.101 (0.075–0.140)
	2003	510	23	7	0	0.048 (0.031–0.071)
	2004	527	42	18	0	0.081 (0.059–0.108)
	2005	704	58	3	0	0.082 (0.063–0.104)
	2006	418	40	1	0	0.138 (0.090–0.252)
	2007	334	10	1	—	0.072 (0.024–0.992)
Little Catherine Creek						
	2001	415	0	3	0	(a)
	2007	275	1	1	—	(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	—	0.045 (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 MY	Number detected MY + 1	Number detected MY + 2	Probability of surviving and migrating in the first year (95% CI)
Fall						
Catherine Creek (cont.)						
	2005	473	44	2	0	0.087 (SE=0.013)
	2006	934	61	12	0	0.077 (0.058–0.110)
	2007	859	59	8	—	0.084 (0.059–0.155)
	2008	600	37	—	—	0.079 (0.052–0.142)
	2009	517	57	—	—	0.259 (0.207–0.336)
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	—	0.160 (0.110–0.279)
	2008	599	49	—	—	0.082 (SE = 0.011)
	2009	584	51	—	—	0.167 (0.136–0.204)
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	—	(a)
	2008	495	33	—	—	0.090 (0.057 = 0.173)
	2009	131	13	—	—	0.165 (0.103–0.258)
Upper Grande Ronde River						
	2000	110	16	0	0	0.227 (0.118–0.650)
	2001	61	12	0	0	0.223 (0.122–0.398)
	2002	165	21	1	0	0.185 (0.108–0.387)
	2003	309	17	1	0	0.094 (0.043–0.956)
	2004	108	1	1	0	0.009 (SE = 0.009)
	2005	288	20	2	0	0.071 (SE=0.016)
	2006	53	5	0	0	0.094 (SE = 0.040)
	2007	485	34	12	—	0.121 (0.065–0.488)
	2008	136	41	—	—	0.420 (0.294–0.657)
	2009	109	6	—	—	0.256 (0.165–0.464)
Spring (FL ≥ 115 mm)						
Catherine Creek						
	2000	305	104	2	0	0.490 (0.392–0.630)

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)						
Catherine Creek (cont.)						
	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	—	0.179 (0.108–0.546)
	2008	128	48	—	—	0.520 (0.358–1.002)
	2009	357	64	—	—	0.582 (0.495–0.694)
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	—	(a)
	2008	128	76	—	—	0.714 (0.576–0.967)
	2009	570	65	—	—	0.646 (0.563–0.754)
Minam River						
	2001	442	269	8	0	0.632 (0.584–0.680)
	2002	197	109	1	0	0.722 (0.598–0.898)
	2003	500	272	0	0	0.662 (0.590–0.753)
	2004	120	68	2	0	0.588 (0.493–0.686)
	2005	161	91	3	0	0.566 (0.485–0.647)
	2006	274	168	1	0	0.665 (0.584–0.809)
	2007	178	68	2	—	0.684 (0.432–1.638)
	2008	291	175	—	—	0.819 (0.689–1.027)
	2009	350	56	—	—	0.670 (0.577–0.789)
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	—	0.315 (0.246–0.453)
	2008	578	263	—	—	0.626 (0.588–0.708)
	2009	612	128	—	—	0.573 (0.513–0.643)

Appendix Table B-3. Continued.

Tag group and stream	MY tagged	Number tagged	Number detected MY	MY + 1	MY + 2	Probability of surviving and migrating in the first year (95% CI)
Spring (FL < 115 mm)						
Catherine Creek						
	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	—	(a)
	2008	476	9	—	—	0.019 (SE=0.006)
	2009	96	0	—	—	(a)
Lostine River						
	2000	84	0	9	0	(a)
	2001	21	1	1	0	(a)
	2002	0	0	0	0	(a)
	2003	1	0	0	0	(a)
	2005	142	0	24	0	(a)
	2006	89	1	16	0	(a)
	2007	172	0	26	—	(a)
	2008	345	3	—	—	0.009 (SE=0.005)
	2009	302	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	—	(a)
	2008	300	0	—	—	(a)
	2009	146	0	—	—	(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	—	(a)
	2008	83	0	—	—	(a)

Appendix Table B-3. Continued.

Tag group and stream	MY tagged	Number tagged	Number detected MY	MY + 1	MY + 2	Probability of surviving and migrating in the first year (95% CI)
Spring (FL < 115 mm)						
Upper Grande Ronde (cont.)						
	2009	78	0	—	—	(a)

Appendix Table B-4. Steelhead fork lengths during tagging at screw traps on Catherine Creek and upper Grande Ronde, Lostine, and Minam rivers during the early migration period 1999–2008, summarized by dam detection history.

			Length at tagging (mm)				
Stream and year	Year				Percentile		
tagged	detected	*N*	Median	Min	25th	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
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
	2002	18	86	65	80	89	106
2001	(a)	824	100	60	85	155	262

[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	Percentile 75th	Max
Lostine River (cont.)							
	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
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
	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

[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.)							
	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
Upper Grande Ronde River							
1999	(a)	108	133	71	122	148	205
2000	(a)	60	124	86	101	145	180
	2001	12	152	115	134	161	180
2001	(a)	165	115	62	80	130	193
	2002	21	130	110	120	150	163
	2003	1	111	—	—	—	—
2002	(a)	309	111	63	76	131	200
	2003	17	133	120	125	140	155
	2004	1	77	—	—	—	—
2003	(a)	108	77	61	71	110	160
	2004	1	113	—	—	—	—
	2005	1	70	—	—	—	—
2004	(a)	288	114	62	90	125	179
	2005	20	127	101	118	137	159
	2006	2	81	72	77	86	90
2005	(a)	53	113	63	73	128	190
	2006	5	136	110	127	176	190
2006	(a)	478	112	54	87	123	190
	2007	33	131	99	119	140	180
	2008	12	104	79	87	112	130
2007	(a)	136	132	59	126	148	309
	2008	41	132	112	126	148	199
2008	(a)	109	126	71	118	134	257
	2009	25	129	114	127	142	181

Appendix Table B-5. Steelhead fork lengths during tagging at screw traps on Catherine Creek and upper Grande Ronde, Lostine, and Minam rivers during the late migration period 2000–2009, summarized by dam detection history.

			Length at tagging (mm)				
					Percentile		
Stream and year tagged	Year detected	*N*	Median	Min	25th	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
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

[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) *N*	Median	Min	Percentile 25th	75th	Max
Lostine River (cont.)							
	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
Minam River							
2001	(a)	442	160	115	144	177	227
	2001	269	167	124	151	183	227
	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

Appendix Table B-5. Continued.

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

Appendix Table B-5. Continued.

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

Appendix Table B-6. Steelhead fork lengths during tagging in rearing areas upstream of the screw trap on Catherine Creek and its tributaries during summer 2000-2006, summarized by migration history.

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

Appendix Table B-6. Continued.

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

Appendix Table B-6. Continued.

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