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Investigations into the Early Life-history of Naturally Produced Spring Chinook Salmon and Summer Steelhead in the Grande Ronde River

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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

We determined migration timing and abundance of juvenile spring Chinook salmon *Oncorhynchus tshawytscha* using rotary screw traps on four streams in the Grande Ronde Subbasin during the 2002 migratory year (MY 2002) from 1 July 2001 through 30 June 2002. Based on migration timing and abundance, two distinct life-history strategies of juvenile spring Chinook salmon could be distinguished. 'Early' migrants left upper rearing areas from 1 July 2001 through 28 January 2002 with a peak in the fall. 'Late' migrants left upper rearing areas from 29 January 2002 through 30 June 2002 with a peak in the spring. At the upper Grande Ronde River trap, we estimated 9,133 juvenile spring Chinook salmon migrated out of upper rearing areas with 18% leaving as early migrants. At the Catherine Creek trap, we estimated 23,362 juvenile spring Chinook salmon migrated out of upper rearing areas with 91% leaving as early migrants. At the Lostine River trap, we estimated 18,140 juvenile spring Chinook salmon migrated out of upper rearing areas with 85% leaving as early migrants. At the Minam River trap, we estimated 79,000 juvenile spring Chinook salmon migrated out of the river with 79% leaving as early migrants.

Spring Chinook salmon from Catherine Creek and the Imnaha, Lostine, and Minam rivers, were PIT-tagged as parr during the summer of 2001 in their rearing areas and were detected at Lower Granite Dam between 28 March and 31 May 2002. Chinook salmon from the Lostine River migrated past the dams earlier (median = 20 April) than the those from Catherine Creek (median = 6 May) and the Minam River (median = 3 May). The migration timing of Chinook salmon from the Imnaha River (median = 4 May) did not differ significantly from the others. Survival to Lower Granite Dam differed between some of the populations. Lostine River Chinook salmon parr had the highest survival probability (0.154), whereas, the survival probabilities for parr from Catherine Creek (0.109), the Imnaha (0.106), and Minam (0.093) were lower but did not differ significantly from each other.

Chinook salmon tagged at the traps were detected at Lower Granite Dam between 25 March and 1 July 2002. Although there was overlap in detection dates, the median detection date for early migrants was before that of late migrants for all four streams. Survival probabilities to Lower Granite Dam for early migrating juvenile Chinook salmon ranged from 0.154 to 0.326 for those tagged in the fall of 2001 at our Catherine Creek and Lostine River screw traps, respectively. Survival probabilities for late migrants ranged from 0.499 to 0.683 for those tagged in the spring of 2002 at our upper Grande Ronde and Lostine river screw traps, respectively.

Overwinter survival did not differ between spring Chinook salmon rearing in upstream and downstream habitats on Catherine Creek and the Lostine River for MY 2002. Upstream overwinter survival probability for Catherine Creek was 0.39 and for the Lostine was 0.36.

We estimated that 68% of the total mortality of late migrant spring Chinook salmon from Catherine Creek to Lower Granite Dam occurred between the upper trap site on Catherine Creek and the downstream trap located at the lower Grande Ronde Valley. Eighty-six percent of the total travel time of late migrants from Catherine Creek to Lower Granite Dam occurred between trap sites even though this distance accounted for only 26% of the total distance to Lower

Granite Dam. Similarly, we estimated that 71% of the total mortality of upper Grande Ronde River late-migrant spring Chinook salmon occurred before fish reached the lower Grande Ronde Valley. Eighty-four percent of the travel time of late migrants from the upper Grande Ronde River trap to Lower Granite Dam occurred between trap sites even though this distance accounted for only 24% of the total distance to Lower Granite Dam.

Egg to parr survival for spring Chinook salmon from brood year 2001 was estimated to be 7.50% for Catherine Creek and 8.49% for the Lostine River. We estimated that 37,337 age-0 immature parr and 301 mature age-1 parr inhabited the upstream rearing areas on Catherine Creek during the summer of 2002. Two percent of the immature age-0 parr estimated to be in Catherine Creek during the summer of 2001 remained in freshwater and matured precociously by August 2002. We estimated there were 1.9 mature male parr for every anadromous female spawner in Catherine Creek in 2002. We estimated that there were 41,209 age-0 immature parr inhabiting the upstream rearing areas on the Lostine River during the summer of 2002. Although we observed mature male parr, we were not able to estimate their population size.

We determined migration timing and abundance of juvenile steelhead/rainbow trout *Oncorhynchus mykiss* using the same rotary screw traps on four streams in the Grande Ronde Subbasin during the 2002 migratory year. Based on migration timing and abundance, early and late migration patterns could be distinguished. For MY 2002, we estimated 17,286 steelhead migrants left upper rearing areas of the upper Grande Ronde River with 6% of these fish leaving as early migrants in the fall to overwinter downstream of the trap. We estimated 45,799 steelhead migrants in Catherine Creek with 42% of these fish leaving as early migrants in the fall. At the Lostine River, we estimated 21,019 steelhead migrated out with 69% of these fish leaving as early migrants in the fall. We estimated 44,872 steelhead migrated out of the Minam River with 18% of these fish leaving as early migrants.

The steelhead collected at trap sites during the 2002 migratory year were comprised of four age groups. Early migrants ranged from 0 to 3 years of age (average: 65% age-0; 29% age-1; 5.8% age-2; 0.06% age-3). The same cohorts comprised the late-migrant populations with ages ranging from 1 to 4 years (38% age-1; 50% age-2; 11% age-3; 0.43% age-4). Within age groups, fish from the Lostine River tended to be larger than the other populations. Steelhead smolts ranged in age from 1 to 3 year with the majority comprised of age-2 fish.

Juvenile steelhead PIT-tagged at screw traps on Catherine Creek, and the upper Grande Ronde, Lostine, and Minam rivers as early and late migrants were detected at Lower Granite Dam between 10 April and 1 July 2002. Early migrants from the Lostine and upper Grande Ronde rivers were detected before (median detection dates: 8 May and 7 May, respectively) the late migrants (23 May and 22 May, respectively) from these streams. There was no significant difference in detection dates between early and late migrants from Catherine Creek (medians: 12 May and 22 May) and the Minam River (medians: 11 May and 20 May).

Survival probabilities to Lower Granite Dam for early migrating steelhead ranged from 0.069 to 0.185 for those tagged in the fall of 2001 at our Catherine Creek and upper Grande Ronde traps, respectively. Survival probabilities to Lower Granite Dam for late migrants ranged from 0.450 to 0.722 for those tagged in the spring of 2002 at our upper Grande Ronde and

Minam river screw traps, respectively. The survival probability to Lower Granite Dam for steelhead tagged in the upper Catherine Creek drainage during the summer of 2001 was 0.087.

We used mark-and-recapture and scale-aging techniques to determine population size and age structure of steelhead in the main-stem Catherine Creek and a tributary, Milk Creek, during the summer of 2002. We estimated that 19,115 steelhead inhabited the main-stem Catherine Creek and 1,825 inhabited Milk Creek. Ages ranged from 0 to 3 for both streams, with age-1 being the most abundant if age-0 fry are not considered.

Summer rearing habitat for spring Chinook salmon parr in Catherine Creek was surveyed in the summer of 2002. In the main-stem Catherine Creek, 30,849 m of stream were surveyed and average stream gradient was 0.96%. The majority (55.2%) of the stream's wetted surface area was composed of riffle habitat while pools comprised 26.4%. Large pools (depth ≥0.8 m and surface area ≥ 20 m^2) had an average frequency of 4.6 pools/km and was similar to the frequency reported in a survey conducted in the early 1990's but less than historic levels. The percent fines at pool tail-outs averaged 21%. In the North Fork Catherine Creek, 9,685 m of stream were surveyed and average gradient was 2.9%. The wetted surface area was comprised of 63.3% rapids and cascades and 9.6% pools. Large pool frequency averaged 1.9 pools/km. This was similar to large pool frequency reported in the early 1990's but less than historic levels. Percent fines at pool tail-outs were similar to the mainstem with an average of 19%. In the South Fork Catherine Creek, 3,927 m of stream were surveyed and average stream gradient was 2.8%. Rapids accounted for 50.5% of the wetted surface area and pools accounted for 12.8%. Large pool frequency averaged 1.4 pools/km and was similar to the frequency reported in the early 1990's but less than historic levels. Percent fines at pool tail-outs were higher than the mainstem or the North Fork Catherine Creek with an average of 28%.

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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 Subbasin is divided into three watershed areas: the Upper Grande Ronde Watershed, the Lower Grande Watershed, and the Wallowa Watershed. The Upper Grande Ronde Watershed includes the Grande Ronde River and its tributaries from the headwaters to its confluence with the Wallowa River. The Lower Grande Ronde Watershed includes the Grande Ronde River and tributaries, excluding the Wallowa River, from the Wallowa River to its confluence with the Snake River. The Wallowa Watershed includes the Wallowa River and its tributaries, including the Lostine and Minam rivers, from the headwaters to its confluence with the Grande Ronde River.

Historically, the Grande Ronde Subbasin produced 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 spring Chinook salmon, were listed threatened under the Endangered Species Act (ESA) in 1992. Snake River steelhead, including Grande Ronde 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, including Wallowa River, Lostine River, Bear Creek and Hurricane Creek; Minam River; Catherine Creek, including Catherine and Indian creeks; Upper Grande Ronde, including upper Grande Ronde River and Sheep Creek; and Lookingglass Creek, of which the endemic spring Chinook salmon population are considered extinct. Four summer steelhead populations have been identified in the subbasin (TRT 2003): Lower Grande Ronde, including the main-stem Grande Ronde and all tributaries, except Joseph Creek, upstream to the confluence of the Wallowa River; Joseph Creek; Wallowa River, including Minam and Lostine rivers; and Upper Grande Ronde, including the main-stem upper Grande Ronde and Lookingglass Creek, Catherine Creek, Indian Creek, and other smaller tributaries.

Numerous factors are thought to have contributed to the decline of spring Chinook salmon and summer steelhead in the Snake River and its tributaries. These factors include juvenile and adult passage problems at main-stem Snake and Columbia river dams, cyclic changes in ocean productivity, overharvest, and habitat degradation associated with timber, agricultural, and land development practices. More than 80% of anadromous fish habitat in the upper Grande Ronde River is considered degraded (USFS 1992). Habitat problems throughout the Grande Ronde Subbasin (reviewed by Bryson 1993) include poor water quality associated with high sedimentation and poor thermal buffering, moderately to severely degraded riparian zones, and a decline in abundance of large pool habitat.

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). With this project, we are acquiring knowledge of juvenile migration patterns, smolt production and survival, and juvenile winter rearing habitat within the subbasin. This project collects data to obtain life stage specific survival estimates (egg-to-parr, parr-to-smolt, and smolt-to-adult), and includes an evaluation of the importance and frequency at which alternative life history tactics are utilized by spring Chinook salmon populations in northeast Oregon.

The spring Chinook salmon and summer steelhead smolt migration from the Grande Ronde Subbasin occurs in spring. Data from Lookingglass Creek (Burck 1993) and Catherine Creek, the Grande Ronde River and the Lostine River (Keefe et al. 1994, 1995; Jonasson et al. 1996, 1997, 1999; Tranquilli et al. 1998; and Monzyk et al. 2000; Reischauer et el. 2003) indicate a substantial number of juveniles move out of upper rearing areas during fall and overwinter downstream within the Grande Ronde 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 in Catherine Creek and the upper Grande Ronde River in fall overwinter in the Grande Ronde River valley. Much of the habitat in these mid-reaches of the Grande Ronde River is degraded. Stream conditions in the Grande Ronde River below 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 little shade or 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 (Keefe et al. 1995, Jonasson et al. 1996, 1997, 1999 and Reischauer et al., 2003). 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 the upper rearing areas in fall and spring may continue rearing within the subbasin for an extended period of time (6 months to several years) before continuing on the smolt migration during the spring. Therefore rearing habitat is not limited to the areas where steelhead are spawned.

Numerous enhancement activities have been undertaken in an effort to recover spring Chinook salmon populations in the Grande Ronde 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 Lostine River. Information we collect will serve as the foundation for assessing the effectiveness of programs currently underway.

GOALS AND OBJECTIVES

This study was designed to document and describe early life history strategies exhibited by spring Chinook salmon and steelhead in the Grande Ronde Subbasin. The objectives of this study for 2002 were to:

1. Document the in-basin migration patterns and estimate egg-to-migrant survival for 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 migrant and spring 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 migrant and spring 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. Determine egg-to-to parr survival for spring Chinook salmon in two local, natural populations in the Grande Ronde Subbasin: Catherine Creek and Lostine River.

6. Investigate the significance of alternate life history strategies of spring Chinook salmon in two local, natural populations in the Grande Ronde Subbasin: Catherine Creek and Lostine River.

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

8. 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.

9. Evaluate methods to estimate the proportion of steelhead captured during fall trapping that are migrating out of rearing areas and will undertake a smolt migration the following spring.

10. Describe the population characteristics of the juvenile steelhead population in Catherine Creek.

11. Determine the quality and quantity of winter concealment habitat in selected spring Chinook salmon upper rearing areas, and quantify and characterize its use by juvenile spring Chinook salmon in the Grande Ronde Subbasin. See Van Dyke and Scarnecchia (2006) for project report for this objective.

12. Document habitat conditions in spring Chinook salmon rearing areas in Catherine Creek.

SPRING CHINOOK SALMON INVESTIGATIONS

Methods

For the purpose of this report, we assume that all juvenile spring Chinook salmon captured in traps were downstream "migrants". The term "migratory year" (MY) refers to the earliest calendar year juveniles were expected to migrate to the ocean. The term "brood year" (BY) refers to the calendar year eggs were fertilized. All spring Chinook salmon referred to in this report were naturally produced unless noted otherwise.

Egg-to-Parr Survival, Parr Abundance, and Age Composition in Summer

We used mark-and-recapture and scale-aging techniques to estimate the abundance of immature and mature parr, by age class, in Catherine Creek and the Lostine River in August 2002. The abundance estimates and redd survey and fecundity data collected for related projects were used to estimate egg-to-parr survival. Our goal for each stream was to mark at least 1,000 immature parr and as many mature parr as we could capture in 5 days. During subsequent sampling, our goal was to capture at least 1,000 immature parr and as many mature parr as possible in 5 days. We collected scales for age determination from the mature parr captured in each stream.

Site Description: Parr were collected, marked, and released upstream of rotary screw traps, in the length of stream encompassing the majority of the spawning and rearing habitat on Catherine Creek and the Lostine River (Figure 1). Sampling on Catherine Creek occurred from the rotary screw trap (rkm 32) upstream to the confluence of the north and south forks of Catherine Creek (rkm 52) and included the lower 2 km of the North Fork Catherine Creek. Sampling on the Lostine River occurred from the rotary screw trap (rkm 3) to the Lostine Guard Station (rkm 30). We did not sample a 9 km long canyon within the study area on the Lostine River because it is unsuitable rearing habitat for juvenile spring Chinook salmon, although adults do spawn upstream and downstream of this reach.

Marking Phase: Parr were collected for marking along the length of Catherine Creek above the screw trap from 29 July to 1 August. On the Lostine River, we collected parr in 6 sections of stream (about 8 km total) scattered throughout the 27 km of spawning and rearing area 12–15 August (Table 1). In most cases, 2–3 snorkelers herded the parr downstream into a seine held perpendicular to the stream flow. Traditional beach seining was also effective in a few areas. Captured fish were held in aerated, 19 L buckets or in aerated, 19 L carboys attached to pack frames and transferred periodically to live cages anchored in shaded areas of the stream near our marking stations. Prior to being marked, fish were anesthetized in an aerated bath containing 40–50 mg/L of tricaine methanesulfonate (MS-222). We marked all mature parr, and any immature parr less than 55 mm fork length (FL), with a caudal fin clip or with diluted, non-toxic, acrylic paint. The paint was injected subcutaneously on the ventral surface slightly anterior of the pelvic fin insertion using a Panjet marking instrument (Hart and Pitcher 1969). Immature parr that were 55 mm FL or greater were either paint-marked, caudal clipped, or PIT-tagged. PIT tags were injected manually with a modified hypodermic syringe as described by Prentice et al. (1986, 1990) and Matthews et al. (1990, 1992). Syringes were disinfected for 10 min in 70% isopropyl alcohol and allowed to dry for 10 min between each use. We used a portable tagging station that consisted of a computer, PIT tag reader, measuring board, and electronic balance to record the tag code, fork length (±1 mm), and weight (±0.1 g) of PIT-tagged fish. We also recorded the fork length and weight of mature parr, and the fork length of paint-marked and caudal clipped immature parr. All fish were handled and marked at stream temperatures of 15°C or less and released in the area of capture within 24 hours of being tagged.

Recapture Phase: Parr were captured and examined for marks during the week following the marking phase on each river; 5–9 August on Catherine Creek and 19–22 August on the Lostine River. Catherine Creek parr were collected from 20 randomly selected 0.4 km long sections. Parr were captured over the length of the Lostine River, from the rotary screw trap to the Lostine Guard Station, except for the 9 km long canyon section. We used the seining methods described for the marking phase to capture parr. Each fish was inspected for marks and maturity status. The numbers of mature and immature parr that were unmarked, paint-marked, caudal clipped, PIT-tagged, or that had lost their PIT tag (i.e., no tag could be detected, but a recent PIT-tagging scar was evident) were recorded.

Age Determination: Age composition estimates for the mature parr from each stream were based on results from scale analyses. Scales were collected from most of the mature parr captured during the marking phase. We identified mature parr based on body morphology and coloration. Mature parr tended to be longer, deeper-bodied, and more yellowish in color (laterally) than immature parr. Precocious maturation of Chinook salmon parr has only been reported for males. Despite this we assumed that all mature parr were male, unless there were unmistakable indications to the contrary. All parr that did not exhibit signs of early maturity were assumed to be age-0 based on data from previous years (Appendix Table A-1). To verify this assumption we also collected scales from the larger (≥ 85 mm fork length) immature parr for age analysis. Scale impressions were made on acetate slides and inspected on a microfiche reader at 42x magnification. Scale aging conventions were followed (Devries and Frie 1996).

Calculations: We used Chapman's modification of the Petersen estimate (Ricker 1975) to determine the abundance of immature and mature parr in Catherine Creek and the Lostine River. We obtained 95% confidence intervals (CI) for the abundance estimates using equation (3.7) in Ricker (1975) and values from Appendix II in Ricker (1975). We used the results of our scale analysis to calculate the proportion of mature parr, of each age j, for each stream. We obtained 95% CI for the proportion of mature parr from table P in Rohlf and Sokal (1995). Using parr abundance and age composition estimates from August 2001 (Reischauer et al. 2003) and 2002, and redd count data from the 2000 and 2001 spawning ground surveys (ODFW, unpublished data) we determined the following regarding spring Chinook salmon populations in Catherine Creek and the Lostine River: 1) the abundance of immature and mature parr, by age class, in August 2002; 2) the percentages of immature age-0 parr present in each stream in August 2001 that were present in August 2002 as mature or immature age-1 parr; 3) the average number of mature and immature age-0 parr (in 2002) produced per redd constructed in 2001; and 4) the average number of mature and immature age-1 parr (in 2002) produced per redd constructed in 2000. We estimated rates of egg-to-parr survival, based on an estimated egg deposition of 3,801 eggs/redd in Catherine Creek and 4,950 in the Lostine River in 2001 (based on fecundity by age of wild fish captured at weirs and spawned at Lookingglass Hatchery and the age composition of female spawners; ODFW, unpublished data) and the number of redds counted above the trap sites on Catherine Creek and the Lostine River.

1) The abundance of parr ($\hat{N}_{i,j,k}$) by maturity *i*, age class *j*, and summer *k*, where *k* = 2002 was calculated as

$$\hat{N}_{i,j,k} = \hat{N}_{i,k} \times \frac{C_{i,j,k}}{C_{i,k}}, \qquad (1)$$

where $\hat{N}_{i,k}$ is the population estimate for parr of maturity *i* during the summer *k*, as determined from separate mark-recapture estimates for mature and immature parr, $C_{i,j,k}$ is the number of fish of maturity *i*, sampled during summer *k*, that were determined by scale analysis to be age *j*, and $C_{i,k}$ is the number of fish of maturity *i* that we aged from scale samples collected during the summer *k*.

2) The number of mature age-1 parr present in the stream a particular summer (*k*) compared to the number of immature age-0 parr present the previous summer (*k-1*), expressed as a percentage was calculated as

$$\frac{\hat{N}_{mature,age-1,k}}{\hat{N}_{immature,age-0,k-1}} \times 100. \qquad (2)$$

This represents the rate of precocious maturation of parr for a particular stream.

3) The average number of mature and immature age-0 parr (estimated for summer *k* using values calculated in equation (1) produced per redd built the previous fall (*k-1*) was calculated as

$$\frac{\hat{N}_{immature,age-0,k} + \hat{N}_{mature,age-0,k}}{R_{k-1}}, \qquad (3)$$

where R_{k-1} is the number of redds counted above the trap site on a particular stream in year *k-1*.

4) The average number of mature and immature age-1 parr present in summer *k* per redd built two falls previous (*k-2*) was calculated as

$$\frac{\hat{N}_{immature,age-1,k} + \hat{N}_{mature,age-1,k}}{R_{k-2}}, \qquad (4)$$

where R_{k-2} is the number of redds counted above the trap site on a particular stream in year *k-2*.

5) The egg-to-parr (age-0) survival, calculated using the estimated number of age-0 parr produced per redd equation (3), an assumed 1:1 ratio of spawning females to redds, and an

estimated fecunditiy ($\hat{E}_{k-1}$) for females returning to the stream to spawn in year *k-1* was calculated as

$$\frac{\hat{N}_{immature,age-0,k} + \hat{N}_{mature,age-0,k}}{R_{k-1} \times \hat{E}_{k-1}}, \tag{5}$$

where the $\hat{E}_{k-1}$ is the estimated fecundities for brood year 2001 (3,801 eggs/female from Catherine Creek and 4,950 eggs/female from the Lostine River; ODFW, unpublished data).

In-Basin Migration Timing and Abundance

The in-basin migration timing and abundance of juvenile spring Chinook salmon in the upper Grande Ronde River, Catherine Creek, the Lostine River, and the Minam River were determined by operating rotary screw traps through out the migratory year. The 2002 migratory year (MY 2002) for spring Chinook salmon within the Grande Ronde Subbasin overlaps two calendar years, and began on 1 July 2001 and ended on 30 June 2002. Spring Chinook salmon in our study streams exhibit two migrational life-history patterns. Early migrants leave upper rearing areas in the fall and overwinter in downstream habitat before continuing their seaward migration out of the subbasin the following spring. Late migrants exhibit another life history strategy whereby they remain in upper rearing areas throughout fall and winter, and initiate their seaward migration in spring. Designations of early and late migratory groups were based on trends in capture rates at trap sites. A common period of diminished capture rates occurs at our trap sites in winter and was used to classify fish into migratory groups. We then determined migration timing and abundance by migratory group.

In the Grande Ronde Subbasin, we operated five rotary screw traps (Figure 1). In the Upper Grande Ronde Watershed, one rotary screw trap was located below 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 below spawning and upper rearing areas near the town of Union at rkm 32. We also operated a third rotary screw trap during spring at the lower end of the Grande Ronde Valley near the town of Elgin at rkm 164. In the Wallowa 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 we attempted to fish the traps continuously through the year, there were times when a trap could not be operated due to low flow or freezing conditions. There were also instances when traps were not operating due to debris blockage and mechanical breakdowns. We did not attempt to adjust population estimates for periods when traps were not operating. For this reason, our estimates represent a minimum number of migrants.

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 only a 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 interrogated for PIT tags. Migrant fry were able to escape from the trap without detection and, therefore, were not included in migrant abundance estimates. Also, sexually mature male parr were not included in migrant abundance estimates. We attempted to measure fork lengths (mm) and weights (g) of at least 100 juvenile spring Chinook salmon each week. Prior to sampling, juvenile spring Chinook salmon were anesthetized with MS-222 (40–60 mg/L). Fish were allowed to recover fully from anesthesia before release into the river. River height was recorded daily from permanent staff gauges. 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. Trap efficiency was determined by releasing a known number of fin-marked or PIT-tagged fish above each trap and enumerating recaptures. Up to 100 juvenile spring Chinook salmon were marked and released each week. 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

$$\hat{E}_j = R_j / M_j \ , \qquad (6)$$

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

$$\hat{N}_j = U_j / \hat{E}_j \ , \qquad (7)$$

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 there were less than 10 recaptured fish in a week, bootstrap variance estimates were greatly expanded. For this reason, we combined consecutive weeks 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 (6 and 7) 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

$$95\%\ CI = 1.96\sqrt{V} \ , \qquad (8)$$

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

The upper Grande Ronde River, Catherine Creek, and Lostine 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 necessitated modifications to our method of estimating migrant abundance of wild spring Chinook salmon at the trap sites. During low hatchery spring Chinook salmon catch periods, the trap was fished continuously throughout a 24 h period as described above. During high catch periods, the trap was fished systematically (each night) for a 2 or 4 h interval (upper Grande Ronde River and Catherine Creek traps: 19:30 to 21:30; Lostine River trap: 20:00 to 24:00) using systematic two-stage sampling. Systematic sampling allowed us to reduce fish handling and overcrowding in the live box, and avoid labor-intensive 24 h trap monitoring. Preliminary 24 h sampling indicated a strong diel pattern in spring Chinook salmon catch rates. The specific intervals were chosen because a relatively large proportion of the total daily catch was captured during these 2 and 4 h time blocks.

Systematic sampling required us to estimate the proportion of the total daily catch captured during our sampling interval. We estimated this proportion by fishing the trap over several 24 h periods prior to systematic sampling. We counted the number of fish trapped during the 2 or 4 h sampling interval and the remaining interval within each 24 h period. The proportion of the total daily catch captured during the sampling interval (i) was estimated by

$$\hat{P}_i = S_i / C \, , \qquad (9)$$

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

We could not mark, release and recapture fish for the purpose of estimating trap efficiency during systematic sampling. Instead, trap efficiency during systematic sampling was calculated from equation (6) by using mark/recapture numbers from one week 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

$$\hat{N}_s = \left(U_i / \hat{P}_i \right) / \hat{E} \, , \qquad (10)$$

where $\hat{N}_s$ is the estimated number of fish migrating past the trap during systematic sampling, U_i is the total number of fish captured during interval i, $\hat{P}_i$ is the proportion of daily catch from equation (9), and $\hat{E}$ is the estimated trap efficiency. Abundance for the total migration at the Catherine Creek, upper Grande Ronde, and Lostine river traps was determined by summing the 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 (6, 9, and 10) drawing R and S_i from the binomial distribution and U_i from the Poisson distribution. Variance of total migrant abundance was determined by summing the variance from the continuous and systematic sampling estimates.

Migration Timing and Survival to Lower Granite Dam

We used detections of PIT-tagged fish at Snake River and Columbia River dams to estimate migration timing and survival probability for each tag group. There were four tag groups for which we estimated migration timing and survival probability to Lower Granite Dam: the summer, fall, winter, and spring tag groups.

The summer tag groups consisted of age-0 parr tagged during July and August 2001 in their upstream rearing habitat. This group included fish that moved out of upper rearing areas as either early or late migrants, and consequently overwintered in either the lower or upper rearing areas before continuing their downstream migration. Therefore, the summer tag group represented timing and survival for the population as a whole. Summer tag group fish were captured using the snorkel-seine method described in **Egg-to-Parr Survival, Parr Abundance, and Age Composition in Summer.** Our goal was to PIT tag 500 parr per stream on Catherine Creek and the Lostine River, and 1,000 parr per stream on the Minam and Imnaha rivers for the summer tag groups.

The fall tag groups represented early migrants that left the upstream rearing areas in the fall and overwintered downstream of our screw traps. For consistency with previous years' data, fish tagged as they moved downstream past our upper trap sites between 1 September 2001 and 28 January 2002 were designated the fall tag group. Fall tag group fish were captured, tagged, and released at our screw traps on the upper Grande Ronde River, Catherine Creek, Lostine River, and Minam River. Our goal was to PIT tag 500 fish at each trap throughout the fall migration.

Both the winter and spring tag groups represented late migrants that overwintered as parr upstream of our traps and migrated downstream in the spring. The difference between the two groups was that the winter group was tagged earlier (December 2001) than the spring group (29 January – 30 June 2002) and therefore experienced overwinter mortality after tagging. Winter tag group fish were caught, tagged, and released a minimum of 8 km above the trap sites to minimize the chance they would pass the trap sites while making localized movements during winter. Fish were caught using dip nets while snorkeling at night. Our goal was to PIT tag 500 fish per stream for the Catherine Creek and Lostine River winter tag groups.

The spring tag groups represented late migrants that left the upstream rearing areas between 29 January 2002 and 30 June 2002. The spring tag group fish were captured, tagged, and released at our screw traps on the Catherine Creek, upper Grande Ronde, Lostine, and Minam rivers. Our goal was to PIT tag 500 fish at each trap throughout the spring migration.

During the 2002 migratory year, PIT tag interrogation systems were used in juvenile bypass systems at six of eight Snake River and Columbia River dams to monitor fish passage. We interrogated all fish for PIT tags upon capture in our screw traps. All recaptured and interrogated fish were identified by their original tag group, insuring the independence of tag groups for analysis. For example, dam detections of fish that were tagged as part of the summer tag group and subsequently recaptured at a screw trap as early migrants, were analyzed as summer tagged fish. At the completion of the 2002 migratory year, we obtained detection information from PIT tag interrogation sites at Lower Granite, Little Goose, Lower Monumental, McNary, John Day, and Bonneville dams.

Calculations: ***Migration Timing:*** We estimated the timing of migration past Lower Granite Dam for each tag group by expanding daily numbers of PIT tag detections according to the proportion of river flow spilled each day. This procedure was necessary because some fish may have passed undetected over the spillway and the amount of spill varies throughout the migration season. We assumed the proportion of fish that passed over the spillway (spill effectiveness) was directly related to the proportion of flow spilled. This assumption conforms fairly well to data obtained using non-species-specific hydroacoustic methods (Kuehl 1986). We also assumed there was no temporal variation either in the proportion of fish diverted from turbine intakes into the bypass system (fish guidance efficiency) or in the proportion of fish that passed through the surface bypass collector. We made these assumptions in light of evidence to the contrary (Giorgi et al. 1988, Swan et al. 1986, Johnson et al. 1997) because the data required to account for such variation were unavailable. The extent to which our results may be biased would depend on the overall rates of fish passage via the bypass system and surface bypass collector, and on the degree to which daily rates of fish passage by these routes may have varied throughout the migration seasons. The number of fish in a particular tag group migrating past Lower Granite Dam by day ($\hat{N}_d$) was estimated by multiplying the 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.cqs.washington.edu/dart/river.html):

$$\hat{N}_d = D_d \times \frac{O_d + L_d}{O_d}, \tag{11}$$

where D_d is the number of PIT tagged fish from a tag group detected at Lower Granite Dam on day *d*, O_d is the outflow (kcfs) measured at Lower Granite Dam forebay on day *d*, and L_d is the spill at Lower Granite dam spill (kcfs) on day *d*. Daily migration estimates were added for each week to obtain weekly migration estimates for each tag group, which were reported graphically. First and last detection dates were reported for each tag group. The median migration date of each tag group was determined from the daily migration estimates. Median migration dates for the spring tag groups may have reflected the dates fish were tagged in addition to the migration pattern. A χ^2 analysis comparing numbers of smolts tagged weekly to the numbers estimated to pass the trap each week was performed to test whether the timing of tagging was representative of spring smolt migration, as intended. If it was not, the median migration date past Lower Granite Dam may have been biased. The travel times for the spring tag groups to reach Lower Granite Dam from the screw traps were summarized for each location.

Survival Probabilities: We used the Cormack-Jolly-Seber method in the SURPH 2.1 program to calculate the probability of survival to Lower Granite Dam for fish in each tag group (Lady et al. 2001). This method takes into account the probability of detection when calculating the probability of survival.

Overwinter Survival Probabilities: We used the winter tag group and the spring tag group survival probabilities (survival to Lower Granite Dam) to indirectly estimate the overwinter survival probability ($\hat{S}_{s,overwinter}$) for late migrants in the upstream rearing habitat on Catherine Creek and the Lostine River:

$$\hat{S}_{s,overwinter} = \frac{\hat{S}_{s,winter}}{\hat{S}_{s.spring}} \tag{12}$$

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

Population Characteristics and Comparisons: The summer tag groups include the various life history patterns displayed by that population and provided information about the population's overall survival and timing of the smolt migration past the dams. In summer of 2001 and 2002, we PIT-tagged parr from populations in Catherine Creek and the Lostine, Minam, and Imnaha rivers to monitor and compare their migration timing as smolts to Lower Granite Dam and their survival probabilities from tagging to the dams on the Snake River. We conducted tagging operations in late summer (Table 1) so that most fish would be large enough to tag (FL $\geq$ 55 mm). Sampling occurred primarily in areas where spawning adults were concentrated the previous year. The collection and PIT-tagging methods were previously described for the mark-and-recapture studies (*see* **Methods; Egg-to-Parr Survival, Parr Abundance, and Age Composition in Summer**). We caught, PIT-tagged, and released between 501 and 1,001 parr per stream in summer 2001; and between 506 and 1,003 in summer 2002 (Table 1). Information on the migration timing and survival of parr PIT-tagged in summer 2002 will be reported next year.

Migration Timing: We determined if migration timing differed between populations using a one way ANOVA on dates of detection, expressed as day of the year, of expanded fish numbers (see expansion explanation in **Comparison of Early Life History Strategies within Populations: *Migration Timing***). When significant differences were found, we used the Tukey pair-wise multiple-comparison procedure ($\alpha = 0.05$) to determine where the differences lay (SPSS Inc. 1992–1997).

Survival Probabilities: Survival probabilities were compared between populations using the modeling and hypothesis testing capabilities of Surph 2.1 (Lady et al. 2001). Several models were developed. The ones that best fit the data were selected using Akaike's Information Criterion. Final model selection was made using likelihood ratio tests.

Comparison of Early Life History Strategies within Populations: Comparisons were made between early and late migrants from each trap location to determine if different life histories were associated with differences in timing of migration past and survival to Lower Granite Dam.

Migration Timing: Timing of migration past Lower Granite Dam was compared between the fall (early migrants) and winter (late migrants) tag groups from Catherine Creek and the Lostine River to investigate differences in seaward migration timing between the two life history strategies. Comparisons were made using the Mann-Whitney rank sum test on detection dates. Spillway flow (and the passage of undetected PIT-tagged fish at the dam) was taken into account by rounding the expanded fish numbers to the nearest integer and creating duplicate 'dummy' detection records for any date with an expanded fish number greater than 1.5. For the upper Grande Ronde and Minam rivers, we used the same method to compare migration timing between the fall (early migrants) and spring (late migrants) tag groups because parr were not tagged in the winter. As noted above, the results may have been affected by bias in the spring tag group migration timing.

Survival Probabilities: Fish that emigrated from upper rearing areas at different times of year and overwintered in different habitats were subject to different environmental conditions, and survival may have varied among fish exhibiting the different life histories as a result. For each stream, we evaluated relative success of early and late migrants by using the Maximum Likelihood Ratio Test to test the null hypothesis that survival probabilities of the fall tag group (early migrants) and the winter tag group (late migrants) were the same. We assumed that any difference in survival probabilities between these two groups was due to differential survival in upstream (used by winter tag group) and downstream (used by fall tag group) overwintering habitat. However, most of the fall group was tagged slightly before the winter group, which could result in a lower survival estimate for the fall tagged fish due to elapsed time rather than over wintering conditions.

Survival and Migration Timing Through the Grande Ronde Valley: During the spring of 2002, we PIT tagged juvenile spring Chinook salmon collected at our rotary screw trap located in the Grande Ronde River (rkm 164) at the lower end of the Grande Ronde Valley. This trap was approximately 93 km downstream of the Catherine Creek trap (rkm 32) and 135 km downstream from the upper Grande Ronde River trap (rkm 299). However, a migrating juvenile salmon from the upper Grande Ronde River actually travels only 93 km between trap sites because a 8.3 km flood control ditch constructed in the valley bypasses 50 km of natural river channel between these trap sites. The stream reach comprising the migration corridor through the Grande Ronde Valley is highly meandering and low gradient relative to other reaches of the corridor to Lower Granite Dam.

A survival probability to Lower Granite Dam calculated for fish tagged at the lower valley trap was compared to the survival probabilities of the spring tag groups from the upper Grande Ronde River and Catherine Creek to indirectly estimate survival of late migrants from each of these populations as they migrated through the Grande Ronde Valley using the equation

$$S_{bj} = S_{uj} / S_l \, , \qquad (13)$$

where S_{bj} is the indirect survival probability for fish migrating between upper trap site *j* and the Grande Ronde Valley trap site, S_{uj} is the survival probability calculated for the spring tag group from upper trap site *j* to Lower Granite Dam, and S_l is the survival probability for the fish tagged at the lower Grande Ronde Valley trap to Lower Granite Dam. In the previous years of this study, the majority (97-99%) of juvenile spring Chinook salmon did not emigrate past the Grande Ronde Valley trap until spring. Because fish tagged at the lower Grande Ronde Valley trap were therefore a combination of early and late migrants from both the upper Grande Ronde River and Catherine Creek, it was not possible to directly compare the survival probabilities of late migrants as they traveled through the migration corridor. We assumed that using a common survival probability at the lower valley trap for indirect comparisons of late-migrant survival was valid because factors causing survival differences between tag groups and populations would affect fish prior to fish reaching the lower valley trap site in the spring. In other words, all fish should encounter similar environmental hazards affecting survival to Lower Granite Dam once they migrate below the lower valley trap in the spring, so we assumed survival would be similar beyond this point regardless of population or migrant group of origin.

We estimated the percentage of total mortality to Lower Granite Dam that occurred between trap sites as:

$$M_{bj} = ((1 - S_{bj}) / (1 - S_{uj}))100 \; ; \qquad (14)$$

M_{bj} is the percentage of the total mortality to Lower Granite Dam occurring between trap site j and the lower Grande Ronde Valley trap site, S_{bj} is the indirect survival probability calculated from equation (13), and S_{uj} is the survival probability estimate to Lower Granite Dam for PIT-tagged fish from upper trap site j.

We also investigated travel times through the migration corridor based on PIT-tagged fish released at a trap site and subsequently detected at Lower Granite Dam. The number of days between the release date and detection date was determined for each fish and median travel time to Lower Granite Dam was calculated for spring tag groups tagged at each trap site. We assumed that travel time to Lower Granite Dam for wild fish PIT-tagged at the lower Grande Ronde Valley trap was representative of the travel time of late migrants originating from Catherine Creek and the upper Grande Ronde River. The travel time between the upper trap sites and the lower Grande Ronde Valley trap was estimated by subtracting the travel time to Lower Granite Dam from the lower Grande Ronde Valley trap from the travel time to Lower Granite Dam from the upper trap sites. We assumed that using a common travel time for fish tagged at the lower Grande Ronde Valley trap in the calculations was valid because travel times from this point to Lower Granite Dam should be similar for all juvenile Chinook salmon regardless of migrant group or population of origin.

Similar analyses were conducted on PIT-tagged hatchery spring Chinook salmon released into Catherine Creek from the Catherine Creek Acclimation Ponds (rkm 48) during the spring of 2002 and recaptured at our Catherine Creek and lower Grande Ronde Valley traps. In this case, we were able to make direct comparisons of survival probabilities as these fish traveled through the migration corridor because we were able to monitor PIT-tag recaptures specific for this group.

Results and Discussion

Egg-to-Parr Survival, Parr Abundance, and Age Composition in Summer

Catherine Creek: We estimated that 301 (95% CI, 170 to 580) mature parr and 37,337 (95% CI, 31,270 to 44,572) immature parr spring Chinook salmon inhabited Catherine Creek in August 2002 (Table 2), based on mark-recapture data for the whole study area. This immature parr estimate was higher than the 2001 estimate of 15,032 (Appendix Table A-3). The mature parr estimate was lower than the 2001 estimate of 986. Results from scale analyses indicated that all of the mature parr sampled were age-1 (Table 3). The one large immature parr that we sampled for scales was determined to be age-0, supporting our assumption that the immature parr were all age-0 (Table 4).

There were 26 and 131 redds counted in the Catherine Creek study area in 2000 and 2001, respectively (ODFW, unpublished data). We estimated that 12 mature and 0 immature age-1 parr were present the summer of 2002 per redd constructed in 2000 (Appendix Table A-4). We estimated that 285 age-0 parr were produced per redd constructed in 2001 (Appendix Table A-4). This was equivalent to an egg-to-parr survival of 7.50%, which was lower than the 1998, 1999, and 2000 (brood year) egg-to-parr survival estimates of 16.28, 18.07, and 14.93%, respectively, and similar to the 1997 survival estimate (Table 5). Of the 15,032 immature age-0 parr estimated to be present in Catherine Creek in August 2001 (Reischauer et al. 2003), 2.0% were estimated to be present as mature age-1 parr in August 2002 (Appendix Table A-5).

We estimated that there were 1.9 mature, wild, male parr present in the late summer of 2002 for each redd counted a month or two later (Appendix Table A-5, *see* **Alternate Life History Strategies** for discussion). We also marked mature hatchery parr and estimated their population to be 87 (95% CI, 39 – 218) during the summer of 2002 (Appendix Table A-3), which equates to approximately 0.6 precocious male hatchery parr available per redd constructed in 2002.

Lostine River: We estimated that 41,209 (95% CI, 31,488 to 53,859) immature parr inhabited the Lostine River in August 2002 (Table 2). We observed mature parr, but did not capture enough to estimate their population. Although we aged scales from only two mature parr, they were both age-1 (Table 3). Scales sampled from 15 of the larger immature parr indicated that they were all age-0, supporting our assumption that all immature parr present in the summer were age-0 (Table 4).

There were 53 and 98 redds counted in the Lostine River study area in 2000 and 2001, respectively (Appendix Table A-4, ODFW, unpublished data). We estimated that 420 immature and 0 mature age-0 parr were produced per redd constructed in the Lostine River in 2001 (Appendix Table A-4). This was equivalent to an egg-to-parr survival of 8.49%, which was at the low end of our range of previous years results (Table 5). Although mature parr were present in the Lostine River, their density was lower than in Catherine Creek and we were unable to calculate production per redd for mature parr or the percentage of age-0 immature parr that remained in freshwater and matured precociously at age-1. Presumably, both values were relatively small. We did not observe mature hatchery, parr during our 2002 summer fieldwork in the Lostine River.

In-Basin Migration Timing and Abundance

For the 2002 migratory year (MY 2002), distinct early and late migration patterns were evident at all of our upper trap sites. Very few fish were caught in the winter months with the exception of the Lostine River trap (Figure 2). For trap sites with previous years of data, the median emigration dates for MY 2002 were within the range of median dates previously reported with the exception of Catherine Creek late migrants. Late migrants from Catherine Creek had a median emigration date that was later than all previous years of this study (Table 6). With the exception of the upper Grande Ronde River migrants, the proportion of the populations leaving upper rearing areas as early migrants was greater than in previous years of this study (Table 6).

Upper Grande Ronde River: The upper Grande Ronde River trap fished for 129 d between 27 September 2001 and 27 June 2002 (Table 7). There was a distinct early and late migration exhibited by juvenile spring Chinook salmon at this trap site (Figure 2). Median emigration date for early migrants past the trap was 24 October (Table 6). The median emigration date for late migrants passing the trap was 1 April. These dates fall within the range of median dates previously recorded for this study.

We estimated a minimum of 9,133 juvenile spring Chinook salmon migrants (95% CI, ± 1,545) moved out of the upper Grande Ronde rearing areas during MY 2002 (Table 6). This migrant estimate falls within the range estimates from previous years of this study. Based on weekly trap efficiencies, we estimated that approximately 18% (1,625 ± 180) of the juvenile spring Chinook salmon were early migrants and 82% (7,508 ± 1,534) were late migrants. These results are consistent with the pattern of a dominant late migration in the upper Grande Ronde River.

Catherine Creek: The Catherine Creek trap fished for 215 d between 06 September 2001 and 26 June 2002 (Table 7). There was a distinct early migration exhibited by juvenile spring Chinook salmon at this trap site. However, the late migration pattern was not as strong this migration year as it has been in the past (Figure 2; Table 6). Median emigration date for early migrants past the trap was 12 October. This was earlier than the median dates from previous years of this study with the exception of MY 2001. The median emigration date for late migrants was 2 April and was later than all median emigration dates from previous years of this study.

We estimated that a minimum of 23,362 ± 2,870 juvenile spring Chinook salmon migrants moved out of the upper Catherine Creek rearing areas during MY 2002 (Table 6). This estimate falls within the upper end of the range of estimates from previous years of this study. Based on weekly trap efficiencies, 91% (21,183 ± 2,846) migrated early and 9% (2,179 ± 373) migrated late. The proportion leaving as late migrants was the smallest observed since we started this study. The Catherine Creek population appears to be different from the upper Grande Ronde population with respect to the proportion of early and late migrants. In contrast with upper Grande Ronde River, the largest outmigration from Catherine Creek has consistently been observed with early migrants.

Lostine River: The Lostine River trap fished for 258 d between 1 July 2001 and 26 June 2002 (Table 7). Distinct early and late migrations were evident at this trap site (Figure 2). Most early migrants left upper rearing areas in October, however there was a smaller peak in January (Figure 2). The median emigration date for all early migrants was 24 October 2001. This is the second earliest date reported in this study with MY 2001 (29 September) being the earliest. It is worth noting that the median date would be about a week earlier if the second migrant peak in January was excluded. Also, the trap was not run for most of July and August, thereby potentially missing some migrants that would have shifted the median date earlier in the year, as was the case in MY 2001 (Reischauer et al. 2003). The median date for late migrants was 6 April 2002 and was well within the range observed in past years of this study.

We estimated that a minimum of 18,140 ± 2,428 juvenile spring Chinook salmon migrants moved out of the Lostine River during MY 2002 (Table 6). Approximately 85% (15,358 ± 2,371) of the juvenile spring Chinook salmon migrated early and 15% (2,782 ± 522) migrated late. As with Catherine Creek late migrants, this is the smallest proportion observed leaving as late migrants since this study began.

Minam River: The Minam River trap fished for 168 d between 1 July 2001 and 30 June 2002 (Table 7). Distinct early and late migrations were evident (Figure 2). The median emigration date of early migrants was 24 October 2001. The median date for late migrants was 8 April 2002.

We estimated that a minimum of 79,000 ± 10,836 juvenile spring Chinook salmon moved out of the Minam River during MY 2002 (Table 6). Approximately 79% (62,708 ± 10,088) of the juvenile spring Chinook salmon migrated early and 21% (16,292 ± 3,957) migrated late. More early migrants may have moved past our trap than reported here because the trap was not started until late September. This is the second year we conducted Chinook salmon migrant abundance on the Minam River and the Chinook salmon abundance this year is considerably larger than MY 2001. Also, the proportion leaving as late migrants is less than we estimated last year.

Size of Migrants: A comparison of mean lengths and weights of juvenile spring Chinook salmon captured in the traps as early and late migrants and in upper rearing areas in winter and those PIT-tagged and released are given in Tables 8 and 9. Length frequency distributions of juvenile spring Chinook salmon caught in all traps by migration period are shown in Figure 3.

Weekly mean lengths of migrants generally increased over time at each of the traps, with the exception of the Lostine River trap (Figure 4). As in previous years, late migrants captured at the Grande Ronde Valley trap were larger than fish captured at the upper Grande Ronde River and Catherine Creek traps in MY 2002.

Migration Timing and Survival to Lower Granite Dam

Juvenile spring Chinook salmon that were PIT tagged at our screw traps in the fall (early migrants) and spring (late migrants), and upstream of the screw traps during the winter (late migrants) allowed us to investigate survival to and migration past Lower Granite Dam in relation to life history. Detections of summer tagged parr allowed us to compare survival and migration timing between populations from different streams.

Population Comparisons: The summer tag groups included the various life history patterns exhibited by a population and allowed us to compare survival and timing between populations and over the years. We PIT tagged and released 503 spring Chinook salmon parr on Catherine Creek and 501 on the Lostine River during August 2001 (Table 10). Parr were captured in their summer rearing areas upstream of our screw traps. During August 2001, we also PIT tagged and released 1,000 parr from the Minam and 1,003 from the Imnaha River that were captured in upstream rearing areas (Table 10).

Migration Timing: Spring Chinook salmon parr that were captured with seines and PIT-tagged on Catherine Creek and the Imnaha, Lostine, and Minam rivers in summer 2001 were detected at Lower Granite Dam over a 65 d period from 28 March to 31 May 2002 (Figure 9). The migratory period of individual populations ranged from 63 days (Lostine River) to 38 days (Catherine Creek). Median dates of detection ranged from 20 April (Lostine River) to 6 May (Catherine Creek).

Migration timing as evaluated by median adjusted detection dates differed between populations (ANOVA, $P = 0.0034$). The Lostine River population migrated earlier than the Minam and Catherine Creek populations (Tukey test, $P < 0.05$). Migration timing of the Imnaha River population did not differ significantly from the Lostine population (Tukey test, $P = 0.0967$) or from the Catherine Creek and Minam River populations ($P = 0.9325$). That timing has differed in previous years, and continues to differ between populations demonstrates the need to manage the hydrosystem so as to maximize survival throughout the entire migratory period of Snake River spring/summer Chinook salmon smolts.

Our findings for migratory year 2002 were generally consistent with past observations (Sankovich et al. 1996, Walters et al. 1997, Tranquilli et al. 1998, Jonasson et al. 1999, Monzyk et al. 2000, Reischauer et al. 2003) (Figure 10). For the Catherine Creek, Imnaha River, and Minam River populations, the median dates of migration in 2002 fell within the range in medians observed from 1993 to 2001. The median migration date for the Lostine River population was earlier than other years.

Survival Probabilities: Survival probabilities for parr tagged in the summer of 2001 were 0.093 for the Minam River, 0.106 for the Imnaha River, 0.109 for the Catherine Creek, and 0.154 for the Lostine River population. To test for differences in survival probabilities between populations, several models were developed. The best model (Minam = Imnaha = Catherine ≠ Lostine) was selected using Akaike's Information Criterion. This reduced model (H_o) was tested against the full model (H_a: Minam ≠ Imnaha ≠ Catherine ≠ Lostine) using the maximum likelihood ratio test. The null model was accepted ($P = 0.69$), supporting the conclusion that the survival probabilities of the Minam, Imnaha, and Catherine populations were not significantly different from each other, but lower than the survival probability of the Lostine population (Table 10).

The survival probabilities for the Minam and Lostine populations were lower than those seen the previous nine years of this study (Figure 11). The survival probabilities for the Catherine Creek and Imnaha populations were at the low end of the range of survival probabilities seen over the previous 9 years.

Comparison of Early Life History Strategies: Juvenile spring Chinook salmon were PIT-tagged and released at screw traps on the upper Grande Ronde River, Catherine Creek, Lostine River, and Minam River (Table 11). Parr were also PIT-tagged upstream of the screw traps on Catherine Creek and the Lostine River during the winter. At the upper Grande Ronde

River trap, we PIT-tagged 344 early- and 536 late-migrating spring Chinook salmon that were not previously tagged. At the Catherine Creek trap, we PIT-tagged 514 early- and 217 late-migrating spring Chinook salmon juveniles that were not previously tagged. We also PIT tagged 431 parr on Catherine Creek during December 2001 for the winter tag group. At the Lostine River trap, we PIT tagged 500 early- and 406 late-migrating juvenile spring Chinook salmon that were not previously tagged. In addition, we PIT tagged and released 564 parr in December 2001 for the winter tag group. At the Minam River trap, we PIT tagged 537 early- and 382 late-migrants that were not previously tagged.

Migration Timing: Median arrival dates at Lower Granite Dam for the fall, winter, and spring tag groups PIT-tagged on Catherine Creek were 6 May, 14 May, and 26 May 2002, respectively (Figure 5, Appendix Table A-6). Median arrival dates at Lower Granite Dam for the fall, winter, and spring tag groups from the Lostine River were 17 April, 7 May, and 7 May 2002, respectively (Figure 6, Appendix Table A-6). Median arrival dates at Lower Granite Dam for the fall and spring tag groups on the Minam River were 18 April and 30 May 2002, respectively (Figure 7, Appendix Table A-6). Median arrival dates at Lower Granite Dam for the fall and spring tag groups on the upper Grande Ronde River were 20 May and 31 May 20`02, respectively (Figure 8, Appendix Table A-6). Chi-square analyses rejected the null hypothesis that the weekly number of parr PIT tagged as they passed the trap in the spring were proportional to the total number estimated to pass the trap by week. Therefore, median detection dates of the spring tag groups may have reflected dates of tagging in addition to the timing of migration. For Catherine Creek and the Lostine River, the migration timing information from the winter tagged parr was used to represent the 'late migrant' life history, to avoid this bias.

As in past years, the early migrants, which were tagged during fall and overwintered in lower rearing areas, reached Lower Granite Dam earlier than late migrants (winter tag group) from Catherine Creek and Lostine River (Mann-Whitney rank sum test, $P < 0.0001$, both locations). On the upper Grande Ronde and Minam rivers, we did not have a winter tag group to compare with early migrants. However, early migrants from the fall tag group reached Lower Granite Dam earlier than the late migrants in the spring tag group (Mann-Whitney rank sum test, $P < 0.0001$), although the migration timing of spring tagged smolts may also reflect the dates of tagging as mentioned above.

Travel times from the screw trap to Lower Granite Dam for late migrants (spring tag group) from the upper Grande Ronde River ranged from 12 to 79 d with a median of 46.5 d (n = 71) (Appendix Table A-7). Travel times for late migrants from Catherine Creek ranged from 13 to 75 d with a median of 52.8 d (n = 27). Travel times for late migrants from the Lostine River ranged from 8 to 57 d with a median of 27.5 (n = 61). Travel times for late migrants from the Minam River ranged from 5 to 52 d with a median of 32.4 (n = 42).

Survival Probabilities: Survival probabilities to Lower Granite Dam for the fall, winter and spring tag groups from Catherine Creek were 0.154, 0.203, and 0.527, respectively (Table 11). Survival probabilities for the fall, winter and spring tag groups from the Lostine River were 0.326, 0.246, and 0.683, respectively. Survival probabilities for the fall and spring tag group from the Minam River were 0.249 and 0.532, respectively; and from the upper Grande Ronde River were 0.308 and 0.499, respectively.

Survival probabilities for Catherine Creek, Lostine, and Minam River fish were highest for the spring tag group (Table 11). We expected that this tag group would have the highest survival because it was the only tag group not subject to overwinter mortality after tagging.

For Catherine Creek and the Lostine River the survival probability of the fall tag group was compared to that of the winter tag group to determine whether upstream or downstream overwintering habitat conferred better survival. “Upstream” refers to areas upstream of the screw trap which is where most spawning occurs, whereas, “downstream” refers to areas downstream of the screw trap which is also downstream of the majority of the spawning.

Results from a Maximum Likelihood Ratio test indicate that there was not a significant difference in survival between fish that over wintered upstream as opposed to downstream in Catherine Creek (P = 0.403) during MY 2002 (Appendix Table A-9). For Catherine Creek, MY 1999 was the only year studied in which upstream habitat conferred better overwinter survival. Otherwise, the comparison of survival probabilities suggested that there was no difference between upstream and downstream environment in regards to overwinter survival (MY 1995, MY 1996, MY 1998) or that downstream habitat conferred better overwinter survival (MY 1997, MY 2000, MY 2001). The overwinter survival of fish in the upper rearing areas of Catherine Creek was approximately 39% for BY 2000. This was within the range of rates observed during the past 7 years of this study (Appendix Table A-10).

No difference between upstream and downstream overwinter survival was noted for the Lostine River for MY 2002 (P = 0.350, Maximum Likelihood Ratio test; Appendix Table A-9). This was in agreement with most of the previous years’ results. For migratory years 1997–2001, survival probabilities only differed between upstream and downstream overwintering fish for MY 1998 and MY 1999, when fish overwintering downstream had a higher survival. The overwinter survival of fish overwintering in the upper rearing areas on the Lostine River was approximately 36% for BY 2000. This rate is the lowest rate observed for Lostine River during the past six years (Appendix Table A-10).

Survival and Migration Timing Through the Grande Ronde Valley: We tagged 167 wild spring Chinook salmon migrants at the lower Grande Ronde Valley trap from 22 March through 12 June 2002 with a median tag date of 16 May 2002. In addition, we captured 159 previously PIT-tagged hatchery spring Chinook salmon at the lower Grande Ronde Valley trap from 9 April to 19 June 2002 with a median recapture date of 11 May 2002. We also captured 1,351 PIT-tagged hatchery spring Chinook salmon at the Catherine Creek trap from 18 March through 14 June 2002 with a median recapture date of 11 April 2002.

The survival probability to Lower Granite Dam for wild Chinook salmon migrants tagged at the lower Grande Ronde Valley trap was 0.776 (95% CI, 0.624 to 1.07). From this survival probability and the survival probability of late migrants tagged at the Catherine Creek trap (S_u=0.527), we estimated a survival rate of 0.680 for Catherine Creek late migrants as they migrated from the Catherine Creek trap to lower Grande Ronde Valley trap site. Based on these survival rates, 68% of the total late-migrant mortality from the Catherine Creek trap to Lower Granite Dam occurred between the Catherine Creek trap and the lower Grande Ronde Valley trap. The distance traveled between trap sites was only 26% (94 km) of the total distance of 356 km from the Catherine Creek trap to Lower Granite Dam. The median travel time to Lower Granite Dam for late migrants tagged at the Catherine Creek trap was 52.6 d and only 7.4 d for Chinook salmon migrants tagged at the lower Grande Ronde Valley trap. Assuming travel times for migrants tagged at the lower valley trap were representative of travel times for Catherine Creek late migrants once they passed the lower valley trap, approximately 86% (45.2 days) of the total travel time occurred in the 94 km between trap sites.

Similarly, based on a survival probability to Lower Granite Dam for the upper Grande Ronde River late migrant tag group (S_u=0.499) and for fish tagged at the lower Grande Ronde Valley trap, we estimated a late-migrant survival rate of 0.643 for fish traveling between these trap sites. We estimated that 71% of the total mortality to Lower Granite Dam occurred while fish migrated between trap sites. The distance between trap sites was only 24% (85 km) of the total distance of 347 km from the upper Grande Ronde River trap to Lower Granite Dam. However, median travel time between traps was 84% (39.1 d) of the total travel time of 46.1 d from the upper trap site to Lower Granite Dam.

Hatchery spring Chinook salmon recaptured at our Catherine Creek trap had a survival probability to Lower Granite Dam of 0.385 (95% CI, 0.339 to 0.454). Hatchery spring Chinook salmon from Catherine Creek recaptured at the lower Grande Ronde Valley trap had an estimated survival probability to Lower Granite Dam of 0.874 (95% CI, 0.713 to 1.26). This translates into an estimated survival rate of 0.441 for hatchery spring Chinook salmon migrating from the Catherine Creek trap to the lower Grande Ronde Valley trap. Based on these survival rates, 91% of the total mortality to Lower Granite Dam occurred between the trap sites. Median travel time from the Catherine Creek trap to Lower Granite Dam was 34 days. Median travel time from the lower Grande Ronde Valley trap to Lower Granite Dam was 9 days indicating that roughly 74% of the total travel time from the Catherine Creek trap to Lower Granite Dam occurred between trap sites.

Alternate Life History Strategies

In northeast Oregon streams almost all of the spring Chinook salmon parr migrate seaward as age-1 smolts. Most spend two to three years in the ocean before returning to their natal streams as mature adults to spawn. Over the years of this investigation we have observed two life-history strategies that deviate from this generalized pattern: seaward migration of smolts at age-2 and maturation of age-0 and age-1 parr in freshwater.

Very few of the PIT-tagged spring Chinook salmon parr from our study streams have smolted as two year olds (for discussion of this *see* Monzyk et al. 2000). Of the 36,234 parr PIT-tagged on Catherine Creek and the Grande Ronde, Imnaha, Lostine, Minam, and Wenaha rivers during the summers from 1992 to 2000 (Walters et al. 1992, 1997; Sankovich et al. 1996; Tranquilli 1998, Monzyk et al. 2000, Reischauer et al. 2003), only 11 (0.03%) were detected in the hydrosystem as age-2 smolts. We assumed that there were no immature age-1 parr present in Catherine Creek and the Lostine River during the summer of 2001 (Reischauer et al. 2003) that could have migrated as age-2 smolts in 2002. However, mature age-1 parr were present in

Catherine Creek and the Lostine River. It is possible that some of the mature age-1 parr could migrate seaward as smolts, although, we have yet to confirm this with PIT tag detections. During the 2002 migratory year, there were no detections of age-2 smolts that had been PIT-tagged as age-0 parr in the summer of 2000 or age-1 parr in the summer of 2001 on Catherine Creek or the Imnaha, Lostine, or Minam rivers.

Precociously mature age-0 or age-1 parr, although uncommon (especially age-0), were also observed in our study streams. We estimated that an average of 1.9 mature, wild, male parr were present for each anadromous female spawner (i.e., redd) in Catherine Creek during the late summer, and early fall of 2002 (Appendix Table A-5). Mature parr were also captured in the Lostine River during the summer of 2002 but we were unable to estimate their population (*see* **Egg-to-Parr Survival, Parr Abundance, and Age Composition in Summer**). Precocious male Chinook salmon parr are capable of fertilizing eggs and producing viable offspring in a hatchery environment (Robertson 1957, Unwin et al. 1999) and may play an important role in the fertilization of eggs in the wild (Gebhards 1960). However, it is still unclear how much, if any, this life history strategy contributes to the wild population. Therefore, we can conclude only that the potential exists for mature, wild, male parr to make significant gametic contributions. Although not an objective of our research, we used mark recapture techniques to estimate that 87 (95% CI, 39 – 218) mature hatchery parr were present in Catherine Creek during the summer of 2002 (Appendix Table A-3). These mature hatchery parr may also spawn with wild adult females. Mature hatchery parr were not observed or captured on the Lostine River during the summer of 2002. Given the usual low abundance of anadromous spawners in northeast Oregon streams, mature male parr (wild and hatchery) may be an important component of the breeding population.

SUMMER STEELHEAD INVESTIGATIONS

Methods

In the Grande Ronde Subbasin, most steelhead populations are sympatric with rainbow trout populations and only steelhead smolts and mature adults can be visually differentiated from resident rainbow trout. We will refer to *Oncorhynchus mykiss* as steelhead in this report, but some of these fish may be the resident form, rainbow trout.

We studied the steelhead in Catherine Creek upstream of our screw trap to learn more about the abundance, migration characteristics, growth rates, and size and age structure of the population. We also used screw traps to study the movement of juvenile steelhead downstream from tributary habitats in Catherine Creek and the Lostine, Minam, and upper Grande Ronde rivers. We assumed all juvenile steelhead captured at trap sites were making directed downstream movements and not localized movements. Violation of this assumption would result in positively biased population estimates.

Characterization of the Steelhead Population in Catherine Creek and Tributaries During Summer

Our work during the summer of 2002 was a continuation of our investigation of steelhead in the upper Catherine Creek drainage that began in the summer of 2000. We estimated the abundance, age composition, and size structure of the Catherine Creek and Milk Creek steelhead populations in the summer of 2002. Recaptures and detections of steelhead PIT-tagged during the summer of 2000 in Catherine Creek, Little Catherine Creek, North Fork Catherine Creek, and the South Fork Catherine Creek and during the summer of 2001 in Catherine Creek and the North Fork Catherine Creek, enabled us to learn more about migration patterns, anadromy, and growth rates of this population.

Summer Abundance Estimates: *Catherine Creek:* We used mark-and-recapture techniques to estimate the abundance of steelhead in the main-stem Catherine Creek during July 2002. Steelhead were collected in Catherine Creek from our screw trap site (rkm 32) upstream 20 km to the confluence of the north and south forks of Catherine Creek. We captured, marked, and released fish in Catherine Creek 15 – 19 July 2002 (Appendix Table B-1). We conducted subsequent sampling at randomly selected 0.4 km sections 22 – 25 July 2002. We fished about 40% of the stream upstream from the trap during resampling. We attempted to mark a sufficient number of fish so that the 95% confidence limits would not exceed 25% of the mean. We collected steelhead for marking by beach seining, herding them (while snorkeling) into a seine set perpendicular to the stream flow, or by angling. We marked captured steelhead with paint or a PIT tag. The same procedures described for spring Chinook salmon parr handling and marking were used for steelhead (*see* **SPRING CHINOOK SALMON INVESTIGATIONS; Methods;** Egg-to-Parr Survival, Parr Abundance, and Age Composition in Summer). Fish that were less than 55 mm fork length were not PIT-tagged. We recorded fork lengths and weights, and collected scales for age analysis from a random subsample of fish. All fish were handled and marked at stream temperatures of 15°C or less and released in the area of capture within 24 hours of tagging. During resampling we used the same methods to catch fish as described above. We measured the length of all captured fish and noted whether they were marked or unmarked. We used Chapman's modification of the Petersen estimate (Ricker 1975) to determine the abundance of parr for each length category. We obtained 95% confidence intervals for the abundance estimates using equation (3.7) in Ricker (1975) and values from Appendix II in Ricker (1975). The numbers of marked, recaptured, and unmarked fish summarized by length categories were used to calculate the Chapman – Peterson population estimate and variance for each length category. Length categories were designated such that there were at least four recaptures for each category to reduce bias in the population estimate. Length category population estimates were summed to obtain the total population estimate ($\hat{N}$). Variances of each length category were summed to compute the total variance, which was then used to calculate the 95% confidence interval.

Milk Creek: Milk Creek is a small tributary (approximately 8 km in length) that enters Catherine Creek at rkm 47. Steelhead were captured for marking between 27 June and 2 July and for examination for marks between 8 July and 10 July 2002 (Appendix Table B-1). Steelhead were captured using a backpack electrofisher and fish were marked with PIT tags. However, young-of-year (generally less than 40 mm FL) were not marked. Tagging methods were the same as used in Catherine Creek. We marked and recaptured fish throughout the lower 7.2 km of Milk Creek. The data were handled as described above for Catherine Creek.

Lengths and Age-Composition of Steelhead in Summer Rearing Areas: Lengths were measured and scale samples were collected from a subsample of steelhead that were handled during the first sampling effort (marking phase) on Catherine and Milk Creeks. Scales were collected from fish of all sizes and were aged as described for juvenile spring Chinook salmon (*see* **SPRING CHINOOK SALMON INVESTIGATIONS**; **Methods; Egg-to-Parr Survival, Parr Abundance, and Age Composition in Summer**). An age-length key was created and used to extrapolate the age composition of the population (DeVries and Frie 1996). Length categories used in the age-length key corresponded to the length categories used in the population estimation.

Growth Rates: Daily growth rates of PIT-tagged steelhead were calculated by dividing the difference in fork lengths between time of marking (during summer 2001) and time of recapture (during summer 2002) for recaptured steelhead by the elapsed time from tagging to recapture. Mean daily growth rates were calculated from individual growth rates. Only fish recaptured 365 ± 14 d after their initial measurement and marking were used for this calculation.

In-Basin Migration Timing and Abundance

The migration timing and abundance of migrating steelhead in Catherine Creek, the upper Grande Ronde, Lostine, and Minam rivers were determined by operating rotary screw traps year round. We followed the same methodology for operating screw traps and analyzing data as described for spring Chinook salmon (*see* **SPRING CHINOOK SALMON INVESTIGATIONS; Methods; In-Basin Migration Timing and Abundance**).

The 2002 migratory year for summer steelhead within the Grande Ronde Subbasin overlaps two calendar years, and begins on 1 July 2001 and ends on 30 June 2002. Similar to spring Chinook salmon, there is a distinct early migration that peaks at our trap sites in the fall. Early migrants leave upper rearing areas in Catherine Creek, the upper Grande Ronde, Lostine, and Minam rivers and overwinter in downstream habitat. Some of these fish continue their seaward migration out of the subbasin the following spring, while others continue to rear in the subbasin for another year before their seaward migration. Late migrants exhibit another life history strategy whereby they remain in upper rearing areas throughout fall and winter, and then leave their upper rearing areas in spring to initiate their seaward migration or continue to rear for another year in other areas of the Grande Ronde Subbasin before initiating their seaward migration. Designations of early and late migratory groups were based on trends in capture rates at trap sites. A common period of diminished capture rates occurs at our trap sites in winter and was used to classify fish into early and late migratory groups. We determined migrant abundance and migration timing at trap sites by migratory group.

Migration Timing to Lower Granite Dam

Detections of PIT-tagged steelhead at Lower Granite Dam on the Snake River were used to estimate migration timing past Lower Granite Dam. Daily detection counts were expanded to account for fish that may have passed undetected in spill at the dam (*see* **SPRING CHINOOK SALMON INVESTIGATIONS; Methods; Migration Timing to Lower Granite Dam**). The fall 2001 tag group was composed of fish that moved past our upper trap sites between 1 September and 28 January (early migrants). The spring 2002 tag group included fish that moved past our upper trap sites between 29 January and 30 June (late migrants). Our goal was to tag 1,000 steelhead in the fall and 500 in the spring at each of our trap sites on the upper Grande Ronde River, Catherine Creek, and Lostine River, and Minam River to assess migration timing of early and late migrants from each location. In order for PIT-tagged fish to be representative of the overall population with respect to migration timing and detection rates, we tagged fish throughout their migration. The same procedures described for spring Chinook salmon parr handling and marking were used for steelhead (*see* **SPRING CHINOOK SALMON INVESTIGATIONS; Methods**). During fall, we tagged steelhead with fork length greater than or equal to 55 mm, whereas during spring, only steelhead with fork length greater than or equal to 115 mm were PIT-tagged. In previous years of this study, steelhead tagged in spring with fork length less than 115 mm were not detected at Snake and Columbia River dams during the same spring in which they were tagged. By using this length criterion during spring, we attempted to tag only seaward migrating steelhead. Overall migration timing for the Catherine Creek steelhead population was determined by examining the detections of fish that were PIT-tagged during the summer of 2001 on Catherine Creek and its tributaries.

First and last detection dates, and the median date of migration past Lower Granite Dam based on expanded dates of detection were determined for the fall and spring tagged fish from each location and for the summer tagged fish from Catherine Creek and its tributaries. *See* **SPRING CHINOOK SALMON INVESTIGATIONS; Methods; Migration Timing to Lower Granite Dam Comparison of Early Life History Strategies within Populations:** ***Migration Timing*** for a discussion of calculating median migration dates. The median detection dates calculated for spring tagged fish may have reflected, to some extent, the dates of tagging rather than the true migration pattern of all late migrants. A chi-square test was used to determine whether the number tagged weekly was proportional to the number migrating past the trap in the spring. We investigated whether detection dates of early and late migrants differed by using the Mann-Whitney rank sum test on expanded dates of detection of fall tagged and spring tagged fish. As mentioned, bias of the spring tag group median migration date would affect the results of the comparison.

Survival to Lower Granite Dam

Steelhead were PIT-tagged at our upstream screw traps during the fall of 1999, 2000, and 2001 and the spring of 2000, 2001, and 2002. Survival probabilities were reported for all combinations of tag group and migration year and were calculated using the SURPH2.1 program (Lady et al. 2001). The term “survival probability” is misleading, because some steelhead may not migrate seaward during the migratory year used for the analysis or at all. For example, when calculating the “survival probability” for steelhead tagged at the Catherine Creek screw trap in the fall of 2001 for migratory year 2002, only dam detections during 2002 were considered and resident fish and those that migrated after 2002 were not accounted for. If we were unable to calculate survival probabilities, detection rates were reported. Detection rates, calculated by dividing the number of tagged steelhead detected in a given migration year by the number in the tag group, will tend to underestimate the survival probability because capture probability is not taken into account.

During the summers of 2000, 2001, and 2002, we captured and PIT-tagged steelhead in their rearing areas upstream of the screw trap on Catherine Creek (Appendix Table B-1, Monzyk et al. 2000, Reischauer et al. 2003). Detections of these PIT-tagged fish at the dams on the Snake and Columbia rivers reflected the prevalence of the anadromous (steelhead) life history pattern in this population and the survival of the juveniles before reaching the dams. However, it was impossible to separate these two components. Survival probabilities for steelhead PIT-tagged during the summers of 2000 and 2001 in their upper rearing areas on Catherine Creek and its tributaries were calculated. All detections at the juvenile detection facilities at the dams regardless of year were taken into account. For example, when calculating the survival probability for steelhead tagged during the summer of 2000, dam detections during 2001 and 2002 were used. Survival probabilities for steelhead PIT tagged during the summer of 2002 will be reported in the 2003 annual report.

Length and Age of Migrants

We measured fork lengths (mm) and weights (g) of approximately 100 randomly selected steelhead captured each week at our rotary screw traps throughout the migratory year. We followed the same methodology for operating screw traps and collecting and measuring steelhead as described for spring Chinook salmon (*see* **SPRING CHINOOK SALMON INVESTIGATIONS; Methods; In-Basin Migration Timing and Abundance**). In addition, we collected scale samples and measured lengths from randomly collected steelhead throughout the early migration period. During the late migration period, we modified this procedure slightly by collecting scales from a stratified subsample with approximately ten scale samples collected from each 10 mm length-group. Scales were analyzed to determine age of steelhead. Scale impressions were made on acetate slides and inspected for annuli on a microfiche reader. Age and length information was used to develop an age-length key for each migration period and trap site. The age-length keys and fork length information collected at the screw traps were then used to determine the age structure for early and late migrants at each trap site. To determine if fish size within age-groups and migration period differed between populations, we compared the lengths of fish with known age (i.e. lengths associated with scale samples) using a Kruskal-Wallis ANOVA on ranks and Dunn’s pair-wise multiple comparison procedure.

Early Migrant Smolt Detections: The age structure of steelhead PIT-tagged at the traps was compared to the age structure of the subset detected at the dams in the spring of 2002. For early migrants, we randomly PIT-tagged and collected scales from steelhead in all size classes encountered at the traps; therefore, these fish were representative of the overall age structure of early migrants at the traps and could be used for comparisons. Only those steelhead in which scale samples provided a known age at time of tagging were used for our analyses.

Steelhead lengths at tagging, grouped by dam detection history, were also compared to investigate the relationship between size and migration patterns and survival to the dams. The fork lengths of all steelhead tagged at the traps in the fall of 2001 were compared to the fork lengths of those subsequently detected at the dams in the spring of 2002 using t-tests or Mann-Whitney Rank Sum Tests. The fork lengths of all steelhead tagged at traps in the fall of 2000 were compared to the lengths of those detected in 2001 and 2002 using a one-way ANOVA or the Kruskal-Wallis one-way ANOVA on ranks.

Late Migrant Smolt Detections: A similar comparison was done for steelhead tagged at the screw traps in the spring 2002, although only larger individuals (fork lengths ≥ 115 mm) were PIT-tagged. We were unable to compare age structure of late migrants detected at dams to their age structure as they passed the traps because we only tagged those fish with fork length greater than or equal to 115 mm.

Migration Pattern of Summer Population: Steelhead lengths at tagging during the summer, upstream of the Catherine Creek trap, were compared for fish grouped by their subsequent recapture and dam detection history. We used a two-way ANOVA to compare the lengths at tagging by summer in which they were tagged (2000 and 2001) and season of downstream migration (fall compared with spring) to determine if size was related to the timing (early or late) of migration out of upper rearing areas. Lengths at tagging were also compared between steelhead that were known to migrate out of upstream rearing habitats before the next summer (fall and spring trap recaptures and dam detections before the next summer), those that stayed upstream through the next summer (all detections at the Catherine Creek screw trap or upstream recaptures during or following the next summer), and all the steelhead tagged during the summer. Data from fish tagged during the summers of 2000 and 2001 were used for this comparison (two-way ANOVA and the Tukey pair-wise multiple comparison procedure).

Results and Discussion

Characterization of the Steelhead Population in Catherine Creek and Tributaries During Summer

Summer Abundance Estimates: We estimated that 19,115 (95% CI, 14,082 to 24,149) steelhead age-1 and older were present in Catherine Creek above our screw trap (rkm 32) in July 2002 (Table 12). This was less than the summer 2001 estimate of 25,736 (95% CI, 21,005 to 31,519) and similar to the summer 2000 estimate of 22,393 (95% CI, 17,461 to 28,689) fish (Appendix Table B-2). Steelhead in the 101 – 120 mm fork length size class were the most abundant. Scale analysis suggested that these were age-1 fish.

We estimated that 1,825 (95% CI, 1,600 to 2,050) steelhead age-1 and older were present in Milk Creek in late June/early July of 2002 (Table 12). As with Catherine Creek, steelhead in the 101 – 120 mm (fork length) size class were the most abundant. This size class corresponds to age-1 and age-2 fish in Milk Creek as determined from scale samples. We captured steelhead throughout Milk Creek from the mouth upstream to the confluence of two 1st order tributaries within a kilometer of the stream's origin. We captured steelhead in the lower part of the east tributary; but did not find any in the north flowing tributary. Although we were not sampling age-0 steelhead, they appeared to be abundant between rkm 2 and 7.

Length and Age Composition of steelhead in Summer Rearing Areas: Analysis of scales taken from steelhead in Catherine Creek indicated the presence of age-1, age-2, and age-3 fish. Age-1 steelhead were the most abundant (Figure 12 and Appendix Table B-3) as determined using our population estimates by length category and a length-age key constructed using our scale data. The length of the smallest fish we aged (age-1) was 71 mm. Although none of the scales analyzed were age-0, we observed many fry approximately 40 mm fork length, which we assumed were age-0. It is likely that not all steelhead fry had emerged from the gravel by the time we started our sampling in mid July.

Scale analysis revealed the presence of ages 1–3 steelhead in Milk Creek (Figure 12 and Appendix Table B-3). As in Catherine Creek, age-1 fish were most common in Milk Creek. However, age-2 fish appeared to be present in Milk Creek in a higher proportion (27%) than in the main-stem of Catherine Creek (14%). We observed many age-0 steelhead in Milk Creek.

The length distributions of the steelhead captured during our marking efforts on Catherine and Milk creeks reflected the age compositions in Catherine Creek and Milk Creek (Figure 13), with sizes corresponding to age-1 fish being the most abundant. The median fork length of steelhead sampled in Catherine Creek was 113 mm, and in Milk Creek was 117 mm. Capture methods may account for differences in length distribution between Catherine and Milk Creeks. We caught fish by snorkel seining in Catherine Creek, which may have resulted in under representing the larger steelhead in comparison to electrofishing on Milk Creek.

Growth Rates: The mean daily growth rate of steelhead tagged upstream of the Catherine Creek trap in the summer of 2001 and recaptured upstream of the screw trap one year later (365 ± 14 days) was 0.11 mm/d (95% CI, ±0.036) (Table 13).

In-Basin Migration Timing and Abundance

Upper Grande Ronde River: The upper Grande Ronde River trap fished for 129 d between 27 September 2001 and 27 June 2002 (Table 14). A distinct early migration was not as evident at this trap site as it was at other upper trap sites (Figure 14). Most juvenile steelhead moved as late migrants during spring months as has been the case for past years of this study. The median emigration date for early migrants passing the trap was 24 October and the median emigration date for late migrants was 15 April. The median migration dates were both within the ranges previously reported in past years of this study (Table 15).

We estimated that a minimum of 17,286 juvenile steelhead (95% CI, ± 1,784) moved out of the upper Grande Ronde River upper rearing areas during MY 2002. This estimate is within estimates from the previous three migratory years study that ranged from 6,108 (MY 1999) to

17,845 fish (MY 2000). Based on weekly trap efficiencies, we estimated approximately 6% (990 ± 269) were early migrants and 94% (16,296 ± 1,763) were late migrants. The pattern of a dominant late migration of juvenile steelhead in the upper Grande Ronde River is consistent for all migratory years studied to date (Table 15). In previous years, the proportion of late migrants has ranged from 60% (MY 1998) to 96% (MY 2001).

Catherine Creek: The Catherine Creek trap fished for 215 d between 06 September 2001 and 26 June 2002 (Table 14). There were distinct early and late migrations exhibited by juvenile steelhead at this trap site (Figure 14). Median emigration date for early migrants was 12 October. The median date for late migrants was 1 May and, similar to juvenile spring Chinook salmon at this trap, this was the latest emigration date reported since the study began (Table 15).

We estimated that a minimum of 45,799 ± 6,271 juvenile steelhead migrated out of the Catherine Creek upper rearing areas during MY 2002. This estimate is the largest estimate reported since this study began (Table 15). Based on weekly trap efficiencies, 42% (19,156 ± 3,013) migrated early and 58% (26,643 ± 5,500) migrated late. The proportion of juvenile steelhead leaving upper rearing areas as late migrants is consistent with the proportions from previous years of this study that range from 47% to 75% (Table 15). The Catherine Creek population appears to be different from the upper Grande Ronde population in that a greater proportion of the overall migrant population tends to leave upper rearing areas before the onset of winter.

Lostine River: The Lostine River trap fished for a total of 258 d between 01 July 2001 and 26 June 2002 (Table 14). Distinct early and late migrations were evident at this trap site (Figure 14). Most early migrants left upper rearing areas in October, but there was a smaller peak in January, similar to juvenile spring Chinook salmon from this river. The median emigration date of early migrants was 18 October. This is the second latest emigration date reported for early migrants with the latest being in MY 2000 (19 October). The date that the median late migrant moved past the trap was 17 April (Table 15). This is earlier than emigration dates reported in previous years of this study.

We estimated that a minimum of 21,019 ± 3,217 steelhead migrants moved out of the Lostine River during MY 2002. We estimated that approximately 69% (14,564 ± 2,690) of the juvenile steelhead migrated early and 31% (6,455 ± 1,764) migrated late. This is a smallest percentage of late migrants reported since this study began (Table 15).

Minam River: The Minam River trap fished for 168 d between 1 July 2001 and 30 June 2002 (Table 14). There were distinct early and late migrations exhibited by juvenile steelhead at this trap site (Figure 14). Median emigration date for early migrants was 24 October and the median date for late migrants was 25 April (Table 15).

We estimated that a minimum of 44,872 ± 19,786 juvenile steelhead migrated out of the Minam River during MY 2002. Based on weekly trap efficiencies, 18% (8,160 ± 3,007) migrated early and 82% (36,712 ± 19,556) migrated late.

Migration Timing to Lower Granite Dam

Upper Grande Ronde River: During MY 2002, we PIT-tagged 165 early- and 543 late-migrating steelhead at the upper Grande Ronde River trap that were not previously tagged (Appendix Table B-5). The median migration date past Lower Granite Dam for the early migrants was 7 May. The first detection was 26 April and the last was 1 June. The late migrants were detected between 14 April and 25 June. The median migration date for the late migrants was 22 May (Figure 15). The early migrants arrived at Lower Granite Dam before the late migrants (Mann-Whitney Rank Sum test, P = 0.0046), although the effects of bias in the spring tagging were not accounted for. Travel times from the screw trap to Lower Granite Dam for late migrating steelhead ranged from 5 to 91 d with a median of 20.6 d (n = 86) (Table 16).

Catherine Creek: During MY 2002, we PIT-tagged 723 early- and 504 late-migrating steelhead at the Catherine Creek trap (Appendix Table B-5). The median migration date for the early migrants was 12 May (Figure 16). The first detection was 16 April and the last was 17 June. The late migrants were detected between 20 April and 1 July, with a median detection date of 22 May. There was no significant difference in detection dates between early and late migrants (Mann-Whitney rank sum test, P = 0.8342), although the effects of bias in the spring tagging were not accounted for. Travel times from the screw trap to Lower Granite Dam for late migrating steelhead ranged from 6 to 65 d with a median of 18.1 d (n = 95) (Table 16).

We PIT –tagged 1,108 steelhead on Catherine Creek and the North Fork Catherine Creek during the summer of 2001 (Appendix Table B-6). Detections of these steelhead represented the overall migration timing the Catherine Creek and North Fork populations. The median date of migration past Lower Granite Dam for steelhead PIT-tagged during the summer of 2001 on Catherine Creek and the North Fork Catherine Creek was 20 May (Figure 17). Tagged steelhead from these locations were detected at Lower Granite Dam between 14 April and 25 June.

Lostine River: At the Lostine River trap, we PIT-tagged 837 early- and 351 late-migrating steelhead that were not previously tagged (Appendix Table B-5). The median migration date for the early migrants was 8 May (Figure 18). The first detection was 10 April and the last was 24 June. The late migrants were detected between 19 April and 30 June, with a median detection date of 23 May. Early migrants were detected at Lower Granite Dam before the late migrants (Mann-Whitney rank sum test, P < 0.0001), although the effects of bias in spring tagging were not accounted for. Travel times from the screw trap to Lower Granite Dam for late migrating steelhead ranged from 3 to 65 d with a median of 25.9 d (n = 72) (Table 16).

Minam River: At the Minam River trap, we PIT-tagged 262 early- and 197 late-migrating steelhead that were not previously tagged (Appendix Table B-5). The median migration date for the early migrants was 11 May (Figure 19). The first detection was 17 April and the last was 31 May. The late migrants were detected between 16 April and 2 June, with a median detection date of 20 May. The median detection dates for early and late migrants were not significantly different (Mann-Whitney rank sum test, P = 0.7696), although the effects of bias in the spring tagging were not accounted for. Travel times from the screw trap to Lower Granite Dam for late migrating steelhead ranged from 4 to 67 d with a mean of 13.9 d (n = 48) (Table 16).

Survival to Lower Granite Dam

Survival probabilities of steelhead tagged in fall 2001 ranged from 0.069 for Catherine Creek fish to 0.154 for Lostine River fish (Table 17). Some steelhead migrants tagged at the screw traps in the fall of 2000 did not migrate past the dams until the following migratory year. For example, two steelhead PIT-tagged at the Minam River trap and 18 tagged at the Lostine trap during the fall of 2000 were detected at the dams during the 2002 migratory year (Appendix Table B-7).

Survival probabilities of steelhead tagged in the spring 2002 (FL ≥ 115 mm) ranged from 0.450 for upper Grande Ronde River fish to 0.722 for Minam River fish (Table 17). Some steelhead tagged at the screw traps in the spring of 2001 did not migrate past the dams until the following migratory year. For example, two steelhead that were PIT-tagged at the Catherine Creek trap, five tagged at the upper Grande Ronde trap, 16 tagged at the Lostine trap, and eight tagged at the Minam trap during the spring of 2001 were not detected at the dams until the 2002 migratory year (Appendix Table B-7).

We were not able to distinguish between steelhead and resident rainbow trout parr in their summer rearing habitat. For this reason, dam detections of steelhead parr PIT-tagged in the summer reflected not just survival to the dam detection sites but also the prevalence of the anadromous life history pattern. The survival probabilities of wild steelhead PIT-tagged in Catherine Creek and its tributaries during the summer of 2001 and calculated using 2002 dam detection records was 0.087 (Table 18). Some steelhead tagged in the summer of 2001 may migrate seaward in 2003. Survival probabilities will be adjusted accordingly in future annual reports. Fifteen steelhead PIT tagged during the summer of 2000 on Catherine Creek and its tributaries were detected at the dams during the 2002 migration year (Table 18). At least one PIT tagged fish from Catherine Creek and each of the tributaries where we have tagged fish the past two summers (Catherine Creek, North Fork Catherine Creek, South Fork Catherine Creek, and Little Catherine Creek) has been detected at the dams, indicating the presence of the anadromous life history pattern among steelhead in all the tributaries studied to date.

Length and Age of Migrants

The steelhead collected at trap sites during the 2002 migratory year included four age-groups. Early migrants ranged from 0 to 3 years of age. The same cohorts composed the late-migrants with ages ranging from 1 to 4 years. With the exception of the upper Grande Ronde River population, the majority of early migrants collected at trap sites were age-0 fish (Table 19). This is in contrast to the 2001 migration year when the majority of early migrants were age-1. For the 2002 migratory year, the proportion of age-0 fish collected at the trap sites averaged 65% (range 39-75%); the proportion of age-1 early migrants averaged 29% (range: 23-61%); age-2 early migrants averaged 5.8% (range: 0-13%; and age-3 early migrants were rare (average: 0.06%) with the only collections occurring at the Lostine River trap (Table 19). The age structure of the late migrants changed, with older fish collected in greater numbers at our trap sites in general. For the late-migrant population, age-1 fish (same cohort as age-0 early migrants) averaged only 38% (range: 28-46%), age-2 fish averaged 50% (range 37-62%), age-3 fish averaged 11% (range 6.9-16%) and age-4 fish averaged 0.43% (range 0-1.4%). Age-4 steelhead were again rare with the only collections occurring on the Lostine and Minam Rivers (Table 19).

Size of migrants within age groups and migration period differed between trap sites. Lostine River steelhead were generally larger than other populations (Table 20). Age-0 early migrants from the Lostine River were significantly larger than the same cohort from other populations ($P < 0.05$). Age-0 early migrants from the Minam River were significantly smaller than the other populations. During the late-migration period, this cohort showed similar trends. Age-1 fish from the Lostine River were still the largest but only significantly different from Minam River fish. There were no significant size differences between populations for age-2 and age-3 late migrants (Table 20).

Early-Migrant Smolt Detections: The age structure of PIT-tagged early migrants with known age was very similar to the age-structure of the overall early-migrant population indicating that PIT-tagged fish were representative of the overall early-migrant population (Table 19 and Table 21). However, the age structure of the overall early-migrant steelhead that were PIT-tagged at the trap sites differed considerably from the subset of these fish subsequently detected at the dams (Table 21). Age-0 fish were observed in greater proportion at the trap sites than they were at the dams. An average 63% of the early migrants PIT-tagged at the traps were age-0, however this cohort (age-1 smolts) comprised only 30% of the fish detected at the dams the following spring (Table 21). In contrast to age-0 fish, age-1 fish were observed in smaller proportion at the trap sites than they were at the dams. An average of only 32% of the fish PIT-tagged in the fall of 2001 were age-1, however, this cohort comprised 64% of the smolts detected at the dams. For the upper Grande Ronde River, this cohort comprised 100% of the smolts detected at the dams, however sample size was small for this trap site (Table 21). The proportion of age-2 fish PIT-tagged at the traps was small (range: 0-8.4%) with the only smolts detected at the dams from this cohort (age-3 smolts) originating from the Lostine River (Table 21). No age-3 fish tagged in the fall of 2001 (age-4 smolts) were detected at the dams the following spring, but few fish in this cohort were PIT-tagged.

Similarly, fork lengths at time of tagging were compared between steelhead detected at the dams in 2002 and all steelhead tagged for the various tag groups (Appendix Tables B-8, B-9, and B-10). Of all the early-migrant steelhead tagged at the traps in the fall of 2001, the larger individuals from each trap tended to be the ones detected at the dams in 2002 (Mann-Whitney rank sum test $P < 0.0001$ for all fall tag sites, Figure 20). This agrees with results for the upper Grande Ronde and Lostine River early migrants tagged in fall 2000 (Reischauer et al., 2003).

Late-Migrant Smolt Detections: As was the case with early-migrant smolts detected at the dams, late-migrant smolts ranged in age from 1 to 3 years. Because we PIT-tagged only fish with fork length greater than or equal to115 mm, we were not able to determine if the age structure differed between fish captured at trap sites and those detected at the dams. However, the larger individuals tagged at the Catherine Creek, upper Grande Ronde, and Lostine River traps in the spring of 2002 tended to be the ones detected at the dams in 2002 (Mann-Whitney rank sum test $P < 0.05$, Figure 21). This agreed with results from MY 2001 for these three locations (Reischauer et al., 2003). There was no significant difference between the lengths of fish tagged and the lengths of fish detected at the dams for fish tagged at the Minam River trap during spring 2002 (Mann-Whitney rank sum test $P = 0.0577$).

Overall, these results indicate that steelhead smolts from the Grande Ronde Subbasin ranged in age from 1 to 3 years with the majority composed of age-2 fish. Peven et al. (1994) found that steelhead smolts from the mid-Columbia River ranged in age from 1 to 7 years with most occurring as age-2 and age-3 fish. Results from previous years of this study showed steelhead smolts ranging from 1 to 3 years of age with the majority comprised of age-2 fish (Monzyk et al. 2000, Reischauer et al. 2003). However, the proportion of age-2 smolts was higher in previous years. The proportion of steelhead smolts within age-groups is known to vary considerably between migration years (Ward and Slaney 1988).

Migration Pattern of Summer Population: When the lengths of fish tagged during the summer were compared by their subsequent dam detection history, a significant difference was noted between those that migrated downstream the following spring, those that remained upstream through the following summer, and the tag group as a whole (two-way ANOVA $P < 0.0001$, Figure 22). As seen with the fall and spring tagged fish, the larger fish tagged during the summer in the Catherine Creek drainage were disproportionately detected at the dams during the subsequent year. Trap recaptures and dam detections suggested that, of the steelhead PIT-tagged during the summers of 2000 and 2001 upstream of the Catherine Creek trap, the larger fish (median fork lengths at the time of tagging 127 and 123, respectively) were more likely to migrate out of the upstream rearing areas within the subsequent year, whereas the smaller fish (median fork length 92.5 for steelhead tagged summer of 2000) were more likely to migrate out more than one year after tagging (Appendix Table B-10). Annual growth of steelhead PIT tagged upstream of the screw trap in the summer of 2001 and recaptured upstream of the screw trap a year later ranged between 33 and 53 mm, equivalent to a mean daily growth rate of 0.114 (N = 4; 95% CI, ± 0.036) (Table 13). Limited trap recaptures of steelhead PIT-tagged in the summers of 2000 and 2001 did not reveal a relationship between length (at tagging) and tendency to migrate out of upper rearing the following fall as opposed to spring ($P = 0.2077$, Figure 23 and Appendix Table B-10). However, small sample sizes resulted in low power (0.11 at $\alpha = 0.05$) to detect a difference.

While some of the differences in age structure and length between all tagged fish and those detected at dams could be the result of greater size-dependent mortality of smaller fish, there is evidence that smaller individuals passing the traps delay their migration past the dams until the subsequent migratory year. For instance, the steelhead that were tagged at the Lostine screw trap in the fall of 2000 and delayed their seaward migration until the 2002 migratory year were generally smaller than the tag group as a whole (Kruskal-Wallis one-way ANOVA on ranks $P < 0.0001$, Figure 24). The same pattern was observed for steelhead tagged during the fall of 1999 (Reischauer et al., 2003), and suggested for steelhead tagged at the Minam trap in the fall of 2000, although the sample size was quite small. Furthermore, although we tagged only the larger fish during the spring of 2001, it is worth noting that a few from each of our four trap sites (5 from the upper Grande Ronde River, 2 from Catherine Creek, 16 from the Lostine River, and 8 from the Minam River) were detected at the dams in 2002 (Appendix Tables B-7 and B-9);

and, lengths of these fish tended to be towards the small end of the range of all those tagged and of those detected in 2001 (Appendix Table B-9).

STREAM HABITAT SURVEY

Methods

The quality and quantity of summer rearing habitat for spring Chinook salmon was assessed in Catherine Creek during the summer of 2002. Stream habitat and riparian areas were surveyed on the main-stem Catherine Creek from rkm 31 to the confluence of the North Fork Catherine Creek and South Fork Catherine Creek at rkm 52. In addition, the lower 5 km of North Fork Catherine Creek from the mouth to the confluence with Middle Fork Catherine Creek were surveyed as well as the lower 2 km of South Fork Catherine Creek. The surveyed areas comprise most of the spawning and summer rearing habitat for spring Chinook salmon in Catherine Creek. We used survey methods developed by Oregon Department of Fish and Wildlife Aquatic Inventories Project (Moore et al. 1997) to describe reach breaks, channel and valley form, habitat unit types, and riparian condition. Reach breaks were determined by changes in valley and channel form, major changes in riparian vegetation type, or changes in land use or ownership. Within each habitat unit we measured depth, surface area, slope, substrate composition, amount of woody debris, and stream shading. For pool units, maximum depth and depth at the pool tail crest was also recorded. For all other unit types, modal or typical depth was measured. Substrate was assessed with ocular estimates of percent distribution by streambed surface composed of substrate material in six size classes: silt and organic material; sand; gravel (2-64 mm); cobble (64-256 mm); boulder; and bedrock. We assessed riparian condition by conducting tree counts by diameter class (diameter at breast height, DBH) and measuring canopy cover along 1-3 transects per reach. Transects were 60 m long and perpendicular to the stream. Each transect consisted of three zones on each side of the stream that were of increasing distance from the stream. Zones were 5 m wide by 10 m long that, in tandem, constituted a 30 m long section on each side of the stream. In addition to the Aquatic Inventories survey protocols, we assessed spawning substrate quality by taking an additional ocular estimate of substrate composition at all pool tail-outs. Estimates of substrate composition were taken within a 0.062 m^2 area where the pool tail crest depth measurement was taken. Also, all pocket pools ($\geq$0.25 m deep and $\geq$2 m^2) within riffle or cascade units were counted to assess the amount of this potential rearing habitat. Surveys were conducted at or near summer base-flow conditions. Measured habitat variables were summarized to assess overall stream habitat quality and quantity. Habitat variables were also summarized by reach to describe changes in habitat quality and quantity along the stream's length.

Results and Discussion

Surveys of spring Chinook salmon rearing habitat were conducted from 8 July through 28 August 2002 on the main-stem Catherine Creek, from 28 August through 3 September on North Fork Catherine Creek, and from 29 August through 20 September on South Fork Catherine Creek.

Main-stem Catherine Creek

Catherine Creek was partitioned into 11 reaches comprising a total of 30,849 m of stream (see Appendix Table C-1 for reach descriptions). Reach 3 was not surveyed because we were denied access by the property owner. Primary channel length of the mainstem was approximately 22,909 m (74% of total survey length) with an overall stream gradient of 0.96% (weighted average). Most of the wetted surface area (55.2%) was comprised of riffle habitat (Table 22). Pool habitat units comprised 26.4% of the wetted surface area and had an average frequency of 15.0 pools/km. Large pools (≥0.8 m deep and ≥ 20 m^2) had an average frequency of 4.6 pools/km. This was slightly higher than large pool frequency of 3.6 pools/km reported by McIntosh et al. (1994) from surveys conducted on the same portion of Catherine Creek in the early 1990's but less than what the authors reported as historic levels (1934-42 surveys) of 9.2 pools/km. The amount of fines (silt and sand) in the stream substrate of habitat units averaged 33% with a ranged from 15 to 39% between reaches. With the exception of Reach 4, fines tended to be higher in the upper reaches of the mainstem (Table 23). At the pool tail-outs, where the majority of Chinook salmon redds are constructed, fines ranged from 11 to 28% with a weighted averaged of 21% (Table 23). Again, fines at pool tail crests tended to be higher in the upper two reaches. Excessive amount of fines in redds can reduce survival of eggs and fry through reduced flow of oxygenated water or by blocking emergence (Chapman 1988). Although this study was not designed to assess the substrate composition in newly constructed redds or the amount of fines intrusion post-construction, the percentage of fines at pool tail-outs observed in this survey could have detrimental effect on egg-to-parr survival (Chapman 1988). Hardwood trees were more dominate than conifers in the riparian zone (30 m on each side of the stream). The number of hardwoods in the riparian zone ranged from 1 to 19.8 trees/100m^2 (Table 24). Generally, fewer hardwoods and conifers were surveyed in Reaches 2-6. This is also reflected in the low canopy closure of riparian areas furthest from the stream channel in these reaches (Zones 2-3; Table 24). This did not, however, translate into reduced stream shading in these reaches. Average stream shading within reaches ranged from 54-69% of complete closure with the highest shading occurred in the uppermost two reaches (Table 24).

North Fork Catherine Creek

North Fork Catherine Creek was partitioned into two reaches comprising a total of 9,685 m of stream. Primary channel length of North Fork Catherine Creek was approximately 5,380 m in length (56% of total). Compared to the main-stem Catherine Creek, more of North Fork Catherine Creek was comprised of split channels. Average gradient of North Fork Catherine Creek was 2.9%. Rapids and cascades comprised a total of 63.3% of the wetted surface area (Table 22). Pools accounted for only 9.6% of the habitat area with a average frequency of 12.8 pools/km. Average large pool frequency was 1.9 pools/km. McIntosh et al. (1994) reported a large pool frequency of 1.7 pools/km in the early 1990's and these authors reported that the frequency between 1934 and 1942 was 6.6 pools/km. The amount of fines in the substrate of habitat units was similar to the mainstem with an average of 34% overall for North Fork Catherine Creek. At the pool tail-outs, fines accounted for 15% in Reach 1 and 20% in Reach 2 with a weighted average of 19% (Table 23). Riparian vegetation was dominated by a mixture of conifer and hardwood trees (Table 24). The number of conifers in the riparian area was greater than in main-stem Catherine Creek. Stream shading was also greater than in main-stem Catherine Creek due in part to the steeper hillslopes along North Fork Catherine Creek.

South Fork Catherine Creek

South Fork Catherine Creek was partitioned into two reaches comprising a total of 3,927 m of stream habitat. Primary channel length was approximately 2,255 m with an average gradient of 2.8%. Rapids comprised 50.5% of the overall habitat area. Pools accounted for only 12.8%, with an average frequency of 20.0 pools/km (Table 22). Average large pool frequency was 1.4 pools/km and was similar to the 1.5 pools/km reported by McIntosh et al. (1994) for surveys conducted in the early 1990's. These authors reported large pool frequency of 3.3 pools/km from surveys conducted from 1934 to 1942. Fines in substrate were higher in South Fork Catherine Creek than main-stem Catherine Creek or North Fork Catherine Creek (Table 23). Fines averaged 43% in the substrate overall and 28% at the pool tail-outs. The high amount of fines in South Fork Catherine Creek and upper portions of Catherine Creek compared to North Fork Catherine Creek and the lower portions of Catherine Creek suggest that South Fork Catherine Creek may be a source fine sediment (Table 23). As with North Fork Catherine Creek, the riparian vegetation was a mixture of conifer and hardwood trees and the amount of stream shading was greater than Catherine Creek (Table 24).

MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

Rearing of juvenile spring Chinook salmon and summer steelhead in the Grande Ronde Subbasin is not confined to the areas in which the adults spawn. Some of the juvenile spring Chinook salmon and steelhead from each of our study streams move out of the spawning and summer rearing areas to overwinter in downstream areas before leaving the subbasin the following spring on their smolt migration, or in the case of steelhead, may rear for an additional year or two in suitable habitat before leaving the subbasin in spring on their smolt migration. These movements of spring Chinook salmon and steelhead point to the need for adequate habitat protection in areas in addition to the upper rearing areas.

Our research has shown that a disproportional amount of mortality of spring Chinook salmon migrants from the upper Grande Ronde River and Catherine Creek populations occurs as they move through the Grande Ronde Valley on their smolt migration.

The information we have gathered thus far on the occurrence of age-2 smolts indicates this life history is rare among northeast Oregon spring Chinook salmon and, in terms of life cycle modeling at least, can probably be discounted. The mature male parr life history is more prevalent and deserves consideration from both life cycle modeling and biological perspectives.

Based on the mature male parr to anadromous female spawner ratios we have observed, it is evident mature male parr hold the potential to make significant gametic contributions to northeast Oregon spring Chinook salmon populations. Given the continual low abundance of adult spawners, mature male parr may be an important means by which the breeding population size is increased.

FUTURE DIRECTIONS

We will continue this early life history study of spring Chinook salmon and summer steelhead in Catherine Creek and the upper Grande Ronde, Lostine, and Minam rivers. As we obtain more information on age-specific fecundities of wild spring Chinook salmon and age structure of spawning populations, we will improve our estimates of egg-to-parr and egg-to-smolt survival. We will survey the spring Chinook salmon spawning and rearing habitat in the upper Grande Ronde, Lostine and Minam rivers over the next three years.

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Table 1. Dates of tagging and number of spring Chinook salmon parr PIT-tagged on various northeast Oregon streams during the summers of 2001 and 2002.

Year, stream	Dates of collection and tagging	Number PIT-tagged and released	Distance to Lower Granite Dam (km)
2001			
Catherine Creek	30 Jul – 2 Aug	503	363–382
Lostine River	6–9 Aug	501	275–301
Minam River	20–23 Aug	996	282–284
Imnaha River	27–28 Aug	1,001	208–227
2002			
Catherine Creek	29 Jul – 1 Aug	506	365–380
Lostine River	12–15 Aug	509	274–302
Minam River	19–22 Aug	1,000	280–283
Imnaha River	26–28 Aug	1,003	209–230

Table 2. Results from spring Chinook salmon mark-and-recapture experiments conducted in Catherine Creek and the Lostine River in August 2002.

Stream, group	Number marked	Number sampled	Number recaptured	Population estimate (95% CI)
Catherine Creek				
immature	1,315	3,432	120	37,337 (31,270–44,572)
mature	57	56	10	301 (170–580)
Lostine River				
immature	1,227	1,744	51	41,209 (31,488–53,859)
mature	2	2	0	—

Table 3. Age composition of mature spring Chinook salmon parr sampled in Catherine Creek and the Lostine, Minam, and Imnaha rivers in summer 2002. Age was determined by scale analysis.

Stream, group	Number of parr sampled	Percent age-0 (95% CI)	Percent age-1 (95% CI)
Catherine Creek	52	0 (0-6.9)	100 (93.1-100)
Lostine River	2	0 (0-84.2)	100 (15.8-100)
Imnaha River	0[a]	—	—
Minam River	5	0 (0-52.2)	100 (47.8-100)

[a] Three mature parr were observed, none were caught.

Table 4. Ages of immature spring Chinook salmon parr with fork length exceeding 85 mm sampled in Catherine Creek and the Lostine, Minam, and Imnaha rivers in summer 2002. Age was determined by scale analysis.

Stream	Number age-0	Number age-1
Catherine Creek	1	0
Lostine River	15	0
Imnaha River	3	0
Minam River	4	0

Table 5. Estimated abundance of age-0 spring Chinook salmon parr during the summer, and the corresponding egg-to-parr survival of spring Chinook salmon in Catherine Creek and the Lostine River for the 1997–2001 brood years.

Stream, brood year	Redds[a]	Fecundity[b]	Total eggs	Age-0 parr abundance	Egg to age-0 parr survival rate (%)
Catherine Creek					
1997	45	3,782	170,190	13,222	7.77
1998	34	4,066	138,244	22,505	16.28
1999	38	3,742	142,196	25,698	18.07
2000	26	3,872	100,672	15,032	14.93
2001	131	3,801	497,931	37,337	7.50
Lostine River					
1997	47	4,925	231,475	40,748	17.60
1998	28	5,393	151,004	28,084	18.60
1999	45	4,963	223,335	12,372	5.54
2000	53	4,925	261,025	33,086	12.68
2001	98	4,950	485,100	41,209	8.49

[a] Redds counted above screw traps on Catherine Creek (rkm 32) and Lostine River (rkm 3).
[b] Average number of eggs per female wild spring Chinook salmon spawned at Lookingglass Hatchery (ODFW, unpublished data) adjusted for age composition of females on the spawning grounds.

Table 6. Population estimates, median emigration dates, and percentage of juvenile spring Chinook salmon population moving as late migrants past trap sites, 1994 to 2002 migratory years. Early migratory period is from 1 July of the preceding year through 28 January of the migratory year. The late migratory period is from 29 January to 30 June.

Stream, migratory year	Population estimate	SE	Median emigration date: Early migrants	Median emigration date: Late migrants	Percentage migrating late
Upper Grande Ronde River					
1994	24,791	1,629	14 Oct[a]	1 Apr	89
1995	38,725	6,474	30 Oct[b]	31 Mar[b]	87
1996	1,118	98	10 Oct[c]	16 Mar	99
1997	82	15	12 Nov	26 Apr[c]	17
1998	6,922	317	31 Oct	23 Mar	66
1999	14,858	1,593	16 Nov	31 Mar	84
2000	14,780	1,056	30 Oct	3 Apr	74
2001	51	16	1 Sep[c]	10 Apr	88
2002	9,133	788	24 Oct	1 Apr	82
Catherine Creek					
1995	17,633	1,055	1 Nov[a]	21 Mar	49
1996	6,857	351	20 Oct	11 Mar	27
1997	4,442	573	01 Nov[a]	13 Mar	10
1998	9,881	617	30 Oct	19 Mar	29
1999	20,311	1,173	14 Nov	23 Mar	38
2000	23,991	1,195	31 Oct	23 Mar	18
2001	21,937	1,164	8 Oct	24 Mar	13
2002	23,362	1,464	12 Oct	2 Apr	9
Lostine River					
1997	4,496	309	26 Nov[a]	30 Mar	52
1998	17,539	1,332	26 Oct	26 Mar	35
1999	34,267	1,343	12 Nov	18 Apr	41
2000	12,250	453	2 Nov	9 Apr	32
2001	13,610	695	29 Sep	20 Apr	23
2002	18,115	1,239	24 Oct	1 Apr	15
Minam River					
2001	28,209	2,369	8 Oct[a]	27 Mar	64
2002	79,000	5,529	24 Oct[a]	8 Apr	21

[a] Trap was started late, thereby potentially missing some early migrants.
[b] Trap was located at rkm 257.
[c] Median date based on small sample size: MY 1996, *n* = 4; MY 1997, *n* = 6; MY 2001, *n* = 2.

Table 7. Catch of juvenile spring Chinook salmon at five trap locations in the Grande Ronde Subbasin during the 2002 migratory year. The early migration period was 1 July 2001 – 28 January 2002. The late migratory group was 29 January – 30 June 2002. Numbers in parentheses are percentage of days fished out of total possible for that trapping period.

Trap site	Migratory group	Trapping period	Days fished	Trap catch
Upper Grande Ronde River	Early	27 Sep 01 – 24 Nov 01	39 (66)	1,056
	Late	19 Mar 02 – 27 Jun 02	72 (91)	331[a]
		27 Mar 02 – 19 Apr 02	18 (75)	435[b]
Catherine Creek	Early	6 Sep 01 – 15 Jan 02	106 (80)	6,701
	Late	19 Feb 02 – 26 Jun 02	95 (85)	301[a]
		1 Apr 02 – 8 Apr 02	6 (75)	20[b]
		10 Apr 02 – 19 Apr 02	8 (80)	28[b]
Grande Ronde Valley	Late	21 Mar 02 – 19 Jun 02	56 (60)	270
Lostine River	Early	1 Jul 01 – 28 Jan 02	134 (63)	4,792
	Late	1 Feb 02 – 26 Jun 02	109 (84)	425[a]
		2 Apr 02 – 18 Apr 02	15 (88)	264[b]
Minam River	Early	1 Jul 01 – 27 Nov 01	60 (40)	18,204
	Late	25 Feb 02 – 30 Jun 02	108 (86)	1,341

[a] Continuous 24-hour trapping.
[b] Trapping with 2-4-hour sub-sampling.

Table 8. Fork lengths of juvenile spring Chinook salmon collected from the study streams during MY 2002. Early and late migrants were captured with a rotary screw trap on each study stream. Min. = minimum, Max. = maximum.

	Lengths (mm) of fish collected					Lengths (mm) of fish tagged and released				
Stream, group	*n*	Mean	SE	Min.	Max.	*n*	Mean	SE	Min.	Max.
Upper Grande Ronde River										
Early migrants	345	78.3	0.34	62	115	344	78.3	0.34	62	115
Late migrants	568	85.0	0.36	60	130	538	84.7	0.33	65	119
Catherine Creek										
Early migrants	845	80.9	0.27	58	124	514	80.7	0.32	58	98
Winter group	431	80.5	0.31	65	99	431	80.5	0.31	65	99
Late migrants	261	90.2	0.53	69	139	214	90.3	0.57	69	139
Lostine River										
Early migrants	1,087	93.2	0.31	65	119	494	94.7	0.43	70	119
Winter group	563	81.5	0.38	55	116	563	81.5	0.38	55	116
Late migrants	660	92.9	0.42	59	126	405	94.4	0.53	60	126
Minam River										
Early migrants	891	74.6	0.28	55	105	534	72.1	0.33	55	100
Late migrants	901	85.0	0.28	63	131	382	85.6	0.48	64	131

Table 9. Weights of juvenile spring Chinook salmon collected from the study streams during MY 2002. Early and late migrants were captured with a rotary screw trap on each study stream. Winter group fish were captured with dipnets upstream of the rotary screw traps. Min. = minimum, Max. = maximum.

	Weights (g) of fish collected					Weights (g) of fish tagged and released				
Stream, group	*n*	Mean	SE	Min.	Max.	*n*	Mean	SE	Min.	Max.
Upper Grande Ronde River										
Early migrants	328	5.11	0.06	2.4	8.9	327	5.12	0.06	2.4	8.9
Late migrants	385	6.59	0.12	2.6	23.1	362	6.39	0.10	2.6	13.7
Catherine Creek										
Early migrants	583	5.89	0.08	2.4	20.3	388	5.87	0.08	2.7	10.7
Winter group	413	5.74	0.07	3.0	11.9	413	5.74	0.07	3.0	11.9
Late migrants	118	7.76	0.25	3.7	24.5	105	7.67	0.23	3.7	17.6
Lostine River										
Early migrants	1,017	9.50	1.01	2.9	21.0	444	10.35	0.15	3.5	21.0
Winter group	548	6.18	0.09	2.2	13.9	548	6.18	0.09	2.2	13.9
Late migrants	653	9.42	0.13	2.8	23.9	402	9.96	0.17	2.8	22.3
Minam River										
Early migrants	793	5.02	0.06	2.0	13.9	436	4.61	0.07	2.0	11.7
Late migrants	892	7.12	0.08	2.5	25.3	381	7.51	0.14	2.5	25.3

Table 10. Survival probabilities to Lower Granite Dam for spring Chinook salmon parr tagged in summer 2001 and detected at Columbia and Snake River dams in 2002. Survival probabilities that have a letter in common are not significantly different ($P \leq 0.05$).

Stream	Number PIT tagged and released	Survival probability (95% CI)
Catherine Creek	502	0.109 a (0.079 – 0.157)
Imnaha River	1,001	0.106 a (0.079 – 0.160)
Lostine River	501	0.154 (0.117 – 0.209)
Minam River	994	0.093 a (0.074 – 0.119)

Table 11. 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 2001 to spring 2002 and detected at the dams during 2002.

Stream, tag group	Number PIT tagged and released	Survival probability (95% CI)
Catherine Creek		
Fall	514	0.154 (0.114–0.245)
Winter	431	0.203 (0.129–0.476)
Spring	217	0.527 (0.411–0.750)
Lostine River		
Fall	500	0.326 (0.258–0.455)
Winter	564	0.246 (0.170–0.464)
Spring	406	0.683 (0.589–0.825)
Minam River		
Fall	537	0.249 (0.201–0.326)
Spring	382	0.532 (0.465–0.644)
Upper Grande Ronde River		
Fall	344	0.308 (0.198–0.653)
Spring	536	0.499 (0.416–0.633)

Table 12. Results from steelhead mark-recapture experiments in the Catherine Creek watershed in summer 2002.

Stream, length group	Number marked	Number recaptured	Number sampled	Population estimate	95% CI
Catherine Creek					
≤ 100 mm	228	11	211	4,046	2,345 – 7,586
101 – 120 mm	282	18	457	6,822	4,409 – 11,078
121 – 140 mm	223	13	339	5,440	3,269 – 9,641
> 140 mm	89	4	155	2,808	1,254 – 7,020
Total				19,115	14,082 – 24,149
Milk Creek					
≤ 100 mm	98	25	88	339	233 – 512
101 – 120 mm	200	70	232	660	524 – 830
121 – 140 mm	122	54	152	342	263 – 444
141 – 160 mm	53	16	90	289	182 – 482
161 – 180 mm	42	20	60	125	82 – 199
> 180 mm	17	9	38	70	39 – 140
Total				1,825	1,600 – 2,050

Table 13. Growth rates of steelhead tagged 26 June – 19 July 2001 in Catherine Creek upstream of the rotary screw trap and recaptured at the trap in fall 2001 and spring 2002, and upstream in summer 2002.

			Growth rate (mm/d)	
Season of recapture, location	*n*	Recapture dates	Mean	95% CI
Fall 2001, trap	35	14 Sep – 17 Dec	0.122	± 0.024
Spring 2002, trap	8	14 Mar – 14 May	0.082	± 0.034
Summer 2002, upstream	4	18 Jul – 25 Jul	0.114	± 0.036

Table 14. Catch of steelhead at five trap locations in the Grande Ronde River Subbasin during the 2002 migratory year. The early migration period was 1 July 2001 – 28 January 2002. The late migratory group was 29 January – 30 June 2002. Numbers in parentheses are percentage of days fished out of total possible for that trapping period.

Trap site	Migratory group	Trapping period	Days fished	Trap catch
Upper Grande Ronde River	Early	27 Sep 01 – 24 Nov 01	39 (66)	350
	Late	19 Mar 02 – 27 Jun 02	72 (91)	2,011
		27 Mar 02 – 19 Apr 02	18 (75)	429[b]
Catherine Creek	Early	6 Sep 01 – 15 Jan 02	106 (80)	3,937
	Late	19 Feb 02 – 26 Jun 02	95 (85)	1,071[a]
		1 Apr 02 – 8 Apr 02	6 (75)	61[b]
		10 Apr 02 – 19 Apr 02	8 (80)	181[b]
Grande Ronde Valley	Late	21 Mar 02 – 19 Jun 02	56 (60)	841
Lostine River	Early	1 Jul 01 – 28 Jan 02	134 (63)	2,638
	Late	1 Feb 02 – 26 Jun 02	109 (84)	746[a]
		2 Apr 02 – 18 Apr 02	15 (88)	118[b]
Minam River	Early	1 Jul 01 – 27 Nov 01	60 (40)	480
	Late	25 Feb 02 – 30 Jun 02	108 (86)	451

[a] Continuous trapping.
[b] Trapping with subsampling.

Table 15. Population estimates, median emigration dates, and percentage of steelhead population moving as late migrants past traps sites, 1997 to 2002 migratory years. Early migratory period is from 1 July of the preceding year through 28 January of the migratory year. The late migratory period is from 29 January to 30 June.

Stream, migratory year	Population estimate	Median emigration date: Early migrants	Median emigration date: Late migrants	Percentage migrating late
Upper Grande Ronde River				
1997	15,104	25 Oct	27 Mar	92
1998	10,133	8 Aug	27 Mar	60
1999	6,108	8 Nov	29 Apr	95
2000	17,845	30 Sep	8 Apr	94
2001	16,067	11 Oct	8 May	96
2002	17,286	24 Oct	15 Apr	94
Catherine Creek				
1997	—[a]	—	14 Apr	—
1998	20,742	22 Sep	4 Apr	58
1999	19,628	2 Nov	15 Apr	75
2000	35,699	30 Oct	16 Apr	61
2001	20,586	24 Sep	31 Mar	56
2002	45,799	12 Oct	1 May	58
Lostine River				
1997	—[b]	—	1 May	—
1998	10,271	4 Oct	24 Apr	46
1999	23,643	17 Oct	1 May	35
2000	11,981	19 Oct	21 Apr	44
2001	16,690	4 Oct	27 Apr	55
2002	21,019	18 Oct	17 Apr	31
Minam River				
2001	28,113	3 Oct	28 Apr	86
2002	44,872	24 Oct	25 Apr	82

[a] Trap not started until week 39.
[b] Trap not started until week 43.

Table 16. Travel time to Lower Granite Dam (LGD) of wild steelhead PIT-tagged at screw traps in spring of 2002 and arriving at Lower Granite Dam in 2002.

Stream	Distance to LGD (km)	Number detected	Travel time (d)		
			Median	Min.	Max.
Catherine Creek	362	95	18.1	6	65
Upper Grande Ronde River	397	86	20.6	5	84
Lostine River	274	72	25.9	3	65
Minam River	245	48	13.9	4	67

Table 17. Survival probabilities to Lower Granite Dam during migratory year 2002 of wild steelhead juveniles PIT-tagged at screw traps on Catherine Creek and the upper Grande Ronde, Lostine, and Minam rivers during fall 2001 and spring 2002.

Season, location tagged	Number tagged	Number detected	Survival probability (95% CI)	
Fall				
Catherine Creek	723	30	0.069	(0.040 – 0.152)
Upper Grande Ronde River	165	21	0.185	(0.108 – 0.387)
Lostine River	837	106	0.154	(0.124 – 0.194)
Minam River	262	11	0.134	(0.041 – 1.971)
Spring				
Catherine Creek	504	212	0.532	(0.465 – 0.615)
Upper Grande Ronde River	543	192	0.450	(0.387 – 0.529)
Lostine River	351	171	0.652	(0.538 – 0.739)
Minam River	197	108	0.722	(0.598 – 0.898)

Table 18. Survival probabilities to Lower Granite Dam of steelhead PIT-tagged on Catherine Creek and its tributaries during summers 2000 and 2001 and detected through the end of the 2002 migratory year. Standard error was reported if it was not possible to calculate the confidence intervals.

Stream, year tagged	Number tagged	Number detected 2001	Number detected 2002	Survival probability through 2002	(95% CI)
Catherine Creek					
2000	410	22	6	0.081	(0.055 - 0.118)
2001	837	—	65	0.105	(0.078 - 0.149)
North Fork Catherine Creek					
2000	117	2	1	0.026	(SE = 0.015)
2001	270	—	8	0.035	(0.015 - 0.085)
South Fork Catherine Creek					
2000	225	5	4	0.041	(0.020 - 0.074)
2001	0	—	—	—	
Little Catherine Creek					
2000	415	0	3	0.010	(0.002 - 0.096)
2001	0	—	—	—	
Total					
2000	1,167	29	15	0.042	(0.031 - 0.056)
2001	1,107	—	73	0.087	(0.066 - 0.120)

Table 19. Age structure of early and late steelhead migrants collected at trap sites during the 2002 migratory year. The same four cohorts were represented in each migrant group but ages increased by one year for late migrants (e.g., age-0 early migrants were same cohort as age-1 late migrants). Age structure was based on an age-length key. Means were weighted by migrant abundance at trap sites.

	Percentage by age				
Migrant group, trap site	Age-0	Age-1	Age-2	Age-3	Age-4
Early					
Upper Grande Ronde River	39	61	0	0	0
Catherine Creek	64	34	2.2	0	0
Lostine River	62	25	13	0.1	0
Minam River	75	23	2.6	0	0
Mean	**65**	**29**	**5.8**	**0.06**	**0**
Late					
Upper Grande Ronde River	0	28	62	10	0
Catherine Creek	0	32	61	6.9	0
Lostine River	0	46	37	16	1.4
Minam River	0	46	39	14	0.8
Mean	**0**	**38**	**50**	**11**	**0.43**

Table 20. Median fork length by age-class for steelhead collected at trap sites during the 2002 migratory year. Letters indicate comparison between trap sites by age-class; medians with the same letter are not significantly different (Kruskal-Wallis, P<0.05).

	Fork length (mm)							
Migrant group,	Catherine Creek		Upper Grande Ronde River		Lostine River		Minam River	
age	median	*n*	median	*n*	median	*n*	median	*n*
Early								
age-0	77.0 a	225	78.0 a	38	88.0 b	171	61.0 c	37
age-1	128.0 d	116	125.0 d	39	157.0 e	113	150.5 e	20
Late								
age-1	78.5 fg	40	79.5 fg	42	88.0 f	41	73.5 g	36
age-2	143.0 h	54	140.0 h	81	138.0 h	51	148.5 h	48
age-3	177.5 i	10	184.5 i	18	189.0 i	31	188.0 i	23

Table 21. Age structure of PIT- tagged early-migrant steelhead of known age, and the subset subsequently detected at downstream dams the following spring. Italicized ages reflect the expected age of smolts when detected at dams. Means were weighted by early-migrant population abundance estimates.

		Percentage by age			
		Age-0	Age-1	Age-2	Age-3
Trap site	*n*	*age-1 smolt*	*age-2 smolt*	*age-3 smolt*	*age-4 smolt*
		PIT-tagged fish			
Upper Grande Ronde River	74	49	51	0	0
Catherine Creek	292	66	32	1.4	0
Lostine River	286	60	31	8.4	0.3
Minam River	57	65	32	3.5	0
Mean		**63**	**32**	**4.1**	**0.10**
		PIT-tagged fish detected at dams			
Upper Grande Ronde River	8	0	100	0	0
Catherine Creek	16	31	69	0	0
Lostine River	38	24	61	16	0
Minam River	9	44	56	0	0
Mean		**30**	**64**	**5.4**	**0**

Table 22. Percentage of stream wetted surface area comprised by different habitat types for the main-stem Catherine Creek, North Fork Catherine Creek, and South Fork Catherine Creek in summer 2002.

Stream	Habitat type	Number of units	Wetted area (m^2)	Percent of total stream area
Catherine Creek				
	Dammed/backwater pools	62	14,469	5.29
	Scour pools	261	57,743	21.1
	Glides	27	10,589	3.87
	Riffles	333	150,889	55.2
	Rapids	44	16,614	6.08
	Cascades	7	745	0.27
	Step/falls	190	17,674	6.46
	Dry units	89	4,628	1.69
	Culverts	6	52	0.02
North Fork Catherine Creek				
	Dammed/backwater pools	0	0	0.0
	Scour pools	69	5,231	9.64
	Glides	3	576	1.06
	Riffles	42	6,294	11.6
	Rapids	67	17,885	33.0
	Cascades	67	16,450	30.3
	Step/falls	38	1,691	3.12
	Dry units	81	6,121	11.3
	Culverts	0	0	0.0
South Fork Catherine Creek				
	Dammed/backwater pools	2	45	0.28
	Scour pools	43	2,024	12.5
	Glides	6	830	5.11
	Riffles	33	2,763	17.0
	Rapids	51	8,196	50.5
	Cascades	10	827	5.09
	Step/falls	23	645	3.97
	Dry units	25	912	5.61
	Culverts	0	0	0.0

Table 23. Stream habitat characteristics measured during surveys conducted on the main-stem Catherine Creek, North Fork Catherine Creek, and South Fork Catherine Creek in summer 2002. Numbers in parentheses are sample size for average percent fines at pool tail-outs.

Stream, reach	Number of units	Total length (m)	Mean unit gradient (%)	Pools/km	Large wood debris pieces/100 m	Average % fines (<2 mm diameter)	Average % fines at pool tail-outs (*n*)
Catherine Creek							
1	59	2,412	0.9	10.1	6.7	32	16 (7)
2	29	1,267	0.6	9.7	2.7	19	11 (7)
3[a]	—	1,440[a]	0.9[a]	—	—	—	—
4	59	1,856	0.5	15.2	19.2	39	20 (13)
5	32	1,256	0.9	6.4	8.8	15	19 (5)
6	94	3,432	0.9	8.0	3.1	25	18 (12)
7	67	2,070	0.9	14.0	10.5	29	20 (9)
8	91	3,348	1.0	9.5	5.5	29	17 (11)
9	302	6,545	1.0	29.7	9.2	34	20 (71)
10	100	2,747	1.0	16.9	10.5	36	28 (21)
11	187	4,475	1.4	17.5	14.7	39	26 (35)
North Fork Catherine Creek							
1	47	1,179	1.8	19.2	5.6	29	15 (13)
2	320	8,506	3.0	12.0	22.1	35	20 (48)
South Fork Catherine Creek							
1	68	1,295	2.2	31.5	9.9	48	32 (15)
2	125	2,632	3.0	15.4	15.6	41	25 (20)

[a] Access was denied; length and gradient were estimated from USGS maps.

Table 24 . Characteristics of riparian habitat measured during surveys conducted on the main-stem Catherine Creek, North Fork Catherine Creek, and South Fork Catherine Creek in summer 2002.

Stream, reach	Canopy closure (%) Zone 1 0-10 m	Zone 2 10-20 m	Zone 3 20-30 m	Average stream shading (% of 180)[a]	Average number of conifers/ 100 m^2	Average number of hardwoods/ 100 m^2
Catherine Creek						
1	57	27	18	59	0.1	10.0
2	44	3	0	58	0.5	1.0
3	—	—	—	—	—	—
4	48	3	0	54	0	1.0
5	66	19	15	57	0	6.8
6	49	23	1	60	1.8	1.3
7	48	52	58	54	0.3	19.0
8	45	35	36	62	1.0	7.0
9	29	68	49	55	2.0	19.8
10	23	28	45	69	2.0	6.7
11	43	53	55	64	4.8	4.3
North Fork Catherine Creek						
1	28	18	53	64	4.7	8.0
2	50	31	27	75	8.9	6.7
South Fork Catherine Creek						
1	50	68	10	79	7.7	10.0
2	14	20	23	74	10.2	3.5

[a] Sample size for stream shading measurements are same as number of units in Table 23.

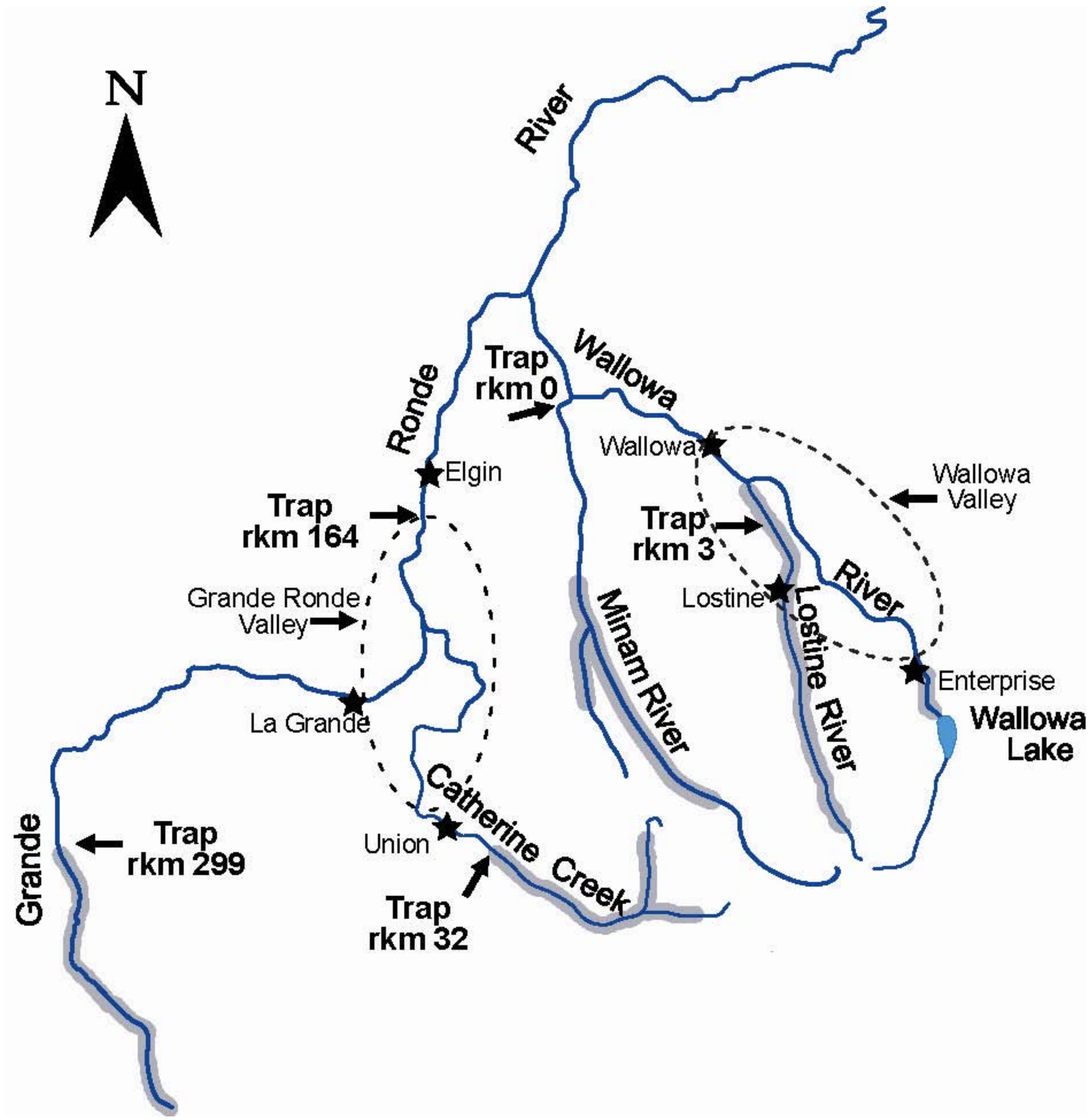

Figure 1. Locations of fish traps in the Grande Ronde Subbasin during the study period. Shaded areas delineate spring Chinook salmon spawning and upper rearing areas in each study stream. Dashed lines indicate the Grande Ronde River and Wallowa River valleys.

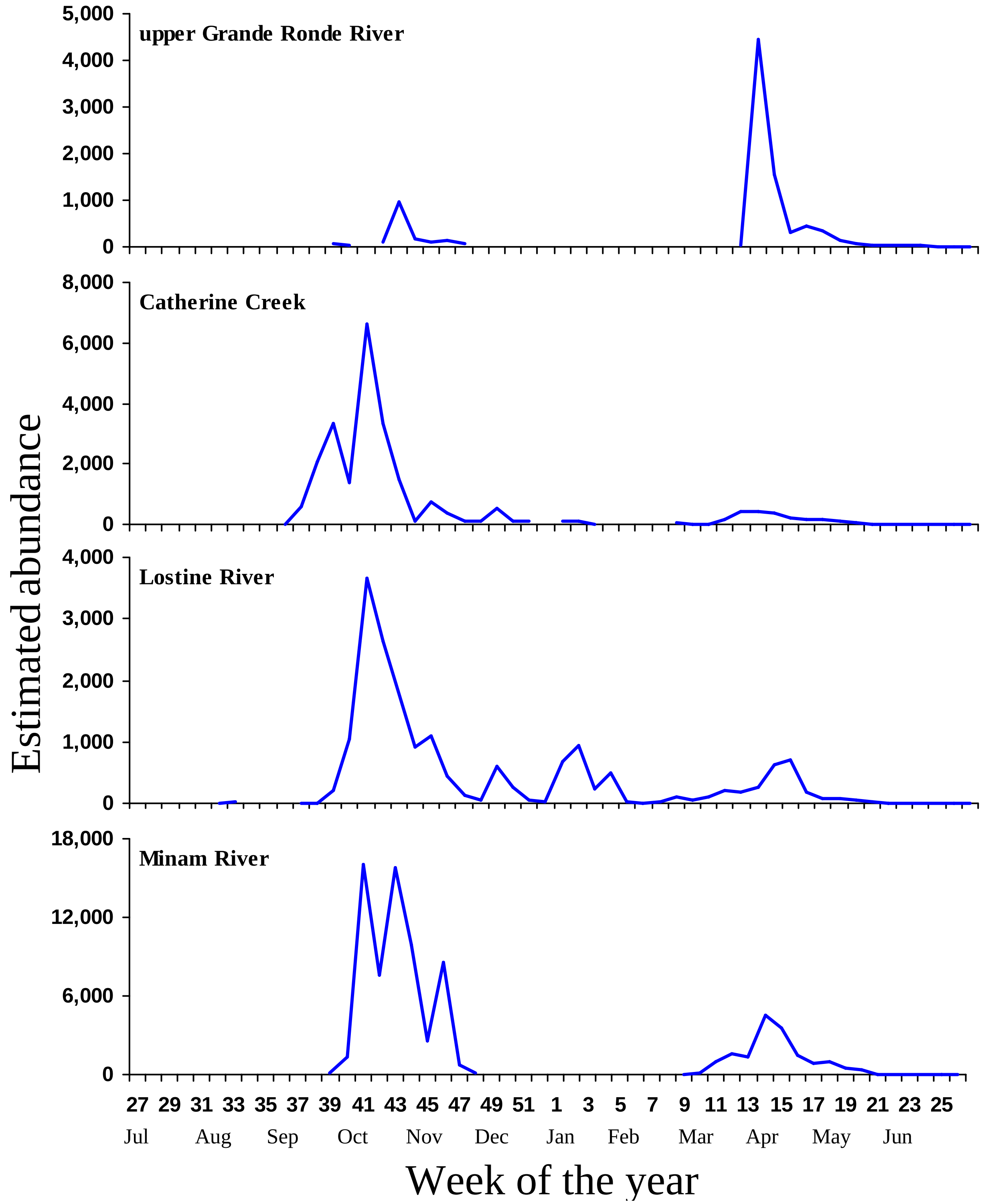

Figure 2. Estimated migration timing and abundance of juvenile spring Chinook salmon migrants captured by rotary screw traps during the 2002 migratory year. Traps were located at rkm 299 of the Grande Ronde River, rkm 32 of Catherine Creek, rkm 3 of the Lostine River, and rkm 0 of the Minam River.

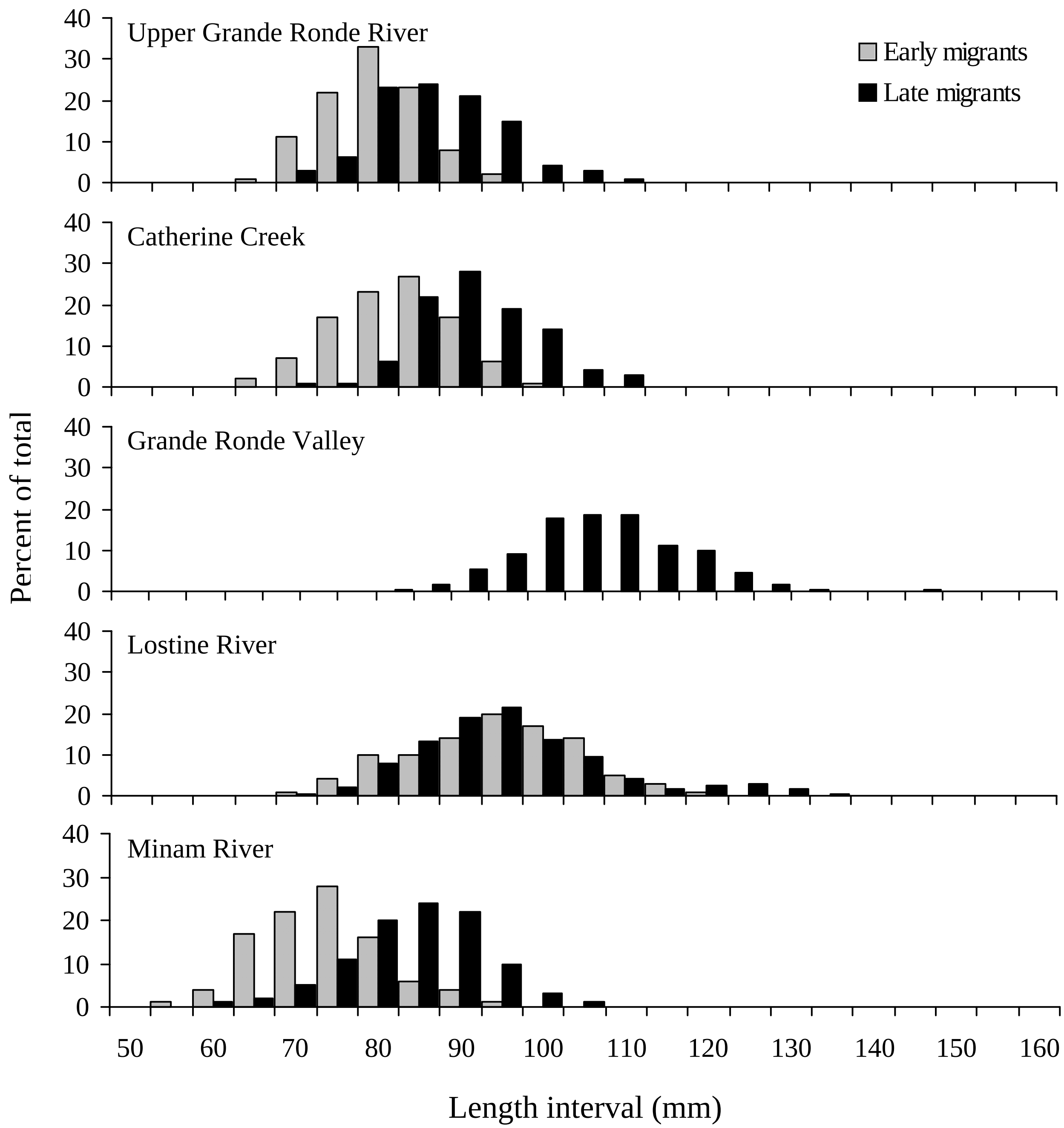

Figure 3. Length frequency distribution (fork length) of early and late migrating juvenile spring Chinook salmon captured at the upper Grande Ronde River (rkm 299), Catherine Creek (rkm 32), Grande Ronde Valley (rkm 164), Lostine River (rkm 3), and Minam River (rkm 0) traps during the 2002 migratory year. The Grande Ronde valley trap was operated only during the late migrant period.

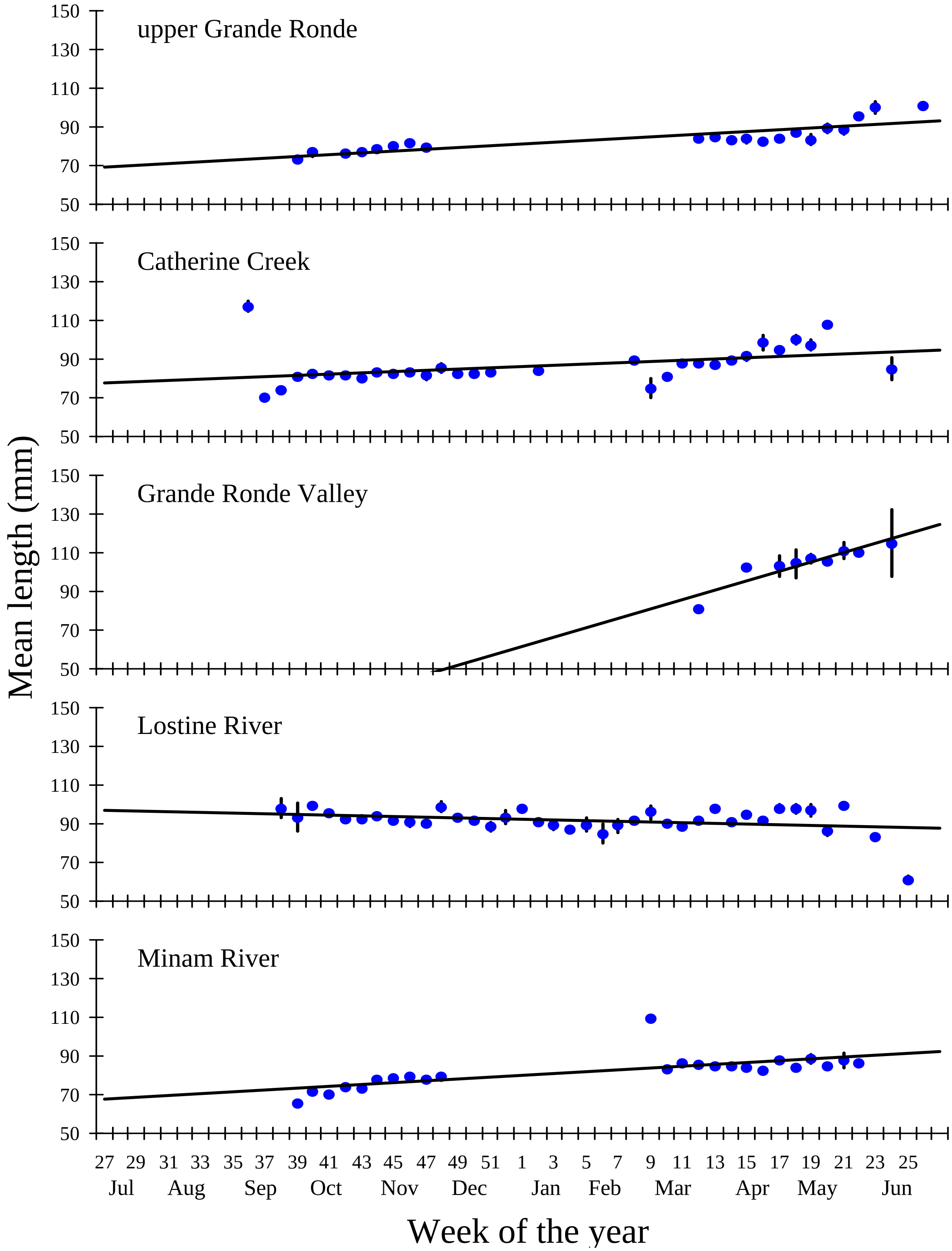

Figure 4. Weekly mean fork lengths (mm) with standard error for spring Chinook salmon captured in rotary screw traps in the Grande Ronde River Subbasin during migratory year 2002.

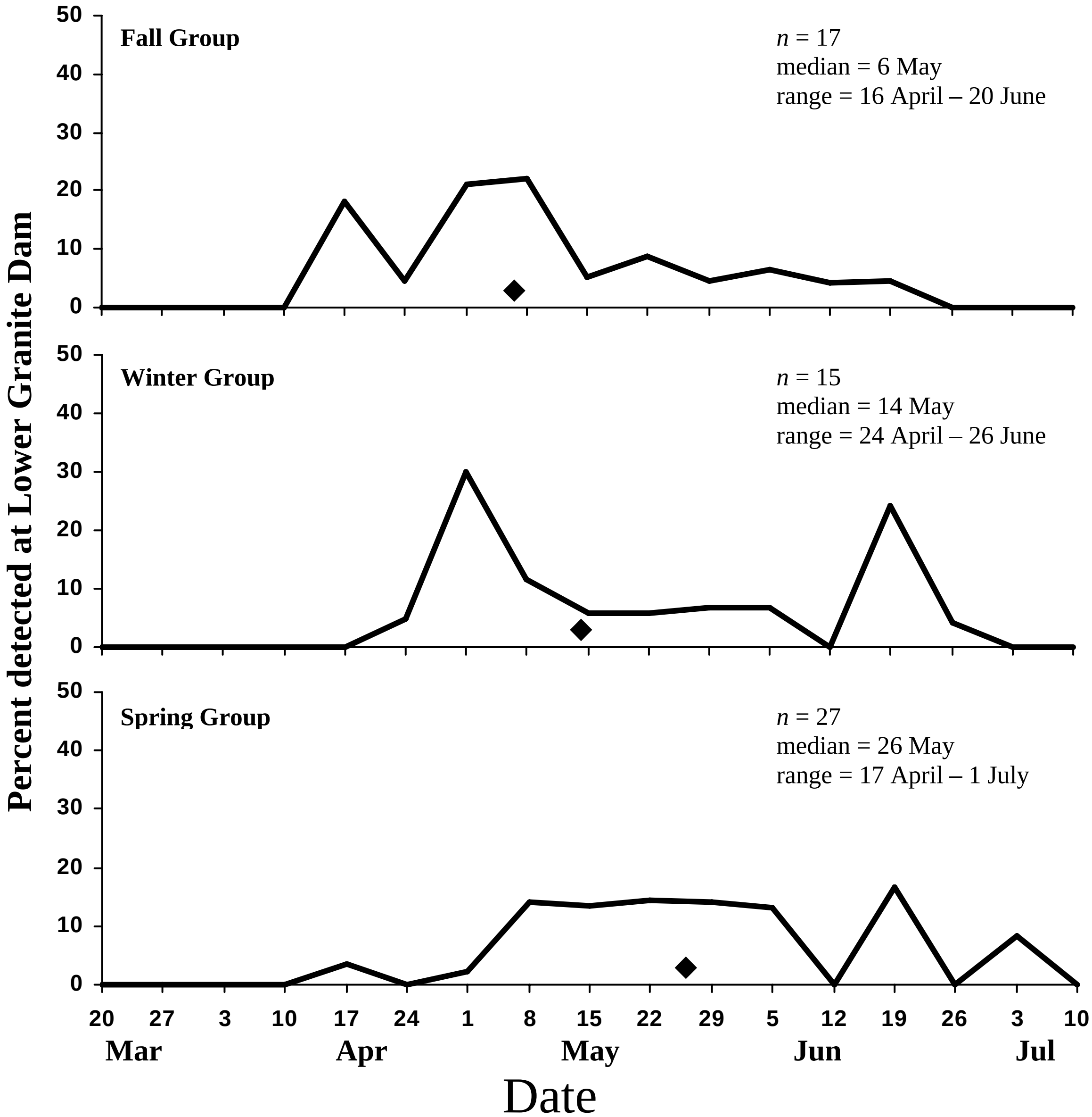

Figure 5. Dates of detection in 2002 at Lower Granite Dam for the fall, winter, and spring tag groups of juvenile spring Chinook salmon PIT-tagged on Catherine Creek, summarized by week and expressed as a percentage of the total detected for each group. ♦ = median arrival date. Detections were expanded for spillway flow.

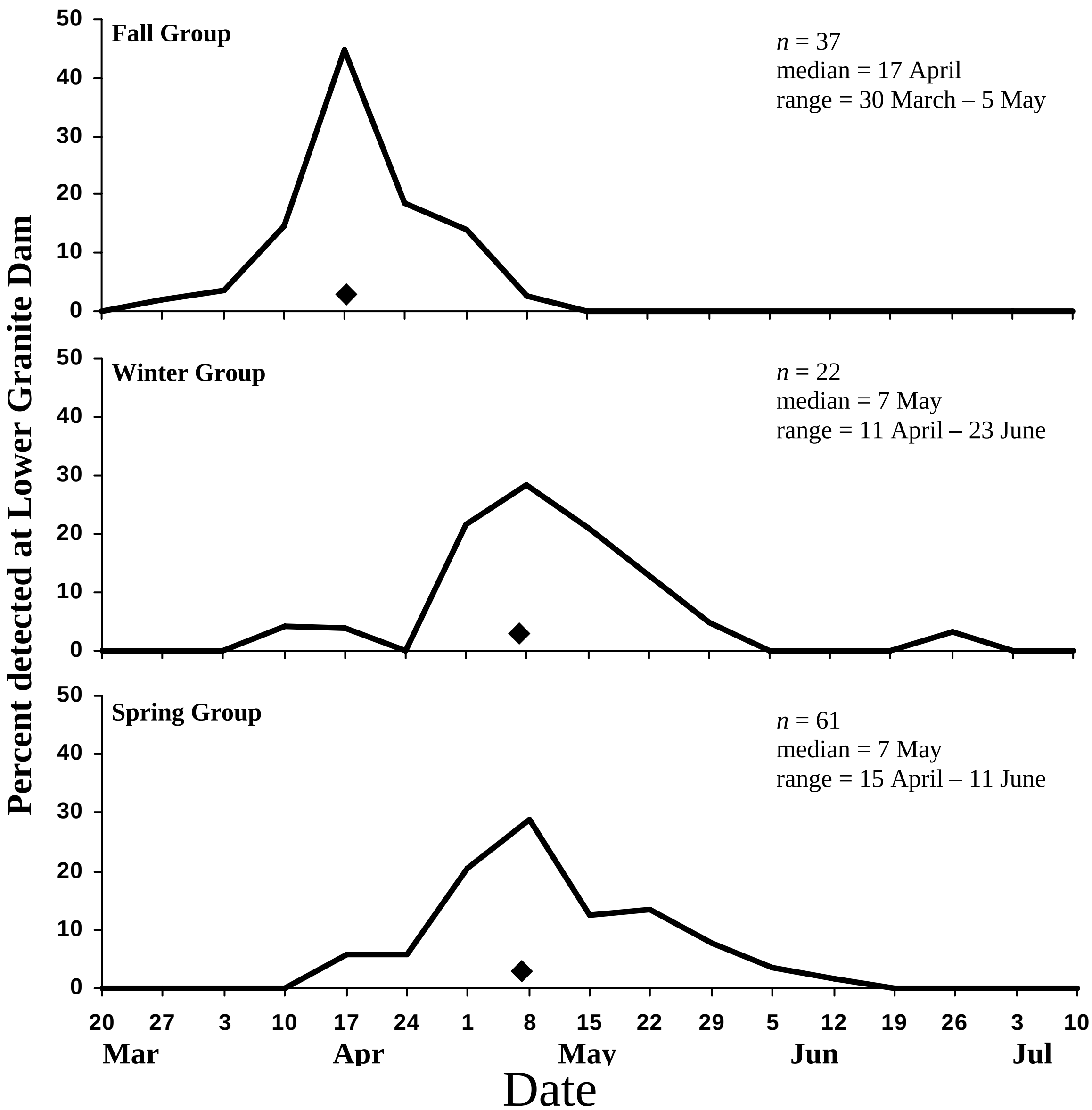

Figure 6. Dates of detection in 2002 at Lower Granite Dam for the fall, winter, and spring tag groups of juvenile spring Chinook salmon PIT-tagged on the Lostine River, summarized by week and expressed as a percentage of the total detected for each group. ♦ = median arrival date. Detections were expanded for spillway flow.

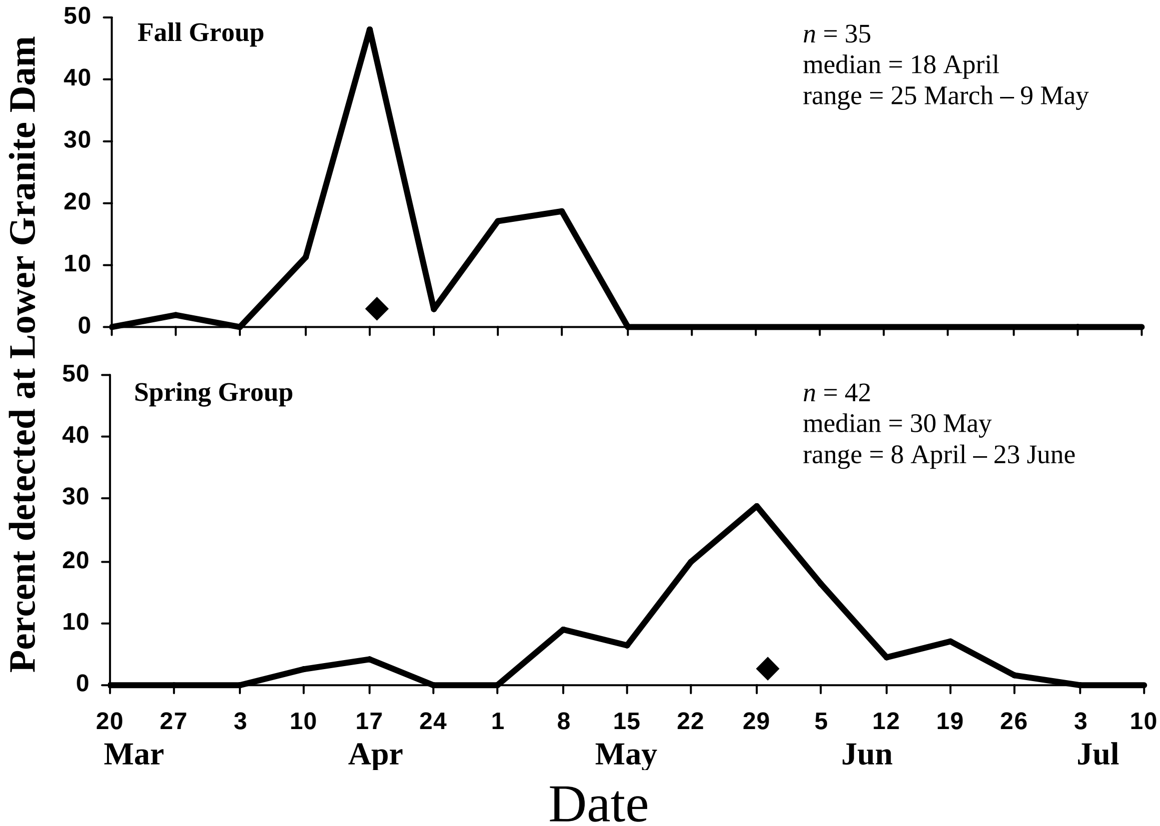

Figure 7. Dates of detection in 2002 at Lower Granite Dam for fall and spring tag groups of juvenile spring Chinook salmon PIT-tagged on the Minam River, summarized by week and expressed as a percentage of the total detected for each group. ♦ = median arrival date. Detections were expanded for spillway flow.

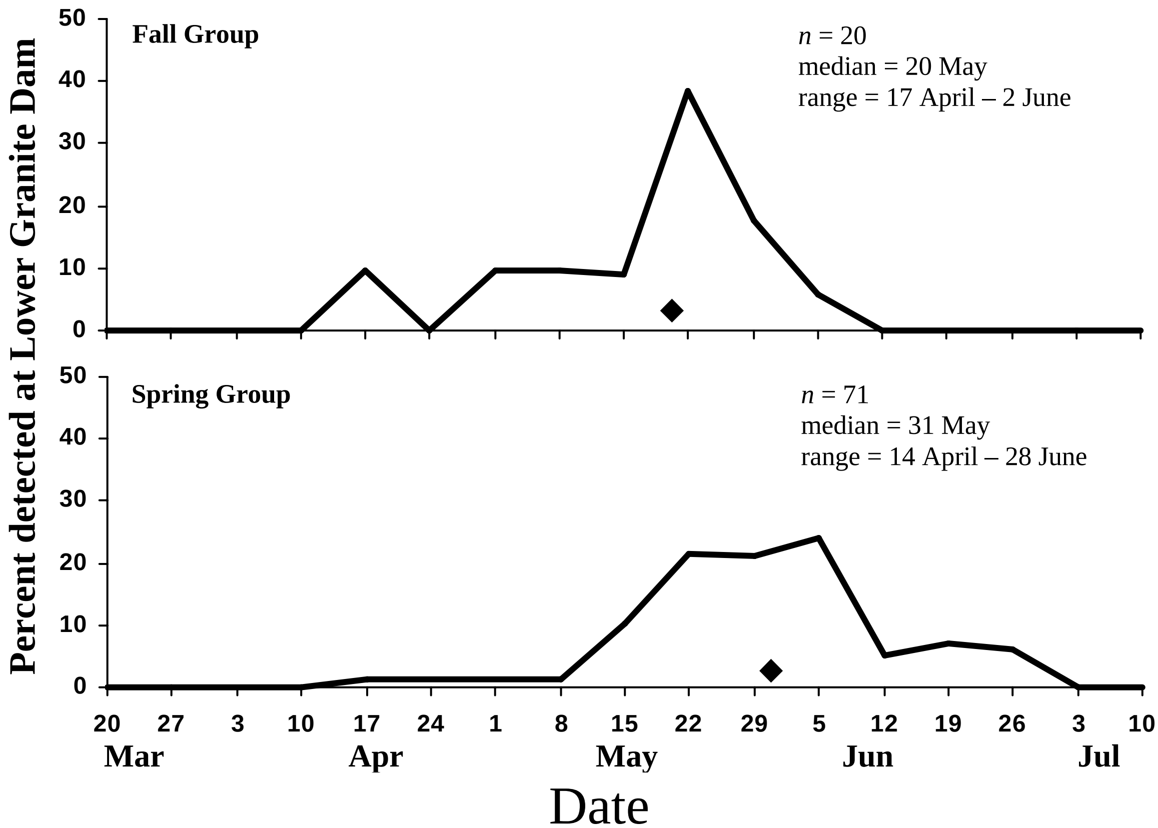

Figure 8. Dates of detection in 2002 at Lower Granite Dam for the fall and spring tag groups of juvenile spring Chinook salmon PIT-tagged on the upper Grande Ronde River, summarized by week and expressed as a percentage of the total detected. ♦ = median arrival date. Detections were expanded for spillway flow.

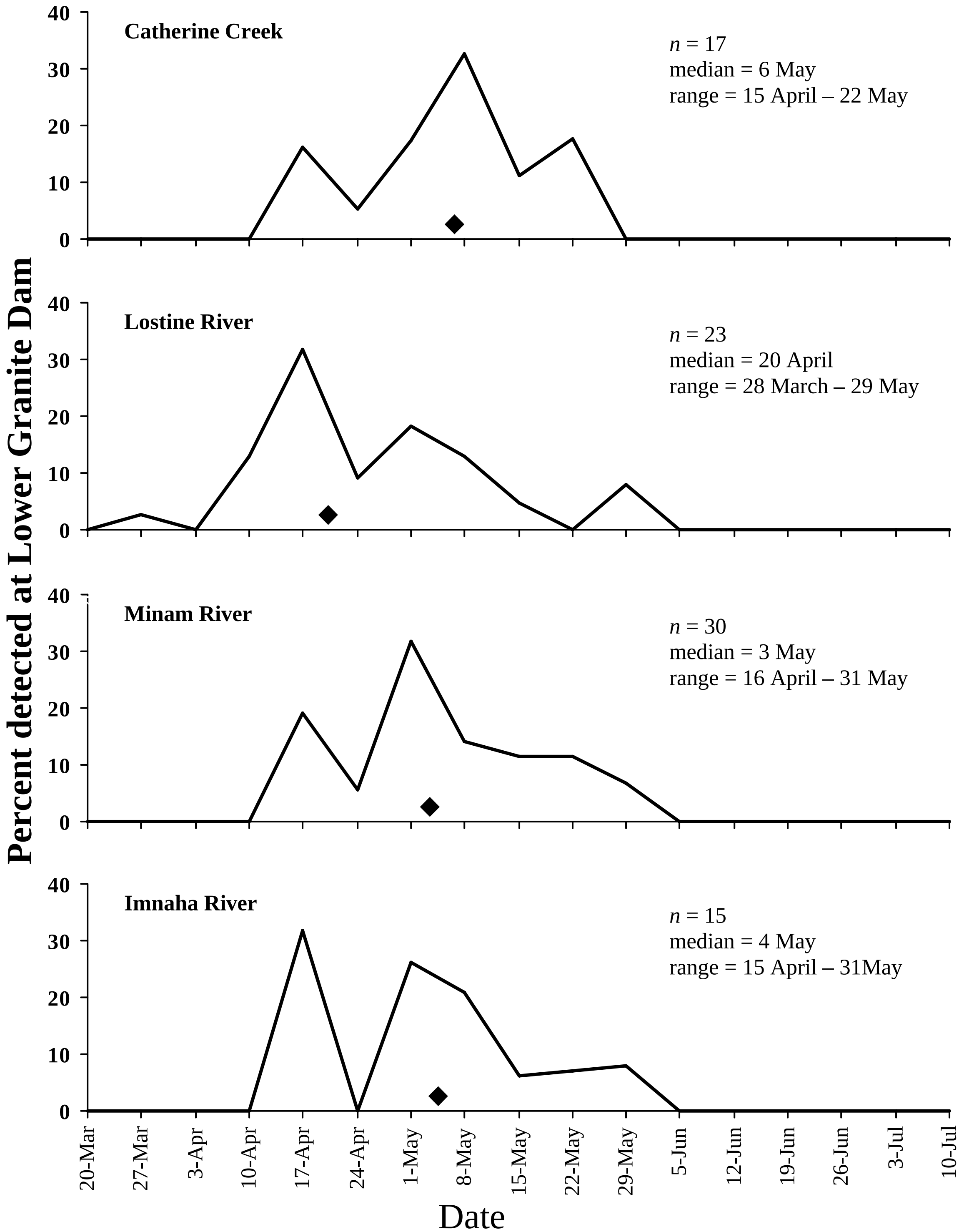

Figure 9. Dates of detection in 2002 at Lower Granite Dam of spring Chinook salmon PIT-tagged as parr on Catherine Creek and the Imnaha, Lostine, and Minam rivers during the summer of 2001, summarized by week and expressed as a percentage of the total detected for each group. ♦ = median arrival date. Detections were expanded for spillway flow.

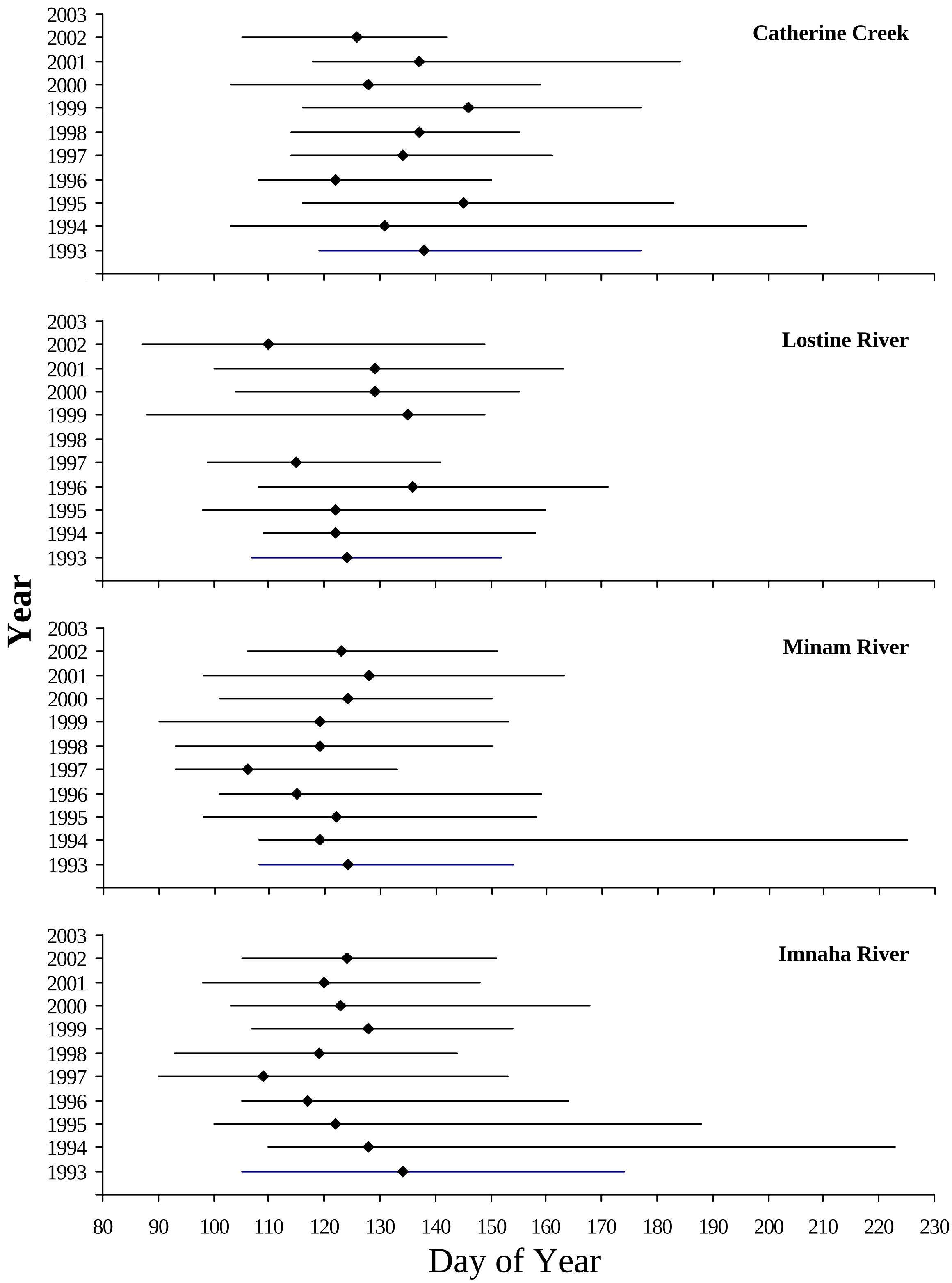

Figure 10. Median (diamonds) and first and last (bars) detection dates at Lower Granite Dam for wild Chinook salmon smolts tagged as parr during the summer in Catherine Creek, Lostine, Minam, and the Imnaha rivers, for migratory years 1993–2002.

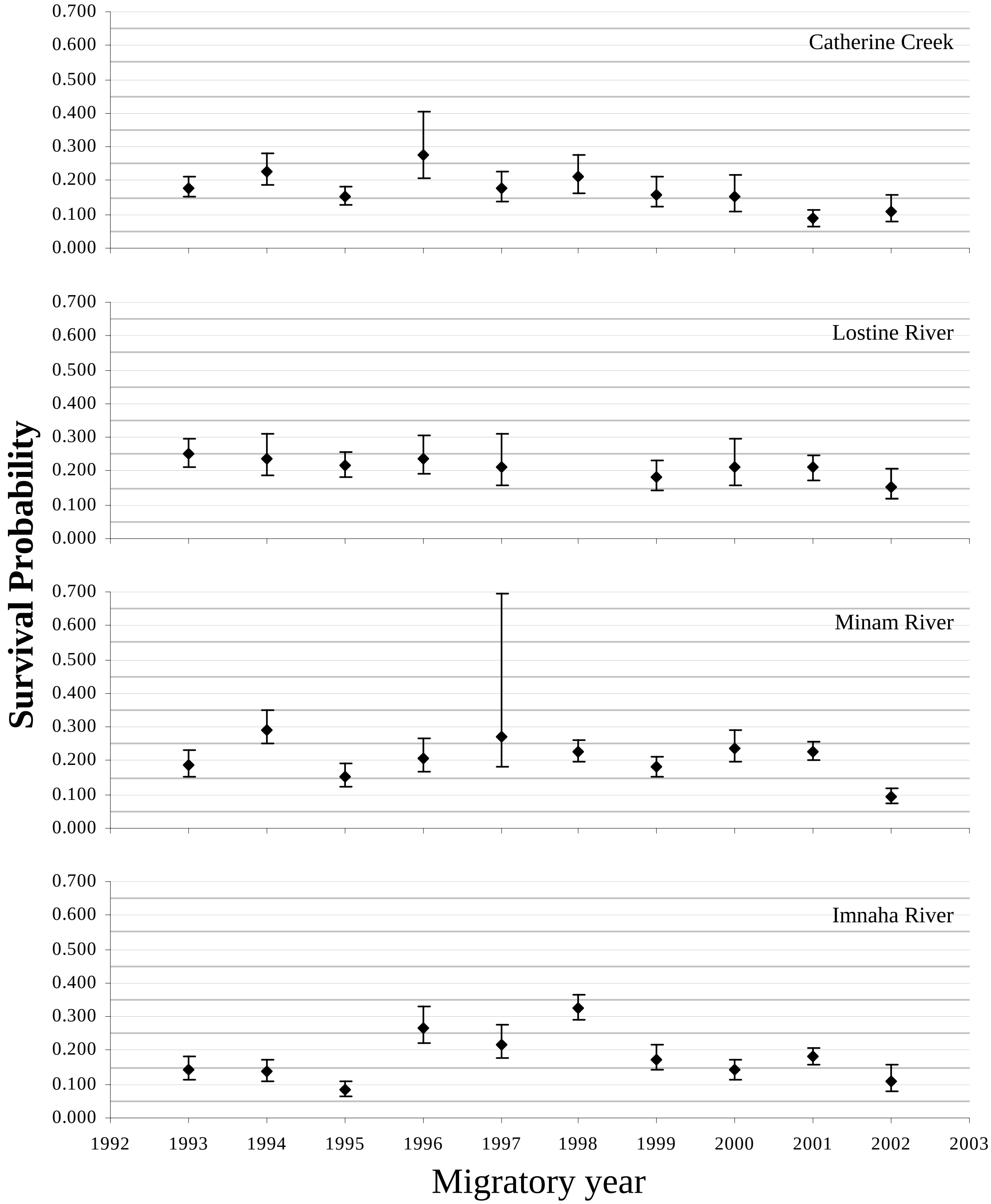

Figure 11. Survival probabilities and 95% CI for spring Chinook salmon parr PIT-tagged during the summer in Catherine Creek and the Lostine, Minam, and Imnaha rivers, for migratory years 1993–2002.

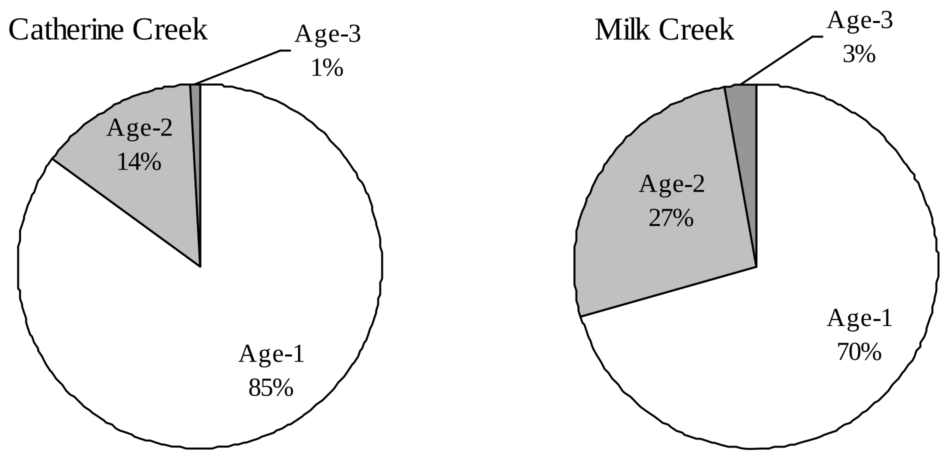

Figure 12. Age composition of the steelhead populations in Catherine Creek and Milk Creek during early summer 2002. Age was determined by scale analysis. Age-0 steelhead are not included, as they were present but not captured for population estimation.

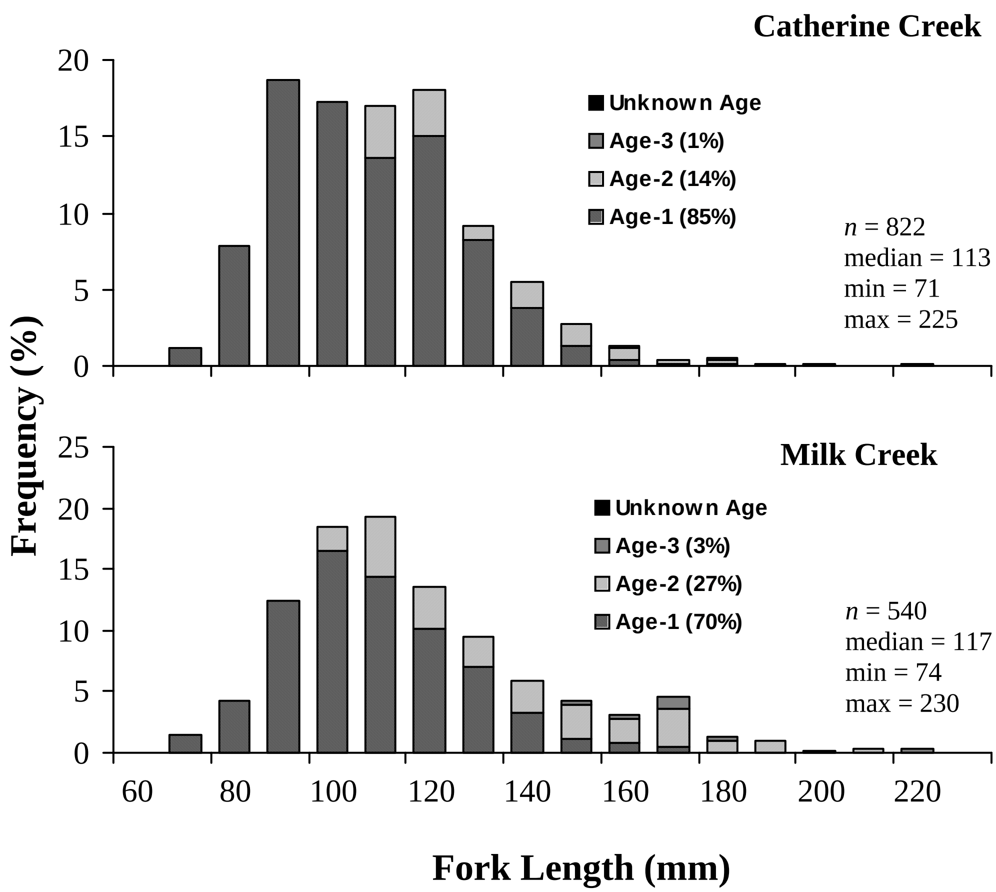

Figure 13. Fork lengths of steelhead in Catherine Creek and Milk Creek measured during the summer of 2002. Only data for age-1 and older fish is displayed.

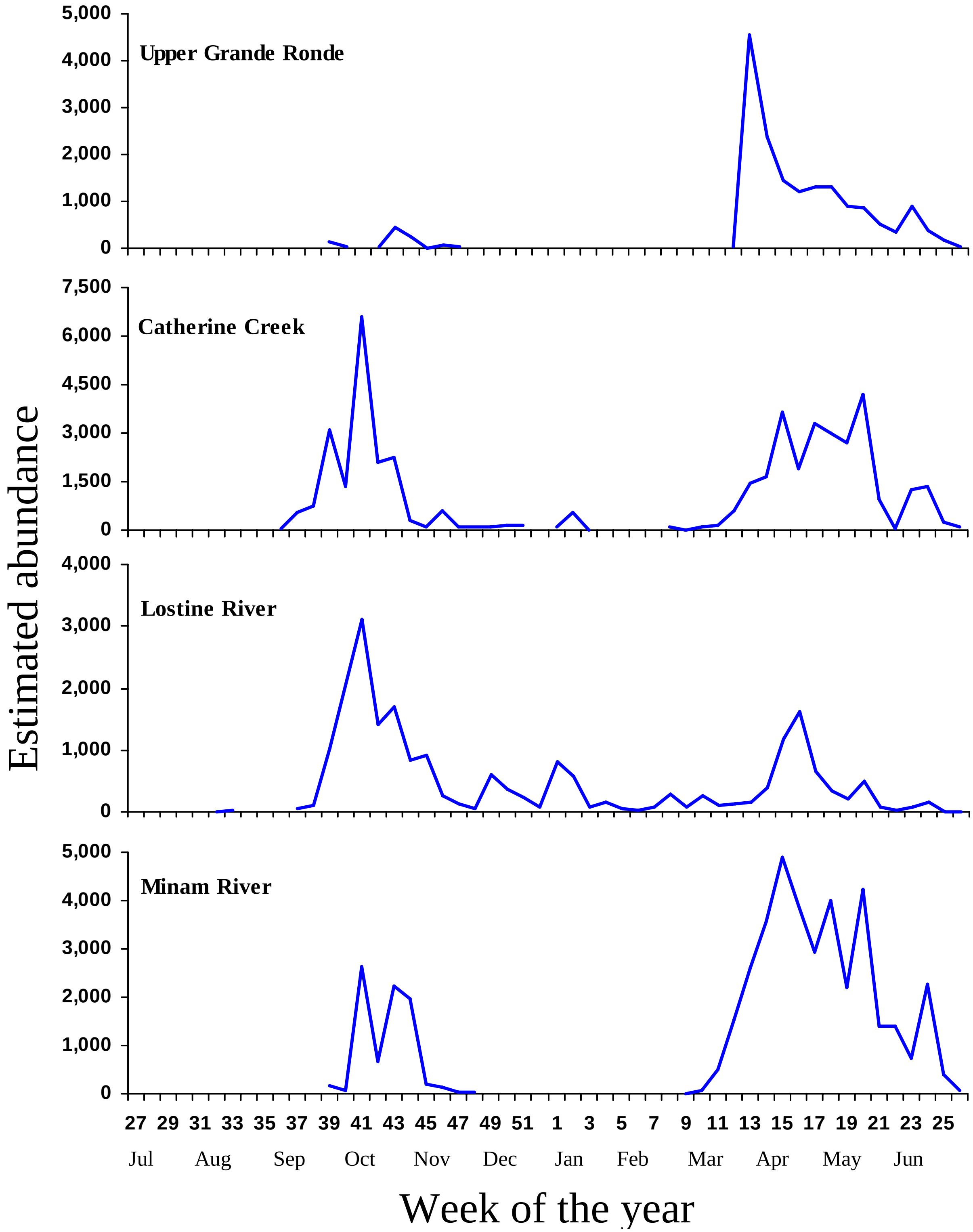

Figure 14. Estimated abundance and migration timing of steelhead migrants captured by rotary screw traps, during migratory year 2002. Traps were located at rkm 299 of the Grande Ronde River, rkm 32 of Catherine Creek, rkm 3 of the Lostine River, and rkm 0 of the Minam River.

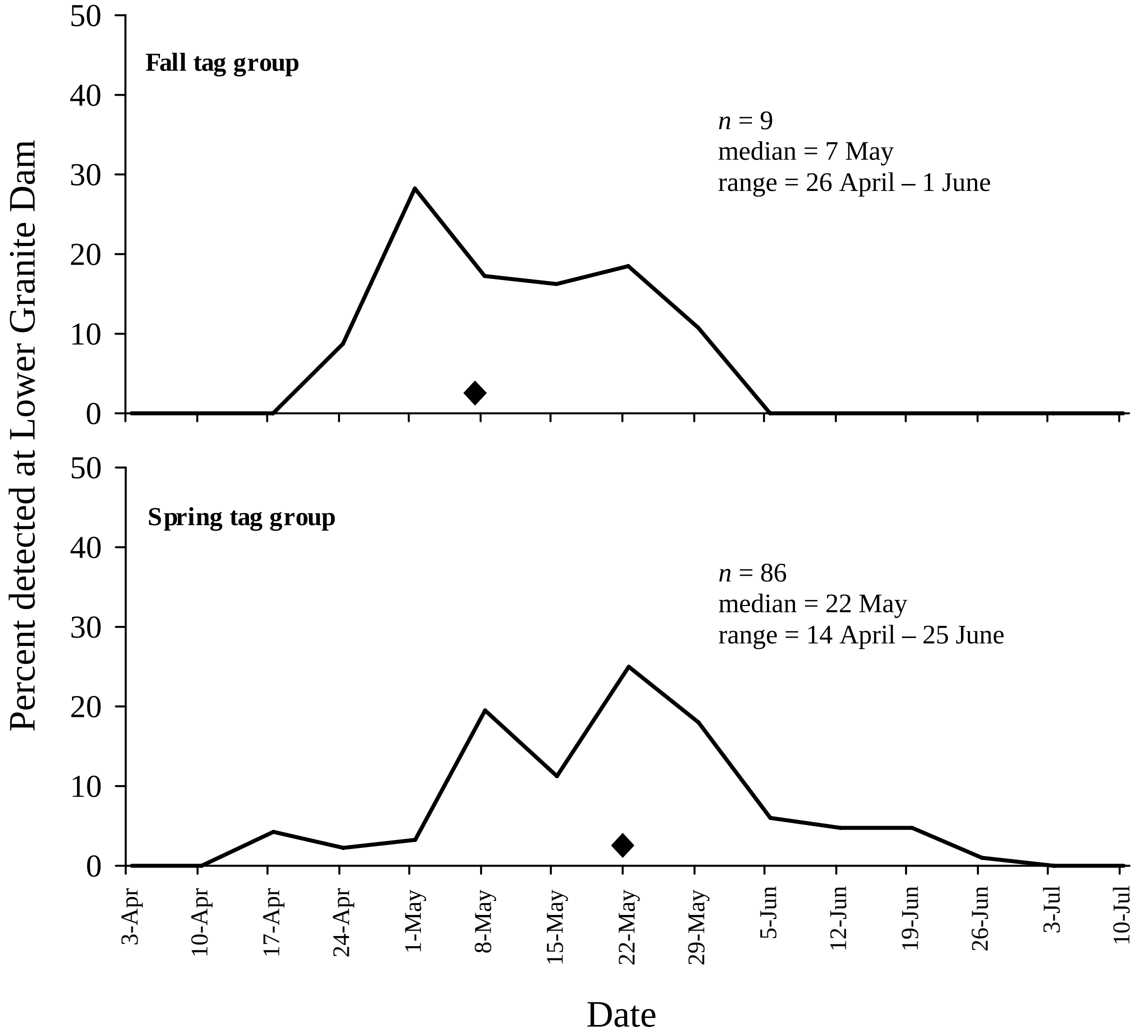

Figure 15. Migration timing by tag group of steelhead PIT-tagged at the screw trap on the upper Grande Ronde River and subsequently detected at Lower Granite Dam during migratory year 2002. ◆ = median detection date. Detection numbers were expanded for spillway flow.

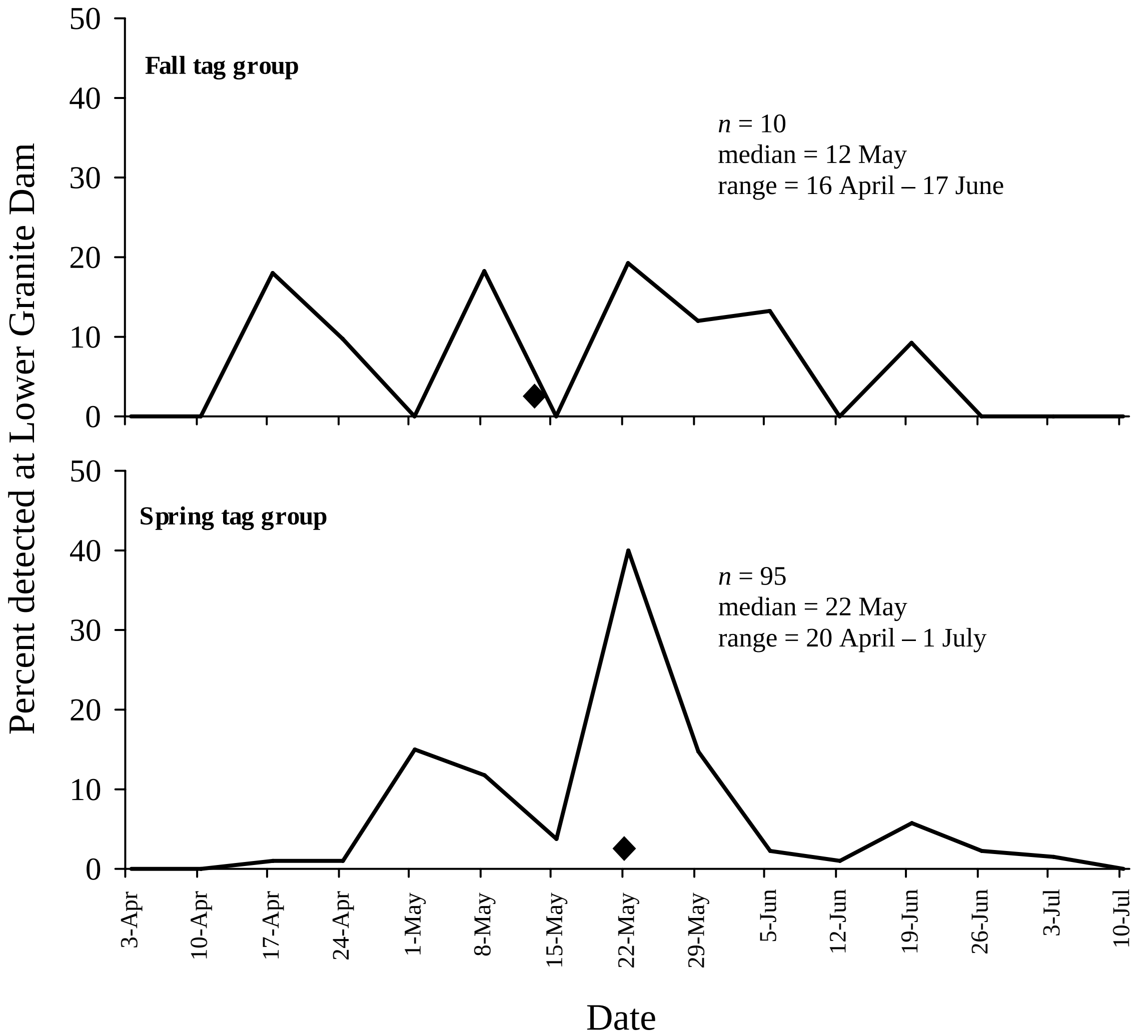

Figure 16. Migration timing by tag group of steelhead PIT-tagged at the screw trap on Catherine Creek and subsequently detected at Lower Granite Dam during migratory year 2002. ◆ = median detection date. Detection numbers were expanded for spillway flow.

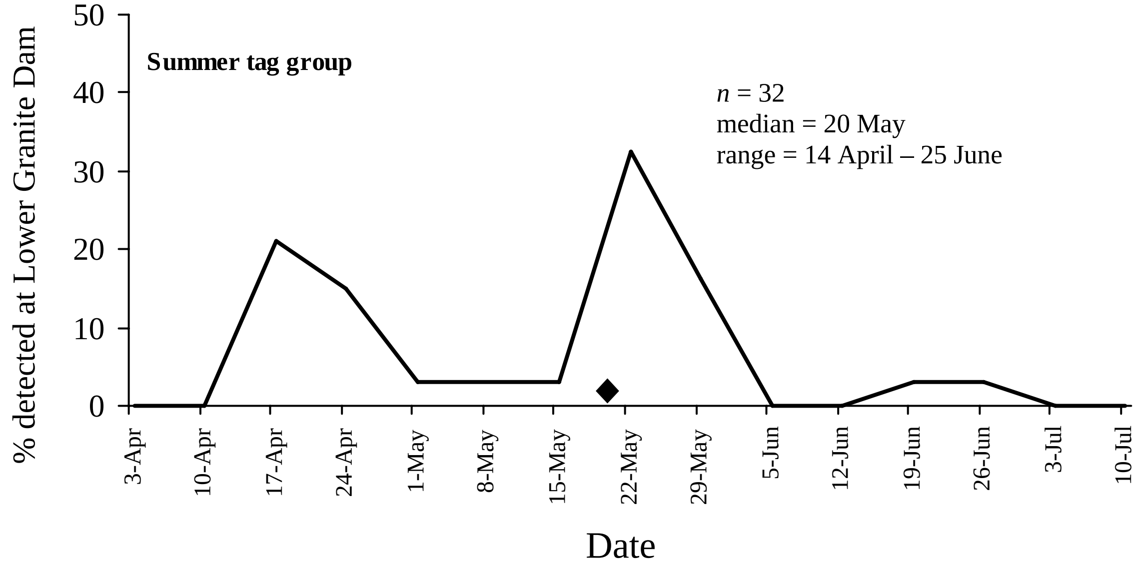

Figure 17. Migration timing of steelhead PIT-tagged as parr on Catherine Creek and North Fork Catherine Creek during the summer of 2001 and subsequently detected at Lower Granite Dam during migratory year 2002. ◆ = median detection date. Detection numbers were expanded for spillway flow.

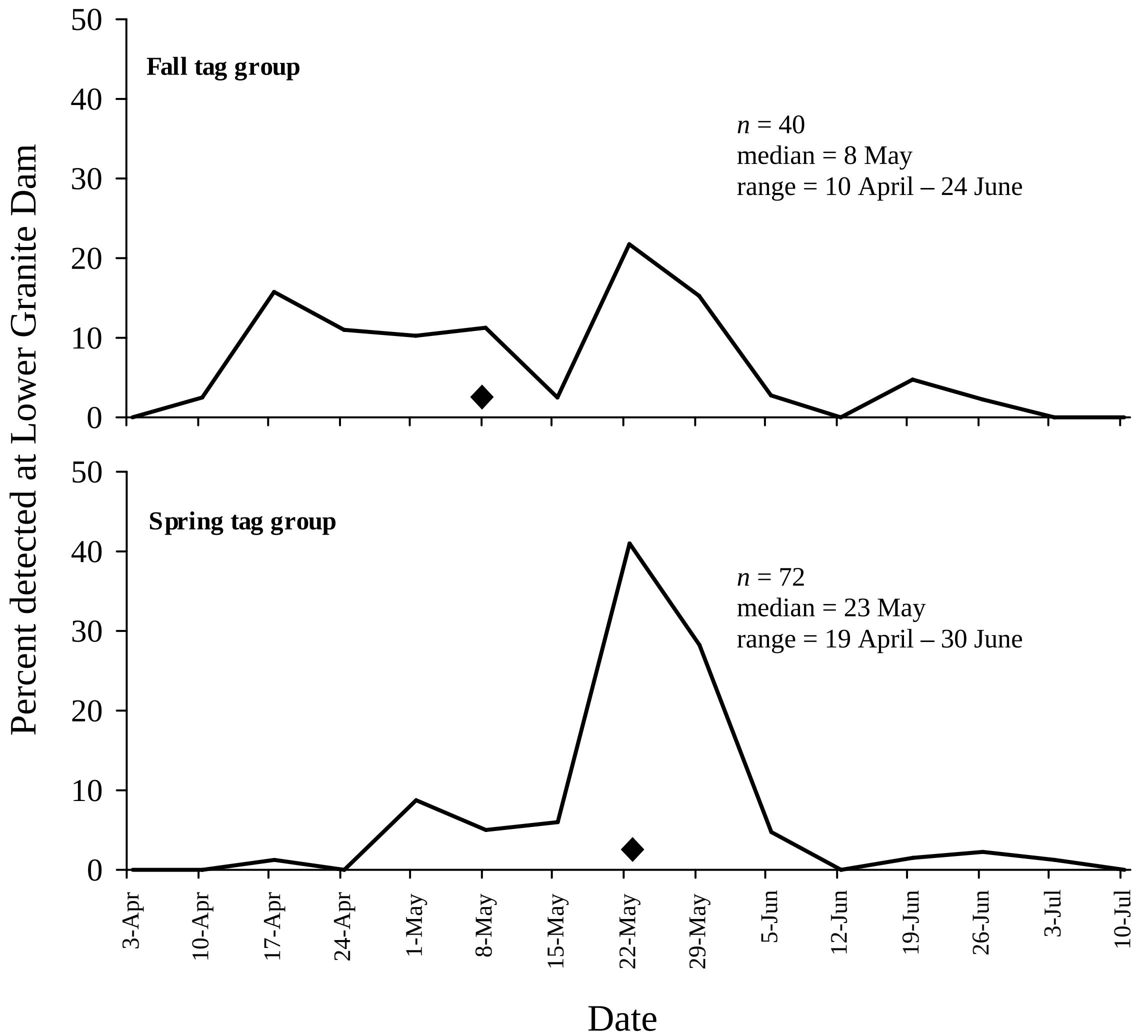

Figure 18. Migration timing by tag group of steelhead PIT-tagged at the screw trap on the Lostine River and subsequently detected at Lower Granite Dam during migratory year 2002. ◆ = median detection date. Detection numbers were expanded for spillway flow.

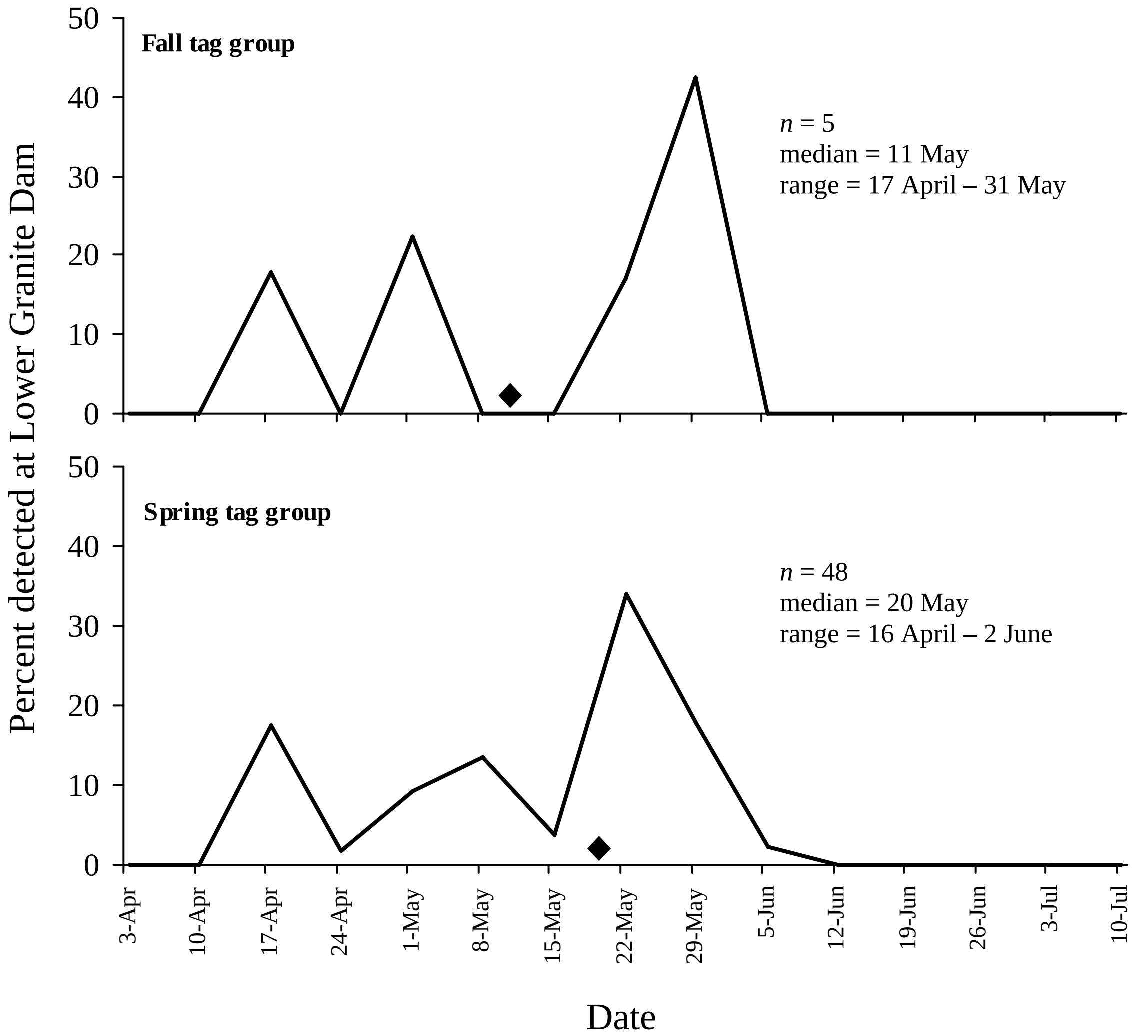

Figure 19. Migration timing by tag group of steelhead PIT-tagged at the screw trap on the Minam River and subsequently detected at Lower Granite Dam during migratory year 2002. ◆ = median detection date. Detection numbers were expanded for spillway flow.

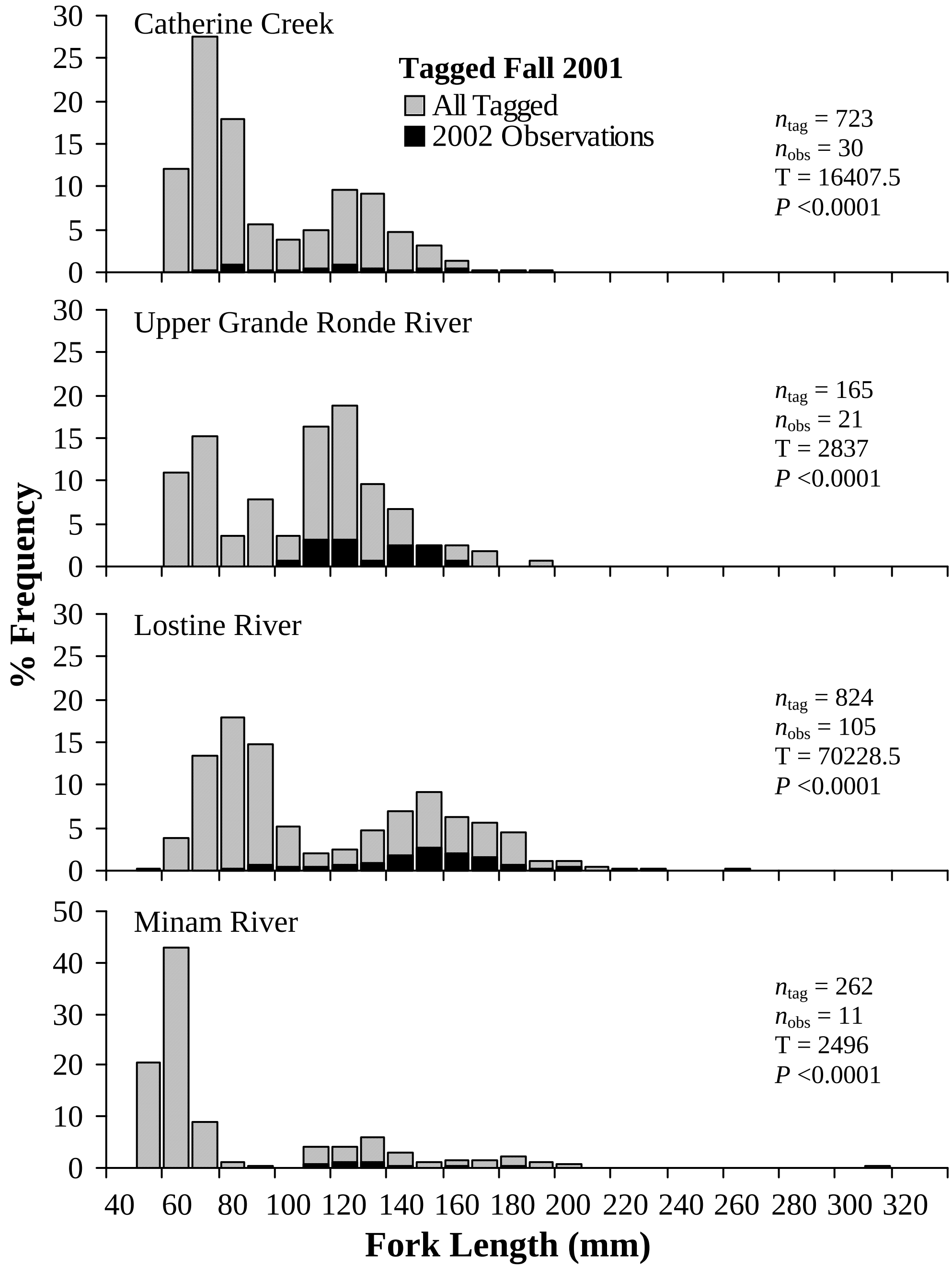

Figure 20. Fork lengths of all steelhead PIT-tagged at screw traps on Catherine Creek and the upper Grande Ronde, Lostine, and Minam rivers in the fall of 2001 and detected at Snake River or Columbia River dams in 2002 compared to lengths of all steelhead in the same tag group. Frequency is expressed as the percent of the total number tagged (n_{tag}). 'n_{obs}' is the number detected.

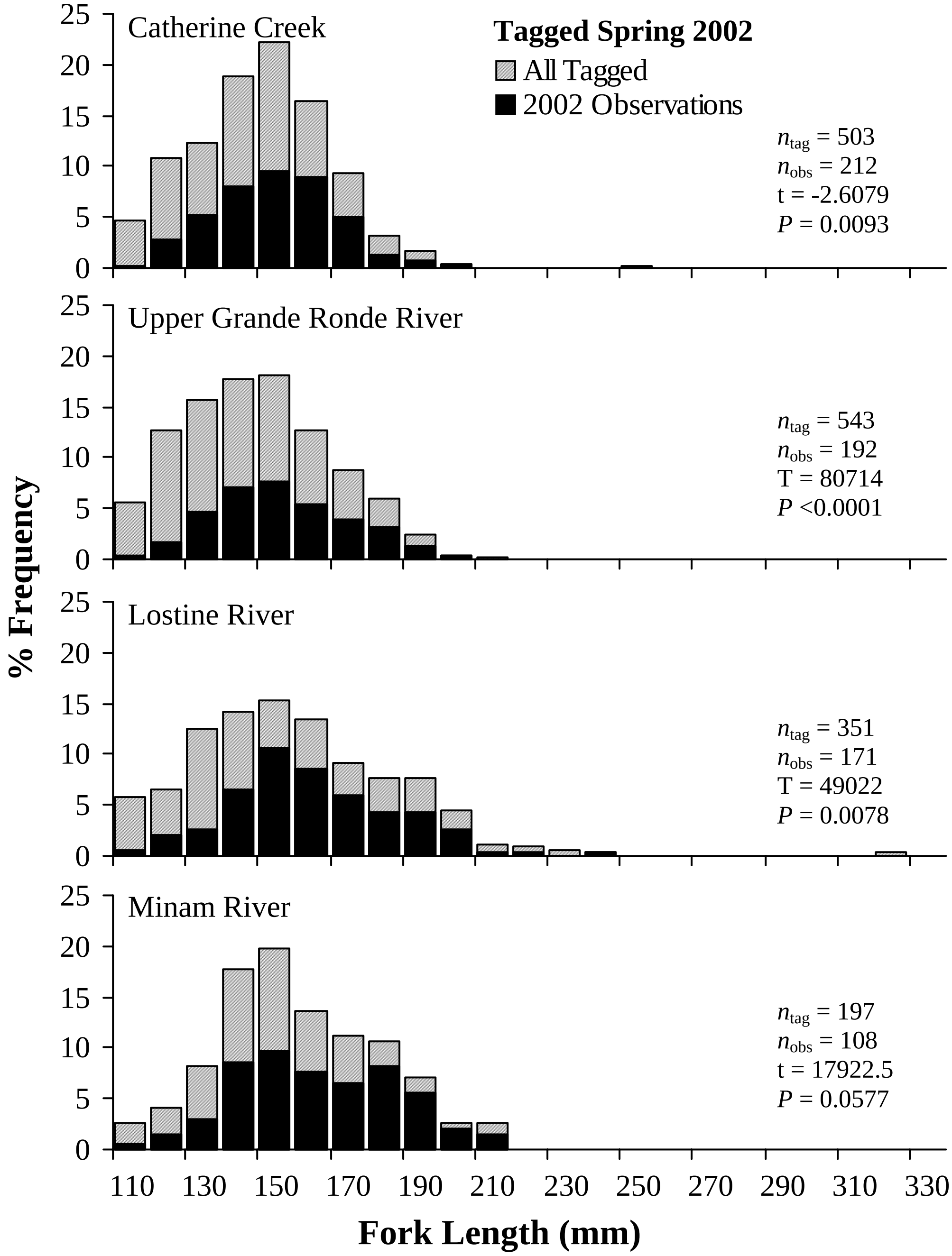

Figure 21. Fork lengths of all steelhead PIT-tagged at screw traps on Catherine Creek and the upper Grande Ronde, Lostine, and Minam rivers in the spring of 2002 and detected at Snake River or Columbia River dams in 2002 compared to lengths of all steelhead in the same tag group. Frequency is expressed as the percent of the total number tagged (n_{tag}). 'n_{obs}' is the number detected.

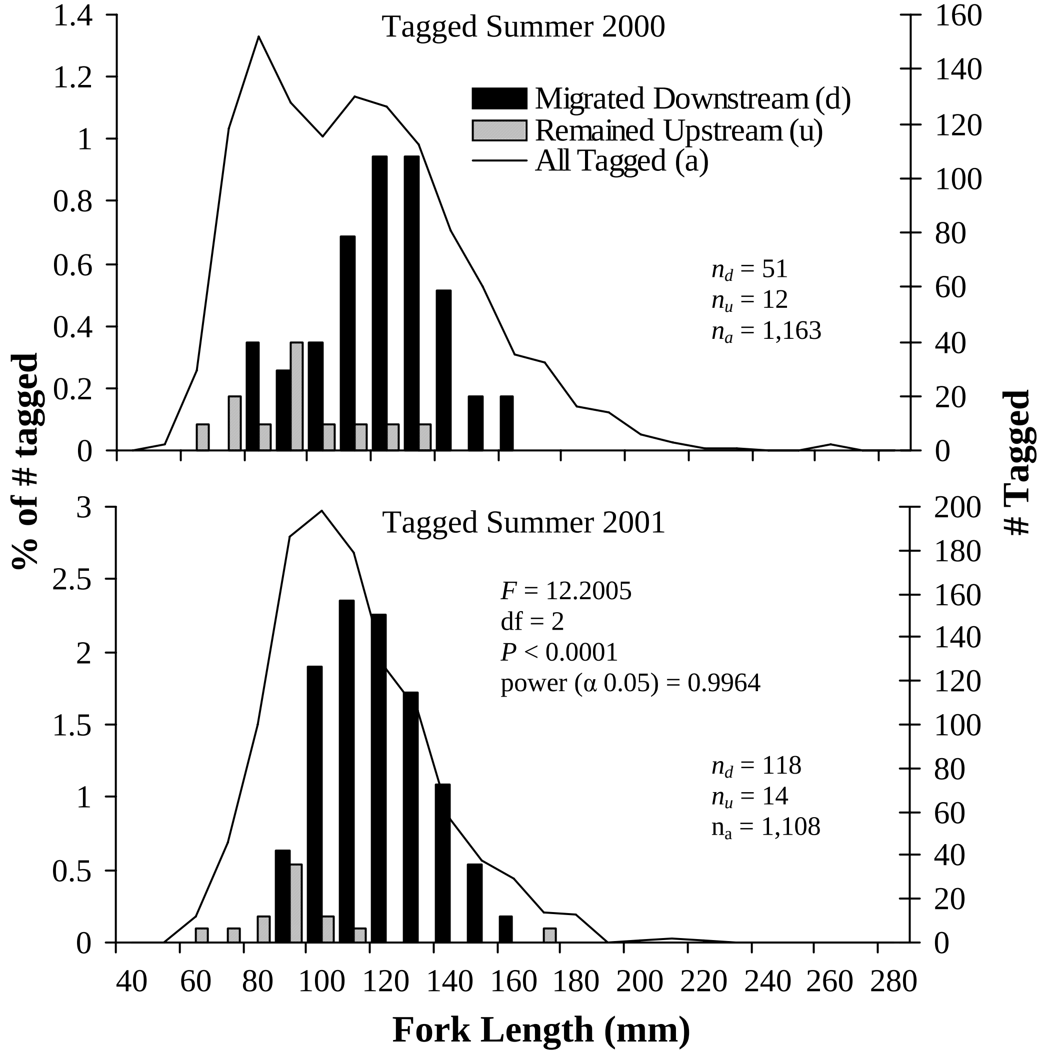

Figure 22. Lengths of steelhead that were tagged upstream of the screw trap on Catherine Creek during the summers of 2000 and 2001, lengths of those migrating downstream from upper rearing habitats before the following summer, and lengths of those known to remain upstream through the following summer. Migrant and non-migrant length frequency is expressed as the percent of the total number tagged. Length frequency of all tagged fish is read on the right hand axis.

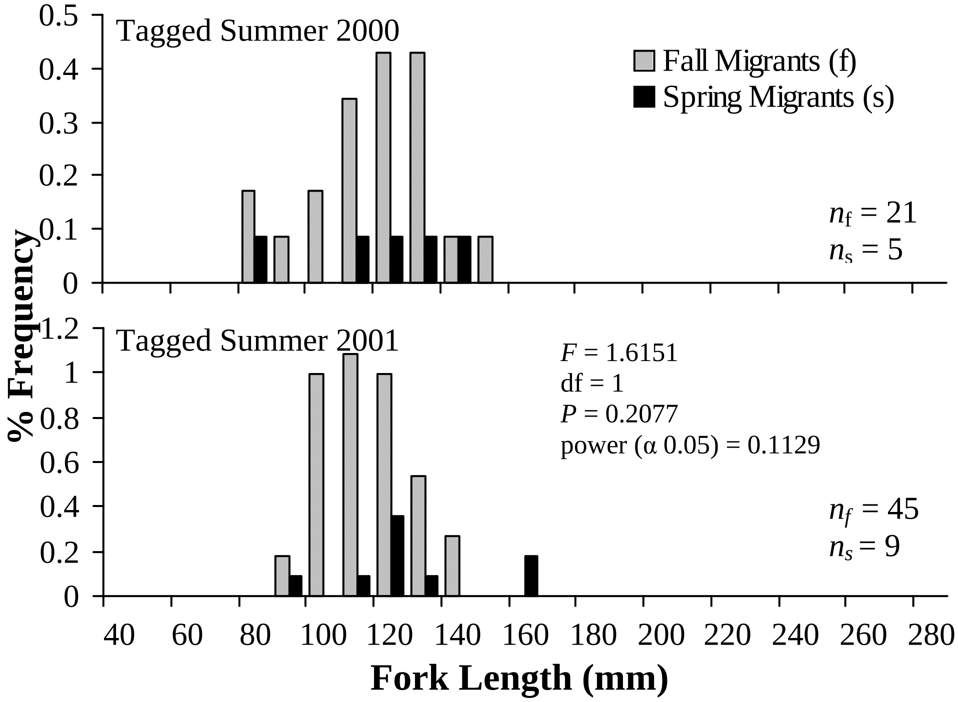

Figure 23. Lengths at tagging of steelhead that were tagged upstream of the screw trap on Catherine Creek during the summer of 2000 and 2001 and recaptured at the screw trap during the fall and spring following tagging. Frequency is expressed as the percent of the total number tagged each summer.

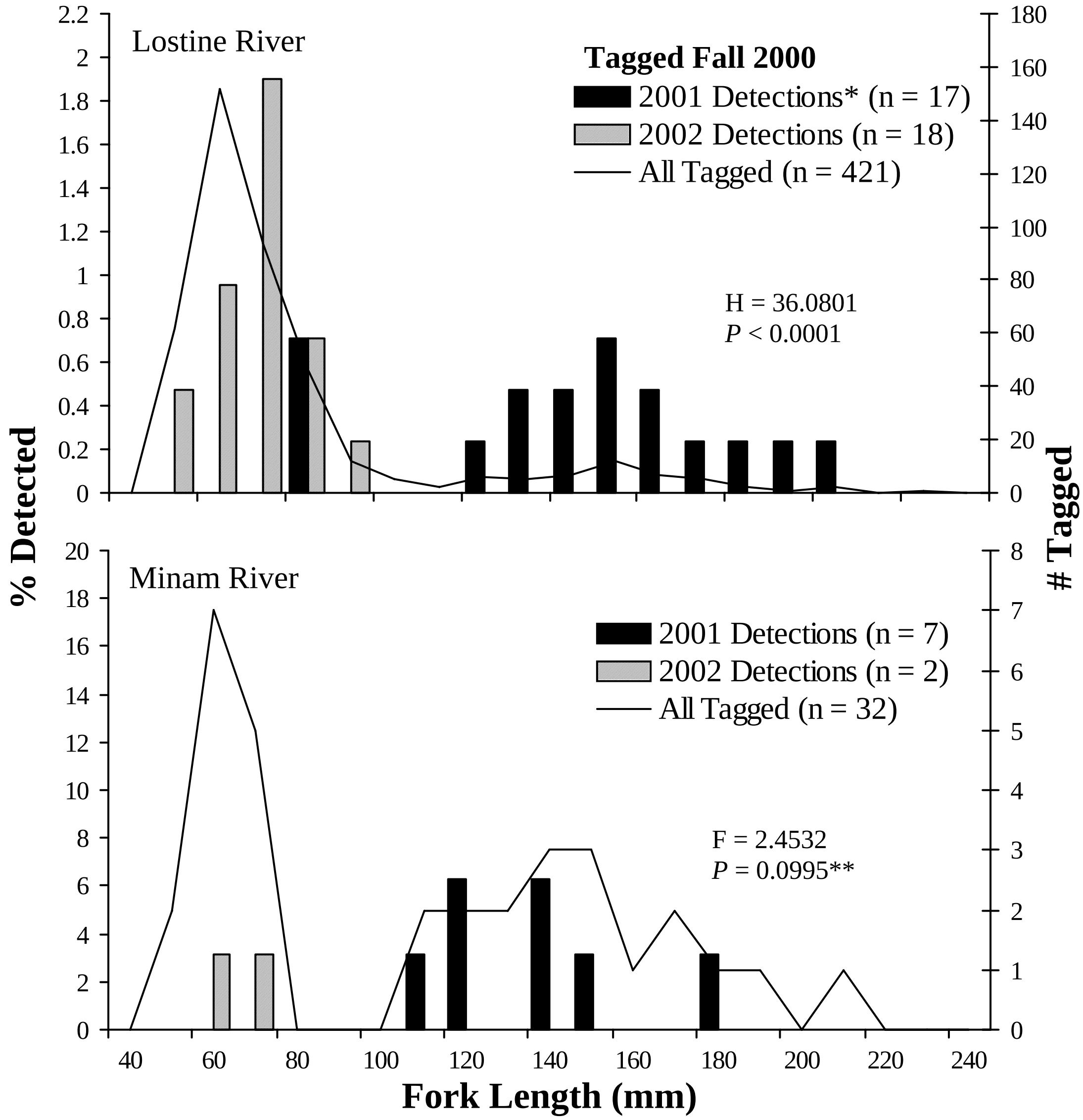

Figure 24. Lengths at time of tagging of steelhead that were PIT-tagged at Lostine and Minam River screw traps during the fall of 2000, lengths of those also detected at the dams in 2001, and lengths of those also detected at the dams in 2002. Frequency is expressed as the percent of the total number tagged. ‘H’ is the test statistic for the Kruskal-Wallis one-way ANOVA on ranks of the lengths. * Median length of the group was significantly different ($\alpha = 0.05$, Dunn’s all pair-wise multiple comparison procedure). ** Power of the test with $\alpha = 0.05$ was 0.2807.

APPENDIX A

A Compilation of Spring Chinook Salmon Data

Appendix Table A-1. Ages of immature and mature, wild spring Chinook salmon parr collected in summer rearing areas of Catherine Creek, and the Lostine, Minam, and Imnaha rivers, 1998 - 2002. Ages were determined by analysis of scales collected from a random subsample of fish caught for PIT-tagging.

	Immature parr			Mature parr		
Stream, year	Age-0	Age-1	% Age-0	Age-0	Age-1	% Age-1
Catherine Creek:						
1998	208	0	100.0	0	113	100.0
1999	204	0	100.0	1	209	99.5
2000	258	3[a]	98.9	0	106	100.0
2001	—	—	—	0	103	100.0
2002	1	0	100.0[b]	0	52	100.0
Lostine River:						
1998	231	0	100.0	0	20	100.0
1999	201	0	100.0	0	23	100.0
2000	110	0	100.0	0	31	100.0
2001	—	—	—	1	3	75.0[c]
2002	15	0	100.0[b]	0	2	100.0[c]
Minam River:						
1998	—	—	—	0	1	100.0[c]
1999	—	—	—	—	—	—
2000	70	0	100.0	—	—	—
2001	212	0	100.0	0	4	100.0[c]
2002	4	0	100.0[b]	0	5	100.0[c]
Imnaha River:						
1998	—	—	—	0	3	100.0[c]
1999	—	—	—	—	—	—
2000	—	—	—	—	—	—
2001	67	0	100.0	—	—	—
2002	3	0	100.0[b]	0	0	0

[a] These parr were collected in early August and it is possible that they were on their way to maturing precociously but their maturity characteristics had not yet developed (see Monzyk et al. 2000).

[b] Scales were only taken from the larger immature parr captured (fork length ≥ 85mm).

[c] Note small sample size.

Appendix Table A-2. Dates of tagging and number of spring Chinook salmon parr PIT-tagged on various northeast Oregon streams during summer, 1998–2002.

Year, stream	Dates of collection and tagging	Number tagged and released	Distance to Lower Granite Dam (km)
1998:			
Catherine Creek	3–7 Aug	502	354–375
Lostine River	10–13 Aug	506	274–302
Minam River	17–19 Aug	1,006	280–284
Imnaha River	24–26 Aug	1,009	237–243
1999:			
Catherine Creek	2–5 Aug	499	358–374
Lostine River	9–11 Aug	509	277–301
Minam River	16–18 Aug	998	279–283
Imnaha River	23–25 Aug	982	208–241
2000:			
Catherine Creek	7–10 Aug	500	370–377
Lostine River	14–17 Aug	490	276–290
Minam River	22 Aug, 18–19 Sep	1,000	282–283
Imnaha River	28–30 Aug	1,000	222–243
2001:			
Catherine Creek	30 Jul – 2 Aug	503	363–382
Lostine River	6–9 Aug	501	275–301
Minam River	20–23 Aug	996	282–284
Imnaha River	27–28 Aug	1,001	208–227
2002:			
Catherine Creek	29 Jul – 1 Aug	506	365-380
Lostine River	12–15 Aug	509	274-302
Minam River	19–22 Aug	1,000	280-283
Imnaha River	26–28 Aug	1,003	209-230

Appendix Table A-3. Spring Chinook salmon parr mark-recapture population estimates on Catherine Creek and the Lostine River during summer, 1998–2002.

Stream, parr maturity, origin	Year	Census data			Population estimate	95% CI
		Marked	Recaptured	Captured		
Catherine Creek:						
Immature, wild	1998	1,050	49	628	13,222	10,047 – 17,819
	1999	1,003	52	1,187	22,505	17,239 – 29,341
	2000	1,262	47	987	25,997	19,651 – 35,151
	2001	1,325	121	1,382	15,032	12,598 – 17,931
	2002	1,315	120	3,432	37,337	31,270 – 44,572
Mature, wild	1998	73	9	57	429	237 – 858
	1999	117	21	136	735	490 – 1,155
	2000	123	14	87	727	445 – 1,254
	2001	111	9	87	986	545 – 1,971
	2002	57	10	56	301	170 – 580
Mature, hatchery[a]	2000	18	5	11	38	18 – 88
	2002	28	4	14	87	39 – 218

[a] Although mature hatchery origin parr were observed other years, a population estimate was only attempted during 2000 and 2002.
[b] Population estimate is biased because R is not greater than or equal to 3 or M x C is not greater than 4N.

Appendix Table A-3. Continued.

Stream, parr maturity, origin	Year	Census data: Marked	Census data: Recaptured	Census data: Captured	Population estimate	95% CI
Lostine River:						
Immature, wild	1998	1,010	22	926	40,748	27,403 – 63,324
	1999	1,000	17	504	28,084	17,926 – 46,377
	2000	974	89	1,141	12,372	10,075 – 15,185
	2001	1,074	62	1,938	33,086	25,901 – 42,226
	2002	1,227	51	1,744	41,209	31,488 – 53,859
Mature, wild	1998	14	1	9	75[b]	23 – 136
	1999	10	0	15	176[b]	—
	2000	35	3	32	297[b]	121 – 743
	2001	5	0	1	12[b]	—
	2002	2	0	2	9[b]	—

Appendix Table A-4. Number of spring Chinook salmon parr and number of parr produced per redd in Catherine Creek and the Lostine River during summer, by brood year, age, and maturity. Number of parr by maturity and age were calculated using mark-recapture population estimates and age ratios for immature and mature parr determined by scale analysis. Italics indicate that population estimate is biased due to a low number of recaptured fish.

		Estimated number of age-0 parr (in BY + 1)			Estimated number of age-1 parr (in BY + 2)		
Stream, brood year	Redds[a]	Immature	Mature	Parr produced/redd	Immature	Mature	Parr produced/redd
Catherine Creek							
1996	15	—	—	—	0	429	29
1997	45	13,222	0	294	0	731	16
1998	34	22,505	4	662	299	703	29
1999	38	25,698	0	676	0	986	26
2000	26	15,032	0	578	0	301	12
2001	131	37,337	0	285	—	—	—
Lostine River							
1996	27	—	—	—	0	(b)	0
1997	47	40,748	(b)	867	0	(b)	0
1998	28	28,084	(b)	1,003	0	*297*	*11*
1999	45	12,372	0	275	0	(b)	0
2000	53	33,086	(b)	624	0	(b)	0
2001	98	41,209	0	420	—	—	—

[a] Redds counted above screw trap on each stream. ODFW unpublished data.
[b] Too few mature parr were captured for population estimate.

Appendix Table A-5. Percentage of immature age-0 spring Chinook salmon parr from one summer that remained in freshwater and matured by the following summer, and number of mature male parr present in relation to the number of redds counted.

Stream, year	Estimated mature parr[a]	Percentage of immature parr from previous summer maturing in freshwater at age-1	Potential for mature male parr to spawn with wild adult females[c]	
			Redds[b]	Mature parr /redd
Catherine Creek				
1998	429	—	34	12.6
1999	735	5.5	38	19.3
2000	703	3.1	26	27.0
2001	986	3.8	131	7.5
2002	301	2.0	156	1.9
Lostine River				
1998	(d)	—	28	(d)
1999	(d)	(d)	45	(d)
2000	297	1.1	53	5.6
2001	(d)	(d)	98	(d)
2002	(d)	(d)	182	(d)

[a] Mark-recapture estimates.
[b] Redds counted above screw trap on each stream. ODFW unpublished data.
[c] We assumed that all mature parr were male.
[d] Too few mature parr captured to estimate the population size.

Appendix Table A-6. Dates of detection at Lower Granite Dam (LGD) of spring Chinook salmon smolts PIT-tagged at screw traps as early and late migrants and during the winter. Italics indicate that median might be biased and reflect when fish were tagged. Numbers of fish detected at Lower Granite Dam were expanded for spillway flow to calculate the median detection date.

Stream, migratory year	Tag group	Migrant group	Number tagged	Number detected at LGD	Detection dates: Median	First	Last
Catherine Creek							
1995	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	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	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	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	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	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	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	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-6. Continued.

Stream, migratory year	Tag group	Migrant group	Number tagged	Number detected at LGD	Detection dates Median	First	Last
Upper Grande Ronde River (rkm 299)							
1994	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
1995[a]	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		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
Grande Ronde River (rkm 164)							
2002	Spring	NA	167	21	23 May	17 May	18 Jun

[a] Trap was located at rkm 257.

Appendix Table A-6. Continued.

Stream, migratory year	Tag group	Migrant group	Number tagged	Number detected at LGD	Detection dates		
					Median	First	Last
Lostine River							
1997	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	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	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	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	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	Fall	Early	501	37	17 Apr	30 Mar	5 May
	Winter	Late	564	22	7 May	11 Apr	23 Jun
	Spring	Late	406	61	*7 May*	15 Apr	11 Jun
Minam River							
2001	Fall	Early	300	107	28 Apr	12 Apr	26 May
	Spring	Late	539	274	*14 May*	16 Apr	18 Aug
2002	Fall	Early	537	35	18 Apr	25 Mar	9 May
	Spring	Late	382	42	*30 May*	8 Apr	23 Jun

Appendix Table A-7. 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, migratory year	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
Upper Grande Ronde River (rkm 299)	397				
1994		93	45.1	17	130
1995[a]		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
Upper Grande Ronde River (rkm 164)	262				
2002		21	6.6	3	22

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

Appendix Table A-7. Continued.

Stream, migratory year	Distance to LGD (km)	Number detected	Travel time (d)		
			Median	Min.	Max
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
Minam River	245				
2001		274	39.5	9	106
2002		42	32.4	5	52

Appendix Table A-8. Spring Chinook salmon survival probabilities from PIT-tagging at screw traps (fall and spring) or upstream of the screw traps (winter and summer) to Lower Granite Dam. Asterisks indicate there were not enough detections to calculate survival probabilities.

			Survival probability		
Tag group, stream	Migratory year	Number released	Probability	SE	95% CI
Summer					
Catherine Creek	1993	1,094	0.178	0.015	0.151 – 0.212
	1994	1,000	0.226	0.023	0.186 – 0.279
	1995	999	0.154	0.014	0.129 – 0.184
	1996	499	0.277	0.047	0.205 – 0.406
	1997	583	0.176	0.021	0.139 – 0.225
	1998	499	0.211	0.027	0.164 – 0.276
	1999	502	0.157	0.021	0.122 – 0.212
	2000	497	0.151	0.026	0.109 – 0.217
	2001	498	0.087	0.013	0.063 – 0.115
	2002	502	0.109	0.019	0.079 – 0.157
Lostine River	1993	997	0.250	0.021	0.214 – 0.296
	1994	725	0.237	0.030	0.188 – 0.309
	1995	1,002	0.215	0.018	0.183 – 0.255
	1996	977	0.237	0.028	0.191 – 0.306
	1997	527	0.213	0.034	0.160 – 0.310
	1999	506	0.180	0.021	0.145 – 0.234
	2000	509	0.212	0.032	0.159 – 0.294
	2001	489	0.210	0.019	0.175 – 0.248
	2002	501	0.154	0.022	0.117 – 0.209
Minam River	1993	994	0.187	0.018	0.115 – 0.230
	1994	997	0.293	0.025	0.249 – 0.350
	1995	996	0.153	0.016	0.124 – 0.191
	1996	998	0.208	0.023	0.169 – 0.264
	1997	589	0.270	0.080	0.181 – 0.693
	1998	992	0.228	0.015	0.199 – 0.259
	1999	1,006	0.181	0.014	0.155 – 0.210
	2000	998	0.239	0.023	0.199 – 0.292
	2001	1,000	0.228	0.014	0.202 – 0.256
	2002	994	0.093	0.011	0.074 – 0.119

Appendix Table A-8. Continued.

Tag group, stream	Migratory year	Number released	Survival probability: Probability	SE	95% CI
Summer, *continued*					
Imnaha River	1993	1,000	0.141	0.016	0.115 – 0.180
	1994	998	0.136	0.016	0.109 – 0.173
	1995	996	0.083	0.011	0.064 – 0.108
	1996	997	0.268	0.027	0.222 – 0.330
	1997	1,017	0.216	0.023	0.179 – 0.276
	1998	1,009	0.325	0.019	0.290 – 0.366
	1999	1,009	0.173	0.019	0.141 – 0.219
	2000	982	0.141	0.014	0.115 – 0.172
	2001	1,000	0.181	0.012	0.158 – 0.206
	2002	1,001	0.106	0.018	0.079 – 0.160
Upper Grande Ronde	1993	918	0.287	0.031	0.237 – 0.365
	1994	1,001	0.144	0.021	0.110 – 0.197
	1995	1,000	0.173	0.016	0.144 – 0.207
Wenaha/SF Wenaha	1993	749	0.214	0.019	0.181 – 0.255
	1994	998	0.144	0.013	0.121 – 0.172
	1995	999	0.146	0.015	0.119 – 0.180
	1996	997	0.212	0.024	0.172 – 0.271
	1997	62	*	*	* – *
Fall trap					
Catherine Creek	1995	502	0.238	0.026	0.193 – 0.297
	1996	508	0.358	0.036	0.296 – 0.446
	1997	399	0.365	0.075	0.256 – 0.588
	1998	582	0.238	0.025	0.194 – 0.293
	1999	644	0.202	0.021	0.166 – 0.250
	2000	677	0.212	0.025	0.17 – 0.269
	2001	508	0.130	0.015	0.103 – 0.162
	2002	514	0.154	0.027	0.114 – 0.245
Lostine River	1997	519	0.312	0.046	0.247 – 0.465
	1998	500	0.448	0.031	0.391 – 0.514
	1999	501	0.422	0.045	0.349 – 0.538
	2000	514	0.317	0.028	0.267 – 0.380
	2001	498	0.335	0.021	0.294 – 0.378
	2002	500	0.326	0.045	0.258 – 0.455
Minam River	2001	300	0.427	0.029	0.371 – 0.485
	2002	537	0.249	0.029	0.201 – 0.326

Appendix Table A-8. Continued.

Tag group, stream	Migratory year	Number released	Survival probability: Probability	SE	95% CI
Fall trap, *continued*					
Upper Grande Ronde	1994	405	0.348	0.0364	0.284 – 0.432
	1995	424	0.228	0.0241	0.184 – 0.281
	1996	5	*	*	* – *
	1997	27	*	*	* – *
	1998	590	0.286	0.0226	0.244 – 0.334
	1999	498	0.269	0.0217	0.229 – 0.315
	2000	493	0.341	0.051	0.260 – 0.476
	2001				
	2002	344	0.308	0.087	0.198 – 0.653
Wallowa River	1999	45	*	*	* – *
Winter					
Catherine Creek	1995	482	0.279	0.028	0.230 – 0.343
	1996	295	0.312	0.134	0.163 – 1.008
	1997	102	0.078	0.032	0.033 – 0.222
	1998	437	0.278	0.029	0.226 – 0.345
	1999	493	0.285	0.033	0.230 – 0.367
	2000	500	0.138	0.021	0.102 – 0.191
	2001	522	0.077	0.013	0.054 – 0.106
	2002	431	0.203	0.062	0.129 – 0.476
Lostine River	1997	388	0.445	0.073	0.334 – 0.650
	1998	504	0.349	0.026	0.301 – 0.403
	1999	491	0.305	0.026	0.259 – 0.363
	2000	511	0.397	0.066	0.296 – 0.576
	2001	499	0.284	0.021	0.245 – 0.326
	2002	564	0.246	0.059	0.170 – 0.464
Upper Grande Ronde	1994	505	0.248	0.0742	0.152 – 0.519
	1995	432	0.151	0.0205	0.115 – 0.199
	1996	0	—		
	1997	0	—		
	1998	124	0.113	0.0284	* – *
	1999	420	0.117	0.022	0.083 – 0.183
	2000	500	0.133	0.02	0.099 – 0.183
	2001	0	—		
	2002	0	—		

Appendix Table A-8. Continued.

Tag group, stream	Migratory year	Number released	Survival probability: Probability	SE	95% CI
Spring trap					
Catherine Creek	1995	348	0.506	0.034	0.441 – 0.578
	1996	276	0.591	0.067	0.480 – 0.755
	1997	81	0.413	0.069	0.292 – 0.580
	1998	453	0.517	0.031	0.459 – 0.583
	1999	502	0.448	0.041	0.379 – 0.545
	2000	431	0.452	0.057	0.359 – 0.598
	2001	328	0.376	0.028	0.322 – 0.433
	2002	217	0.527	0.076	0.411 – 0.750
Lostine River	1997	475	0.769	0.09	0.63 – 1.009
	1998	484	0.784	0.03	0.728 – 0.845
	1999	599	0.744	0.048	0.664 – 0.857
	2000	355	0.660	0.068	0.546 – 0.823
	2001	442	0.695	0.024	0.648 – 0.741
	2002	406	0.683	0.057	0.589 – 0.825
Minam River	2001	536	0.619	0.022	0.576 – 0.661
	2002	382	0.532	0.041	0.465 – 0.644
Upper Grande Ronde	1994	571	0.462	0.043	0.387 – 0.563
	1995	368	0.6094	0.035	0.545 – 0.683
	1996	327	0.5122	0.068	0.404 – 0.690
	1997	0	—	—	
	1998	512	0.5482	0.034	0.487 – 0.622
	1999	528	0.538	0.029	0.486 – 0.601
	2000	495	0.560	0.051	0.472 – 0.680
	2001	6	*	*	* – *
	2002	536	0.499	0.052	0.416 – 0.633
Grande Ronde River	2001	4	*	*	* – *
(trap at rkm 164)	2002	167	0.776	0.102	0.624 – 1.073

Appendix Table A-9. Comparisons of overwinter survival of spring Chinook salmon parr in rearing areas upstream (above screw trap) and downstream (below screw trap) on Catherine Creek and the Lostine and Grande Ronde rivers. Fall migrant life history corresponds to overwintering downstream, spring migrant life history corresponds to overwintering upstream. Screw traps are located on Catherine Creek at rkm 32, Lostine River at rkm 3, and Grande Ronde River at rkm 299, except migratory year 1995 when the upper Grande Ronde River trap was at rkm 257. *P*-value is based on the maximum likelihood ratio test comparing the fit of the null model (fall tag group survival probability = winter tag group survival probability) to the fit of the full model (fall tag group survival probability ≠ winter tag group survival probability).

	Catherine Creek		Lostine River		Grande Ronde River	
Migratory year	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	—	—

Appendix Table A-10. Overwinter survival rates of spring Chinook salmon parr overwintering upstream of screw traps on Catherine Creek and the 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 migratory year 1995 when the upper Grande Ronde River trap was at rkm 257. Survival rates were calculated by dividing the survival probability of the winter tag group by the survival probability of the spring tag group.

Migratory	Brood	Overwinter survival in upper rearing areas		
year	year	Catherine Creek	Lostine River	Upper Grande Ronde River
1994	1992	—	—	0.54
1995	1993	0.55	—	0.25
1996	1994	0.53	—	—
1997	1995	0.19	0.58	—
1998	1996	0.54	0.45	0.21
1999	1997	0.64	0.41	0.22
2000	1998	0.31	0.60	0.24
2001	1999	0.20	0.41	—
2002	2000	0.39	0.36	—

Appendix Table A-11. Dates of detection at Lower Granite Dam of spring Chinook salmon smolts PIT-tagged as parr during the previous summer, 1993–2002 migratory years. Numbers of fish detected at Lower Granite Dam were expanded for spillway flow to calculate the median detection date.

Stream, migratory year	Number detected	Detection dates		
		Median	First	Last
Catherine Creek:				
1993	125	18 May	29 Apr	26 Jun
1994	91	11 May	13 Apr	26 Jul
1995	88	25 May	26 Apr	2 Jul
1996	60	1 May	17 Apr	29 May
1997	51	14 May	24 Apr	10 Jun
1998	43	17 May	24 Apr	4 Jun
1999	20	26 May	26 Apr	26 Jun
2000	30	7 May	12 Apr	7 Jun
2001	33	17 May	28 Apr	3 Jul
2002	17	6 May	15 Apr	22 May
Upper Grande Ronde River:				
1993	117	17 May	23 Apr	20 Jun
1994	57	29 May	23 Apr	29 Aug
1995	89	29 May	12 Apr	1 Jul
Lostine River:				
1993	136	4 May	17 Apr	1 Jun
1994	77	2 May	19 Apr	7 Jun
1995	115	2 May	8 Apr	19 Jun
1996	129	15 May	17 Apr	19 Jun
1997	43	25 Apr	9 Apr	21 May
1999	19	15 May	29 Mar	29 May
2000	36	8 May	13 Apr	3 Jun
2001	87	9 May	10 Apr	12 Jun
2002	23	20 Apr	28 Mar	29 May
Imnaha River:				
1993	74	14 May	15 Apr	23 Jun
1994	65	8 May	20 Apr	11 Aug
1995	41	2 May	10 Apr	7 Jul
1996	158	26 Apr	14 Apr	12 Jun
1997	98	19 Apr	31 Mar	2 Jun
1998	159	29 Apr	3 Apr	24 May
1999	41	8 May	17 Apr	3 Jun
2000	63	2 May	12 Apr	16 Jun
2001	159	30 Apr	8 Apr	28 May
2002	15	4 May	15 Apr	31 May

Appendix Table A-11. Continued.

Stream, migratory year	Number detected	Detection dates Median	First	Last
Minam River:				
1993	113	4 May	18 Apr	3 Jun
1994	120	29 Apr	18 Apr	13 Aug
1995	71	2 May	8 Apr	7 Jun
1996	117	24 Apr	10 Apr	7 Jun
1997	49	16 Apr	3 Apr	13 May
1998	123	29 Apr	3 Apr	30 May
1999	50	29 Apr	31 Mar	2 Jun
2000	74	3 May	10 Apr	29 May
2001	178	8 May	8 Apr	12 Jun
2002	30	3 May	16 Apr	31 May
Wenaha and South Fork Wenaha rivers:				
1993	84	28 Apr	14 Apr	15 May
1994	93	24 Apr	18 Apr	6 Jun
1995	76	26 Apr	9 Apr	15 May
1996	105	21 Apr	13 Apr	16 May
1997	10	16 Apr	9 Apr	23 Apr

APPENDIX B

A Compilation of Steelhead Data

Appendix Table B-1. Dates of tagging and number of juvenile steelhead PIT-tagged on Catherine Creek and its tributaries during summer, 2000 – 2002.

Stream, year tagged	Dates of collection and tagging	Number tagged
Catherine Creek		
2000	27 Jun – 29 Jun	412
2001	16 Jul – 19 Jul	837
2002	15 Jul – 19 Jul	511
North Fork Catherine Creek		
2000	31 Jul – 1 Aug	117
2001	26 Jun – 28 Jun	270
South Fork Catherine Creek		
2000	5 Jul – 24 Jul	225
Little Catherine Creek		
2000	2 Aug – 3 Aug	415
Milk Creek		
2002	27 Jun – 2 Jul	532

Appendix Table B-2. Population estimates of wild steelhead in Catherine Creek and its tributaries above the screw trap (rkm 32) during summer.

Stream, year	Sampling methods	Estimation methods	Population estimate	
			Number	95% CI
Catherine Creek				
2000	Snorkel seine, hook and line	Mark-recapture	22,393	17,461–28,689
2001	Snorkel seine	Mark-recapture	25,736	21,005–31,519
2002	Snorkel seine, hook and line	Mark-recapture	19,115	14,082–24,149
South Fork Catherine Creek				
2000	Electrofishing	Mark-recapture	9,971	5,892–18,002
North Fork Catherine Creek				
2001	Snorkel observation, electrofishing, snorkel seine	Mark-recapture, Hankin and Reeves (1988)	10,338	5,137–15,539
Milk Creek				
2002	Electrofishing	Mark-recapture	1,825	1,600–2,050

Appendix Table B-3. Age composition of steelhead sampled in Catherine Creek and its tributaries during summer, 2000 – 2002. Age was determined by scale analysis. We assumed that the length distribution of all the fish captured for marking was representative of the whole population.

Stream, year sampled	Age	*n*	Length range (FL, mm)	Percent of population	95% CI
Catherine Creek					
2000	0	4	65-72	2.6[a]	1.2-7.0
	1	92	69-160	59.9[a]	52.1-67.6
	2	46	113-218	29.9[a]	23.2-37.7
	3	12	163-263	7.8[a]	4.6-13.5
2001	0	0		(b)	
	1	196	72-163	86.7[a]	81.6-90.7
	2	29	114-200	12.8[a]	8.8-17.9
	3	1	221	0.4[a]	0.0-2.4
2002	0	0	—	(c)	—
	1	88	71-183	84.9[d]	—
	2	25	119-202	14.3[d]	—
	3	2	169-184	0.8[d]	—
South Fork Catherine Creek					
2000	0	3	59-69	6.1[a]	1.7-16.7
	1	35	86-167	71.4[a]	57.0-82.3
	2	7	123-177	14.3[a]	6.7-26.8
	3	4	159-198	8.1[a]	2.8-18.8
North Fork Catherine Creek					
2001	0	8	52-98	17.3[d]	—
	1	106	70-159	55.9[d]	—
	2	52	118-213	24.4[d]	—
	3	6	178-215	2.5[d]	—
Milk Creek					
2002	0	0	—	(c)	—
	1	80	74-175	70.7[d]	—
	2	42	108-212	26.7[d]	—
	3	6	151-230	2.6[d]	—

[a] Scales were taken from a random subset of fish captured for marking.
[b] The fork lengths of 13 of the 1,024 (1.3%) steelhead measured on Catherine Creek were less than 72 mm. It is likely that some of these fish are age-0.
[c] Age-0 fry were not targeted in our study although they were observed in the stream.
[d] Percentage of population in each age class was calculated using an age-length key.

Appendix Table B-4. Travel time to Lower Granite Dam of wild steelhead PIT-tagged at screw traps in spring and detected at the dam in the same migratory year.

Stream, km above Lower Granite Dam, migratory year	Number detected	Travel time (d)		
		Median	Min	Max
Upper Grande Ronde River, 397				
2000	73	31.2	6	78
2001	180	37.3	8	152
2002	86	20.6	5	91
Catherine Creek, 362				
2000	63	26.6	7	91
2001	88	33.2	7	74
2002	95	18.1	6	65
Lostine River, 274				
2000	166	11.7	4	66
2001	164	13.9	5	109
2002	72	25.9	3	65
Minam River, 245				
2001	240	16.6	5	110
2002	48	13.9	4	67

Appendix Table B-5. Detection dates at Lower Granite Dam of wild steelhead PIT-tagged at screw traps in the fall and spring and detected during the same migratory year. Numbers of fish detected were expanded for spillway flow to calculate the median detection date. Italics indicate that the median might be biased and reflect when fish were tagged.

Stream, migratory year	Season of tagging	Number tagged	Number detected	Detection dates		
				Median	First	Last
Upper Grande Ronde River						
2000	Fall	110	7	30 Apr	18 Apr	26 May
	Spring	462	73	*7 May*	31 Mar	28 Jun
2001	Fall	61	10	7 May	28 Apr	29 Jun
	Spring	475	180	*5 May*	26 Apr	28 Aug
2002	Fall	165	9	7 May	26 Apr	1 Jun
	Spring	543	86	*22 May*	14 Apr	25 Jun
Catherine Creek						
2000	Fall	989	43	20 Apr	2 Apr	29 Jun
	Spring	502	63	*6 May*	6 Apr	10 Jun
2001	Fall	561	66	6 May	18 Apr	12 Jun
	Spring	266	88	*14 May*	22 Apr	11 Jun
2002	Fall	723	10	12 May	16 Apr	17 Jun
	Spring	504	95	*22 May*	20 Apr	1 Jul
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
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

Appendix Table B-6. Detection dates at Lower Granite Dam of wild steelhead PIT-tagged in the upper rearing areas of Catherine Creek during summer and detected the following spring. Numbers of fish detected were expanded for spillway flow to calculate medians.

Year of tagging, stream	Number tagged	Number detected	Detection dates		
			Median	First	Last
2000					
Catherine Creek	412	19	8 May	25 Apr	25 Jun
North Fork Catherine Creek	117	2	7 May	1 May	12 May
South Fork Catherine Creek	225	5	6 May	2 May	14 May
Little Catherine Creek	415	0	—	—	—
Total for 2000	**1,169**	**26**	**8 May**	**25 Apr**	**25 Jun**
2001					
Catherine Creek	838	28	20 May	14 Apr	25 Jun
North Fork Catherine Creek	270	4	7 May	26 Apr	31 May
Total for 2001	**1,108**	**32**	**20 May**	**14 Apr**	**25 Jun**

Appendix Table B-7. Survival probabilities to Lower Granite Dam for steelhead PIT-tagged at screw traps during fall and spring.

Tag group, stream	MY tagged	Number tagged	Number detected: MY	Number detected: MY + 1	Number detected: MY + 2	Cumulative survival probability: Probability	SE	95% CI
Fall								
Catherine Creek								
	2000	989	73	14	0	0.108	0.013	0.085 – 0.136
	2001	561	67	0	–	0.120	0.014	0.095 – 0.149
	2002	723	30	–	–	0.069	0.022	0.040 – 0.152
Upper Grande Ronde River								
	2000	110	16	0	0	0.227	0.087	0.118 – 0.650
	2001	61	12	0	–	0.223	0.063	0.122 – 0.398
	2002	165	21	–	–	0.185	0.055	0.108 – 0.387
Lostine River								
	2000	777	157	11	0	0.271	0.022	0.231 – 0.320
	2001	421	17	18	–	0.098	0.018	0.068 – 0.141
	2002	837	106	–	–	0.154	0.017	0.124 – 0.194
Minam River								
	2001	32	7	2	–	0.294	0.084	0.152 – 0.485
	2002	262	11	–	–	0.134	0.113	0.041 – 1.971
Spring (FL ≥ 115 mm)								
Catherine Creek								
	2000	305	103	2	0	0.480	0.054	0.388 – 0.608
	2001	248	96	2	–	0.404	0.032	0.342 – 0.468
	2002	504	212	–	–	0.532	0.038	0.465 – 0.615
Upper Grande Ronde River								
	2000	324	99	1	0	0.394	0.041	0.329 – 0.487
	2001	465	196	5	–	0.467	0.026	0.417 – 0.521
	2002	543	192	–	–	0.450	0.035	0.387 – 0.529
Lostine River								
	2000	442	234	4	0	0.640	0.034	0.576 – 0.711
	2001	323	182	16	–	0.643	0.029	0.585 – 0.700
	2002	351	171	–	–	0.625	0.050	0.538 – 0.739

Appendix Table B-7. Continued.

Tag group, stream	MY tagged	Number tagged	Number detected			Cumulative survival probability		
			MY	MY + 1	MY + 2	Probability	SE	95% CI
Spring (FL ≥ 115 mm)								
Minam River								
	2001	442	269	8	–	0.654	0.025	0.605 – 0.702
	2002	197	108	–	–	0.722	0.073	0.598 – 0.898
Spring (FL <115 mm)								
Catherine Creek								
	2000	189	0	10	1	0.060	0.018	0.032 – 0.103
	2001	19	1	2	–	NA	–	– – –
	2002	6	0	–	–	0.000	–	– – –
Upper Grande Ronde River								
	2000	129	0	5	0	0.039	0.017	0 – 0.314
	2001	7	0	0	–	0.000		– – –
	2002	17	2	–	–	0.118	0.078	– – –
Lostine River								
	2000	84	0	9	0	0.109	0.034	0.054 – 0.188
	2001	21	1	1	–	NA	–	– – –
	2002	0	0	–	–	–	–	– – –
Minam River								
	2001	9	0	0	–	0.000	–	– – –
	2002	1	0	–	–	0.000	–	– – –

Appendix Table B-8. Fork lengths of steelhead PIT-tagged at screw traps on Catherine Creek and the upper Grande Ronde, Lostine, and Minam rivers in the fall (early migrants), summarized by dam detection history.

Stream, year tagged	Year detected	*N*	Length at tagging (mm)				
					Percentile		
			Median	Min	25th	75th	Max
Upper Grande Ronde River							
1999	–[a]	108	132.5	71	121.5	148	205
2000	–[a]	60	124	86	100.5	144.5	180
	2001	12	152	115	133.5	160.5	180
2001	–[a]	165	115	62	79.8	130	193
	2002	21	130	110	119.8	150	163
Catherine Creek							
1999	–[a]	986	101	60	76	142	200
	2000	73	148	67	132.8	162	195
	2001	14	77	61	73	86	118
2000	–[a]	561	136	76	124	150.3	204
	2001	67	139	102	126.3	151.8	195
2001	–[a]	723	85	62	75	124	193
	2002	30	127.5	78	91	136	170
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	145.8	177.5	212
	2002	18	85.5	65	80	89	106
2001	–[a]	824	100	60	85	155	262
	2002	105	155	87	140	168.5	205

[a] Data represents the whole tag group, regardless of detection history.

Appendix Table B-8. Continued.

Stream, year tagged	Year detected	N	Length at tagging (mm)				
					Percentile		
			Median	Min	25th	75th	Max
Minam River							
2000	–[a]	32	121.5	58	69	152.5	218
	2001	7	147	114	126	154.5	183
	2002	2	67.5	63	63	72	72
2001	–[a]	262	66	55	61	117	318
	2002	11	132	120	123.5	146.8	185

Appendix Table B-9. Fork lengths of steelhead PIT-tagged at screw traps on Catherine Creek and the upper Grande Ronde, Lostine, and Minam rivers in the spring (late migrants), summarized by dam detection history.

Stream, year tagged	Year detected	*N*	Length at tagging (mm)				
					Percentile		
			Median	Min	25th	75th	Max
Upper Grande Ronde River							
2000	–[a]	453	133	71	107.8	152	225
	2000	99	155	115	139.3	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	149.8	152
2002	–[a]	543	150	115	135	164	216
	2002	192	155	115	144	170	209
Catherine Creek							
2000	–[a]	494	131.5	61	86	150	210
	2000	103	152	120	143	166.8	210
	2001	12	78.5	70	73	103.5	125
	2002	1	87	87	–	–	87
2001[b]	–[a]	247	142	115	131	154	190
	2001	96	150	115	138	161	190
	2002	2	119.5	115	115	124	124
2002[b]	–[a]	503	152	115	139	163.8	260
	2002	212	155.5	115	143.5	166	208
Lostine River							
2000	–[a]	526	160	66	145	175	329
	2000	234	168	123	157	179	236
	2001	13	89	66	79.5	127.5	158
2001[b]	–[a]	323	163	115	148	180	292
	2001	182	171.5	121	157	185	292
	2002	16	140.5	115	120.5	156	160
2002[b]	–[a]	351	158	115	141	177.8	326
	2002	171	163	115	152	179.8	244

[a] Data represents the whole tag group, regardless of detection history.
[b] Only steelhead with fork length exceeding 114 mm were tagged.

Appendix Table B-9. Continued.

Stream, year tagged	Year detected	*N*	Length at tagging (mm)				
					Percentile		
			Median	Min	25th	75th	Max
Minam River							
2001 [b]	– [a]	442	160	115	144	177	227
	2001	269	167	124	151	183	227
	2002	8	136	118	124.5	151	169
2002 [b]	– [a]	197	158	115	147	179	219
	2002	108	164	119	151	185	219

Appendix Table B-10. Fork lengths of steelhead PIT-tagged upstream of the screw trap on Catherine Creek and its tributaries during summer 2000 and 2001, summarized by migration history.

	Length at tagging (mm)					
				Percentile		
Tag group, migration history	*N*	Median	Min	25th	75th	Max
PIT-tagged summer 2000						
All PIT-tagged	1,163	113	59	90.0	136.8	263
Recaptured in trap, fall 2000	21	124	83	111.8	135.8	152
Recaptured in trap, spring 2001	5	125	88	106.0	140.5	142
Migrated past trap before summer 2001	51	127	83	113.0	138.8	170
Detected at dams, spring 2001	29	130	85	113.8	142.5	170
Remaining upstream, summer 2001	12	92	63	83.5	106.0	136
Migrated past trap between summer 2001 and summer 2002	4	92.5	92	92.0	114.5	136
Remaining upstream, summer 2002	3	117	92	98.3	118.5	119
Detected at dams, spring 2002	15	92	72	78.0	103.0	133
PIT-tagged summer 2001						
All PIT-tagged	1,108	111.5	63	97.0	130.0	221
Recaptured in trap, fall 2001	45	118	99	109.8	126.3	147
Recaptured in trap, spring 2002	9	129	97	122.3	142.3	168
Migrated past trap before summer 2002	118	123	96	112.0	135.0	168
Detected at dams, spring 2002	73	128	96	112.0	137.0	161
Remaining upstream, summer 2002	14	94.5	68	86.0	105.0	177

Appendix Table B-11. Growth rates of steelhead tagged during summer upstream of the Catherine Creek screw trap and recaptured the following fall, spring, and summer.

Year of tagging	Season, year, location of recapture	*n*	Recapture dates	Growth rate (mm/d)	
				Mean	95% CI
2000	Fall 2000, trap	20	18 Sep – 5 Dec 2000	0.173	± 0.039
2000	Spring 2001, trap	5	21 Mar – 10 Apr 2001	0.062	± 0.048
2000	Summer 2001, upstream	1	26 Jun 2001	0.073	–
2001	Fall 2001, trap	35	14 Sep – 17 Dec	0.122	± 0.024
2001	Spring 2002, trap	8	14 Mar – 14 May	0.082	± 0.034
2001	Summer 2002, upstream	4	18 Jul – 25 Jul	0.114	± 0.036

APPENDIX C

Stream Habitat Survey Data

Appendix Table C-1. Location and description of the reaches surveyed on the main-stem Catherine Creek, North Fork Catherine Creek, and South Fork Catherine Creek during the summer 2002.

Reach	Description
	Catherine Creek
1	Starting UTM (11T 0434100 5005067). Began approximately 1600 m (1 mile) SE of the town of Union where Highway 203 veers away from the creek. Reach 1 extended 1,784 m to just upstream (400 m) of the fish weir operated by CTUIR. This reach was characterized as having a broad valley floor with constraining terraces. The stream channel was constrained by alternating hill slope and terraces. Dominant streamside vegetation was deciduous trees (~30-50 cm DBH) with shrubs as the sub-dominant vegetation. Land use was predominantly heavy grazing.
2	Starting UTM (11T 0435104 5004013). Began approximately 400 m upstream from the fish weir and extended 1,235 m upstream to the property boundary with the Southern Cross ranch where survey access was denied. The valley was broad with multiple terraces and the stream channel was predominantly single and unconstrained. Dominant streamside vegetation was mixed conifer and deciduous. Land use was predominantly heavy grazing.
3	Starting UTM (11T 0435660 5003240). Access to this reach was denied. Ownership was the Southern Cross ranch. The reach extended approximately 1,440 m with an overall gradient of 0.9% as estimated from U.S. Geodetic Survey maps. Stream shading and substrate composition were estimated by taking the average from 15 habitat units directly upstream and downstream of the reach (n = 30).
4	Starting UTM (11T 0436485 5002482). Began at the upstream boundary of the Southern Cross Ranch and extended upstream 1,381m to where the valley constricts. Valley form was broad with constraining terraces. The stream channel was constrained by terraces only (no hill slope). Predominant streamside vegetation was deciduous trees (~30-50 cm DBH). Land use was predominantly heavy grazing.
5	Starting UTM (11T 0437245 5001737). Began where stream encounters the hillside and extended 1,242 m upstream to where the valley constricts. Valley form was broad with constraining terraces. Channel form was constrained by alternating hill slope and high terraces. Land use was predominantly heavy grazing
6	Starting UTM (11T 0438101 5000720). Began at end of the broad valley and extended 2,947 m to Badger Flat bridge crossing. This reach was characterized as having a narrow valley floor with an open V-shape. The channel was constrained by hill slopes. Streamside vegetation was dominated by mixed conifer and deciduous trees (~30-50 cm DBH). Land use was predominantly light grazing.
7	Starting UTM (11T 0440297 4999882). Began at Badger Flat bridge and extended 1,545 m to the boundary of the Catherine Creek State Park. The valley floor was broad with multiple terraces that did not always constrain the channel. Streamside vegetation was dominated by mixed conifer and deciduous trees (~30-50 cm DBH). Land use was predominantly light grazing.

Appendix Table C-1. Continued.

Reach	Description
	Catherine Creek (continued)
8	Starting UTM (11T 0441522 4999916). Began at the Catherine Creek State Park boundary and extended 2,567 m to the tributary junction of Little Catherine Creek. Valley form was broad with the channel constrained by alternating hill slope and terraces. Streamside vegetation was dominated by mixed conifer and deciduous trees (~30-50sm DBH).
9	Starting UTM (11T 0443383 4998552). Reach 9 began at the confluence of Little Catherine Creek and extended 3,518 m to just upstream of the junction of Catherine Creek Lane and Highway 203. This reach was characterized as having a broad valley floor with constraining terraces. The stream channel was constrained by terraces. Streamside vegetation was predominantly conifer trees (~30-50 cm DBH). Land use was predominantly light grazing.
10	Starting UTM (11T 0445370 4996606). Reach 10 began approximately 400 m upstream from the Highway 203/Catherine Creek Lane road junction and extended 1,916 m upstream. Reach 10 had a broad valley floor with constraining terraces. The stream channel was constrained by alternating terraces and hill slopes. Predominant streamside vegetation was mixed conifer and deciduous trees (~30-50 cm DBH).
11	Starting UTM (11T 0446760 4995900). Reach 11 extended 2,759m to the junction with the South Fork Catherine Creek. Valley form was broad with multiple terraces. The stream was unconstrained with some anastomosing channels. Streamside vegetation was predominantly conifers (~30-50 cm DBH). Land use was predominantly light grazing.
	North Fork Catherine Creek
1	Starting UTM (11T 0449166 4996302). Reach 1 began at its confluence and extended approximately 538 m upstream to the beginning of U.S. Forest Service property boundary. Valley floor was broad with multiple terraces. Channel form was unconstrained and braided. Streamside vegetation was mixed conifer and deciduous (~15-30 cm DBH). Land use was predominantly heavy grazing.
2	Starting UTM (11T 0449560 4996560). Reach 2 began at the U.S. Forest Service boundary and extended approximately 4,093 m upstream to the confluence with the Middle Fork Catherine Creek. Channel from was constrained by alternating hill slope and high terraces. Predominant streamside vegetation was conifers (~30-50 cm DBH).

Appendix Table C-1. Continued.

Reach	Description
	South Fork Catherine Creek
1	Starting UTM (11T 0449166 4996302). Reach 1 began at its confluence and extended approximately 553 m to start of the U.S. Forest Service boundary. Valley floor was broad with multiple terraces. Channel form was predominately unconstrained single channel. Predominant streamside vegetation was conifer (~30-50 cm DBH) and land use was predominantly heavy grazing.
2	Starting UTM (11T 0449540 4996570). Reach 2 began at the U.S. Forest Service boundary and extended approximately 1,410 m upstream to a probable adult Chinook salmon passage barrier (debris dam with 1.5 m step). Channel from was constrained by alternating hill slope and high terraces. Predominant streamside vegetation was conifers (~30-50 cm DBH).