FISH RESEARCH PROJECT OREGON INVESTIGATIONS INTO THE EARLY LIFE HISTORY OF NATURALLY PRODUCED SPRING CHINOOK SALMON IN THE GRANDE RONDE RIVER BASIN

Project Period: 1 September 1998 to 31 August 1999

Annual Progress Report

DOE/BP-33299-6

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views of this report are the author's and do not necessarily represent the views of BPA.

This document should be cited as follows:

Jonasson, Brian C., J. Vincent Tranquilli, Paul Sankovich, Erick S. Van Dyke, MaryLouise Keefe, Richard W. Carmichael - Oregon Department of Fish and Wildlife, Fish Research Project Oregon Investigations Into The Early Life History Of Naturally Produced Spring Chinook Salmon In The Grande Ronde River Basin Annual Progress Report Project Period: 1 September 1998 to 31 August 1999, Report to Bonneville Power Administration, Contract No. 1994B133299, Project No. 199202604, 61 electronic pages (BPA Report DOE/BP-33299-6)

This report and other BPA Fish and Wildlife Publications are available on the Internet at:

http://www.efw.bpa.gov/cgi-bin/efw/FW/publications.cgi

For other information on electronic documents or other printed media, contact or write to:

Bonneville Power Administration
Environment, Fish and Wildlife Division
P.O. Box 3621
905 N.E. 11th Avenue
Portland, OR 97208-3621

Please include title, author, and DOE/BP number in the request.

FISH RESEARCH PROJECT
OREGON

INVESTIGATIONS INTO THE EARLY LIFE HISTORY OF NATURALLY PRODUCED SPRING CHINOOK SALMON IN THE GRANDE RONDE RIVER BASIN

ANNUAL PROGRESS REPORT

Project Period: 1 September 1998 to 31 August 1999

Prepared by:

Brian C. Jonasson
J. Vincent Tranquilli
Paul Sankovich
Erick S. Van Dyke
MaryLouise Keefe
Richard W. Carmichael

Oregon Department of Fish and Wildlife
La Grande, OR

Funded by

U. S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621

Project Number 92-026-04
Contract Number 94B133299

ABSTRACT

We determined migration timing and abundance of juvenile spring chinook salmon from three populations in the Grande Ronde River basin. We estimated 13,180 juvenile chinook salmon left upper rearing areas of the Grande Ronde River from July 1998 to June 1999; approximately 0.2% of the migrants left in summer, 18% in fall and 82% in spring. We estimated 15,949 juvenile chinook salmon left upper rearing areas of Catherine Creek from July 1998 to June 1999; approximately 0.2% of the migrants left in summer, 57% in fall, 2% in winter, and 41% in spring. We estimated 14,537 juvenile chinook salmon left the Grande Ronde Valley, located below the upper rearing areas in Catherine Creek and the Grande Ronde River, from October 1998 to June 1999; approximately 99% of the migrants left in spring. We estimated 31,113 juvenile chinook salmon left upper rearing areas of the Lostine River from July 1998 to June 1999; approximately 4% of the migrants left in summer, 57% in fall, 3% in winter, and 36% in spring. We estimated 42,705 juvenile spring chinook salmon left the Wallowa Valley, located below the mouth of the Lostine River, from August 1998 to June 1999; approximately 46% of the migrants left in fall, 6% in winter, and 47% in spring.

Juvenile chinook salmon PIT-tagged on the upper Grande Ronde River were detected at Lower Granite Dam from 31 March to 20 June 1999, with a median passage date of 5 May. PIT-tagged salmon from Catherine Creek were detected at Lower Granite Dam from 19 April to 9 July 1999, with a median passage date of 24 May. PIT-tagged salmon from the Lostine River were detected at Lower Granite Dam from 31 March through 8 July 1999, with a median passage date of 4 May. Juveniles tagged as they left the upper rearing areas of the Grande Ronde River in fall and that overwintered in areas downstream were detected in the hydrosystem at a higher rate than fish tagged during winter in the upper rearing areas, indicating a higher overwinter survival in the downstream areas. Juveniles tagged as they left the upper rearing areas of Catherine Creek in fall and that overwintered in areas downstream were detected in the hydrosystem at a lower rate than fish tagged during winter in the upper rearing areas, indicating a higher overwinter survival in the upper rearing areas. Juveniles tagged as they left the upper rearing areas of the Lostine River in fall and that overwintered in areas downstream were detected in the hydrosystem at a similar rate to fish tagged during winter in the upper rearing areas, indicating similar overwinter survival in the upstream and downstream areas.

Chinook salmon parr were generally associated with low velocity habitat types, that is pools, during both winter and summer in the Lostine River.

In summer 1998, we PIT-tagged parr on Catherine Creek and the Imnaha, Lostine, and Minam rivers in order to monitor their subsequent migration as smolts through the Snake and Columbia River hydrosystem. We found significant differences among populations in smolt migration timing at Lower Granite Dam in 1999. Fish from Catherine Creek and the Imnaha, Lostine, and Minam rivers were detected in the hydrosystem at rates of 14.1, 14.2, 17.2, and 17.1%, respectively.

In 1999, we estimated parr abundance and the number of parr produced per redd in Catherine Creek and the Lostine River. We estimated that 731 mature, age 1+ male parr, 22,505 immature, age 0+ parr, and 4 mature age 0+ parr were present in Catherine Creek in August. An average of 16 mature, age 1+ male parr and 662 immature, age 0+ parr were produced from each redd constructed in 1997 and 1998, respectively, for an estimated egg to parr survival of 15.2% for the 1998 brood year spring chinook salmon in Catherine Creek. We estimated that 28,084

immature, age 0+ parr were present in the Lostine River in August. We were unable to estimate the abundance of mature male parr in the Lostine River in August. An average of 1,003 immature, age 0+ parr were produced from each redd constructed in 1998 for an estimated egg to parr survival of 23.1%. For every anadromous female spawner in Catherine Creek in 1998, there were an estimated 16 mature male parr.

CONTENTS

FIGURES

TABLES

TABLES (continued)

Number | Page

EXECUTIVE SUMMARY

Objectives

1. Document the annual in-basin migration patterns, including abundance, timing, and duration, of juvenile spring chinook salmon in the upper Grande Ronde River, Catherine Creek, and the Lostine River.

2. Estimate and compare survival indices from tagging to smolt detection at mainstem Snake and Columbia river dams for juveniles that leave upper river rearing areas at different times of the year.

3. Determine summer and winter habitat utilization and preference of juvenile spring chinook salmon in the Lostine River.

4. Estimate and compare survival indices at mainstem Columbia and Snake River dams for migrants from four local, natural populations in the Grande Ronde River and Imnaha River basins.

5. Document the annual migration patterns for spring chinook salmon juveniles from four local, natural populations in the Grande Ronde River and Imnaha River basins.

6. Determine survival to parr stage for spring chinook salmon in two local, natural populations in the Grande Ronde River Basin.

7. Investigate the significance of alternate life history strategies of spring chinook salmon in two local, natural populations in the Grande Ronde River Basin.

Accomplishments

We accomplished all of our objectives in 1999.

Findings

In the Grande Ronde River Basin, migration timing and abundance of juvenile spring chinook salmon was determined by operating rotary screw traps in both upper and lower river reaches of the Grande Ronde River and Wallowa River valleys. At the upper Grande Ronde River trap, 4,644 juvenile chinook salmon were captured from 5 July 1998 through 28 June 1999. The catch was expanded to an estimate of 13,180 migrants. Approximately 0.2% of the migrant population left upper rearing areas in Grande Ronde River during summer, 18% in fall, and 82% in spring. At the Catherine Creek trap, 6,433 juvenile chinook salmon were captured from 2 July through 23 June 1999 and the catch was expanded to an estimate of 15,949 migrants. Approximately 0.2% of the migrant population left upper rearing areas in Catherine Creek during summer, 57% in fall, 2% in winter, and 41% in spring. At the lower Grande Ronde River trap, 1,844 juvenile chinook salmon were captured as they left the Grande Ronde Valley from 25 November 1998 through 28 June 1999. The catch was expanded to an estimate of 14,537 migrants. Approximately 99% of the migrant population left the Grande Ronde Valley in spring. At the Lostine River trap, 10,705 juvenile chinook salmon were captured from 22 July 1998 through 7 June 1999. The catch was expanded to an estimate of 31,113 migrants. Approximately 4% of the migrant population left upper rearing areas in Lostine River during summer, 57% in fall, 3% in winter, and 36% in spring. At the Wallowa River trap, 6,359 juvenile spring chinook salmon were captured as they left the Wallowa Valley from 19 August 1998 through 12 June 1999. The catch was expanded to an estimate of 42,705 migrants. Approximately 46% of the migrant population left the Wallowa Valley in fall, 6% in winter, and 47% in spring.

Passive integrated transponders (PIT tags) were used to individually mark fish captured in traps and make subsequent observations without sacrificing the fish. Juvenile chinook salmon PIT-tagged on the upper Grande Ronde River were detected at Lower Granite Dam from 31 March to 20 June 1999, with a median passage date of 5 May. Cumulative mainstem dam detection rates for the different tag groups ranged from 10.0 to 50.5%. Fish tagged during spring were detected at the highest rate. The detection rate of fish that were tagged as they left the upper rearing area in fall and that overwintered in areas downstream (26.0%) was over twice that of fish tagged during winter in upper rearing areas (10.0%). PIT-tagged salmon from Catherine Creek were detected at Lower Granite Dam from 19 April to 9 July 1999, with a median passage date of 24 May. Cumulative mainstem dam detection rates for the different tag groups ranged from 17.4 to 36.1%. Fish tagged during spring were detected at the highest rate. Juvenile salmon tagged as they left the upper rearing area in fall and overwintered in areas downstream were detected at 17.4%, a lower rate than fish tagged during winter in the upper rearing area at 23.5%. Lostine River fish were detected at Lower Granite Dam from 31 March through 8 July 1999, with a median passage date of 4 May. Cumulative mainstem dam detection rates for the different tag groups ranged from 28.3 to 60.5%, with fish tagged during spring detected at the highest rate. Fish tagged as they left the upper rearing area in fall and that overwintered in areas downstream were detected at a rate similar to fish tagged during winter in upper rearing areas, 33.3% and 28.3%, respectively.

Chinook salmon parr were generally associated with low velocity habitat types during both winter and summer habitat surveys. Parr were found in the greatest abundance in dammed, alcove, and backwater pools during winter, and alcove and backwater pools during summer. During winter habitat surveys, parr were observed from Pole Bridge Picnic Area to the mouth (rkm 23-0). During summer habitat surveys, parr were observed rearing from Turkey Flat Campground to Williamson Campground (rkm 39-30) and from the Pole Bridge Picnic Area to the mouth.

Chinook salmon parr that were collected by seining and PIT-tagged on Catherine Creek and the Imnaha, Lostine, and Minam rivers in summer 1998 were detected at Lower Granite Dam from 29 March to 26 June 1999. Median dates of migration ranged from 29 April (Minam River) to 29 May (Catherine Creek), and migration timing differed significantly among populations ($P<0.001$). Cumulative detection rates (i.e., first-time detections at all dams outfitted with PIT tag monitoring facilities) varied little among populations, ranging from 14.1%

(Catherine Creek) to 17.2% (Lostine River).

During the 1999 migration, there were no detections of any age 2+ smolts that had been PIT-tagged as parr on Catherine Creek and the Imnaha and Minam rivers in 1997. We estimated previously that there were no immature, age 1+ parr (i.e., fish that would presumably become age 2+ smolts) in Catherine Creek in summer 1998 (Tranquilli et al. 1998).

Using mark-and-recapture and scale-aging techniques, we determined that 731 mature, age 1+ parr; no immature, age 1+ parr; 22,505 immature, age 0+ parr; and 4 mature, age 0+ parr resided in Catherine Creek in August 1999. An average of 16 mature and no immature, age 1+ parr were produced from each redd constructed in 1997. An average of 662 immature and 0.1 mature, age 0+ parr were produced from each redd constructed in 1998 for an egg to parr survival rate of 15.2%. We estimated that 5.5% of the immature, age 0+ parr inhabiting Catherine Creek in August 1998 matured and were present in Catherine Creek in August 1999. There were an estimated 19 mature male parr for every anadromous female spawner in Catherine Creek in 1999.

An estimated 28,084 immature, age 0+ parr inhabited the Lostine River in August 1999. We were unable to estimate the abundance of mature parr, but their numbers were probably relatively small: we captured only 25 mature parr during nine days of sampling. We estimated that an average of 1,003 immature and no mature, age 0+ parr were produced from each redd constructed in the Lostine River in 1998 for an egg to parr survival rate of 23.1%. An average of at least 0.5 mature, age 1+ parr and no immature, age 1+ parr were produced from each redd constructed in 1997. At least 0.06% of the immature, age 0+ parr estimated to be present in the Lostine River in 1998 matured and were present in the Lostine River in August 1999. There were a minimum of 0.5 mature male parr for every anadromous female spawner in the Lostine River in 1999.

Management Implications and Recommendations

The Grande Ronde River Valley provides more than a migration corridor for juvenile chinook salmon. Although the proportion varies annually, large numbers of juveniles leave upper rearing areas in Catherine Creek and the upper Grande Ronde River in fall and overwinter in the Grande Ronde River Valley. Four years of data for the upper Grande Ronde population indicate salmon that overwinter in the valley survive at a higher rate than salmon that overwinter in upper rearing areas, yet a larger proportion of the migrants overwinter in the upper rearing areas. Enhancing habitat conditions to improve overwinter survival in the upper Grande Ronde River should be given priority.

Juvenile chinook salmon that leave upper rearing areas in Catherine Creek and the upper Grande Ronde and Lostine rivers during fall overwinter in lower river reaches and arrive at Lower Granite Dam earlier in spring than juveniles that overwinter in upper rearing areas. As environmental conditions in the Snake and Columbia rivers vary throughout the smolt migration, survival may vary among fish exhibiting the different life histories. In general, fall-migrating salmon have been detected at mainstem dams at rates similar to or higher than those for salmon that overwinter in upper rearing areas. However, in some years detection rates for salmon that overwinter in upper areas have been greater for an individual population. These differences point out the need to maintain the diversity of life history strategies observed in the Grande Ronde River Basin. What may be a successful strategy one year may not be as successful in another year under different conditions.

Juvenile chinook salmon use the lower reaches of non-natal tributaries in addition to the spawning streams for rearing both in the upper Grande Ronde River and Catherine Creek. These non-natal tributaries as well as spawning streams should be protected and enhanced. Juvenile chinook salmon are more abundant in pools than glides or riffles during both summer and winter. Maintenance of existing pool habitat and increasing habitat diversity should be a component of habitat management for chinook salmon populations in northeast Oregon streams.

The differences that exist between local populations and life history types in migration timing at Lower Granite Dam demonstrate the need to manage the hydrosystem so as to maximize survival throughout the entire migratory period of Snake River spring/summer chinook salmon smolts. Maintenance of the remaining populations in the Grande Ronde River and Imnaha River basins, their specific life histories, and any unique genetic resources they possess is critical to the continued persistence of chinook salmon in northeast Oregon and elsewhere in the Snake River Basin.

The information we have gathered thus far on the occurrence of age 2+ smolts indicates this life history is rare among northeast Oregon 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 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.

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. Historically, the Grande Ronde River Basin 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. In addition, spring chinook salmon populations in the Grande Ronde River Basin have diminished in size and are substantially depressed from historic levels. It is estimated that prior to the construction of the Snake and Columbia river dams, more than 20,000 adult spring chinook salmon returned to spawn in the Grande Ronde River Basin annually (ODFW 1990). A spawning escapement of 12,200 adults was estimated for the basin in 1957 (USACE 1975). Recent population estimates vary from year to year, but remain at least an order of magnitude lower than historic estimates. In 1998, estimated escapement for the basin was 759 adults (253 redds x 3.0 adults/redd). The range of spring chinook salmon spawning in the Grande Ronde River Basin also has been constricted. Historically, spring chinook salmon were distributed among 21 streams, yet today most production is limited to only six tributaries, including the upper Grande Ronde River, Catherine Creek, Lookingglass Creek, the Minam River, the Lostine River, and the Wenaha River (ODFW 1990).

Numerous factors are thought to have contributed to the decline of spring chinook salmon in the Snake River and its tributaries. These factors include juvenile and adult passage problems at mainstem 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 to be degraded (USFS 1992). Habitat problems throughout the Grande Ronde River Basin (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.

Precipitous declines in Snake River spring chinook salmon populations resulted in these stocks, including Grande Ronde River stocks, being listed as threatened under the Endangered Species Act (October 1992). 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). In addition, knowledge of juvenile migration patterns, smolt production and survival, and juvenile winter rearing habitat is needed within the basin. We currently are expanding our efforts to include life stage specific survival estimates (egg-to-parr, parr-to-smolt, and smolt-to-adult), and an evaluation of the importance and frequency at which alternative life history tactics are utilized by spring chinook salmon populations in northeast Oregon.

Both historic and recent estimates of juvenile production in the basin are lacking. However, given the dramatic decline in adult returns to the basin and the extent of habitat degradation, it is reasonable to assume that juvenile production is lower now than in the past. Recent parr-to-smolt survival estimates for populations in the Grande Ronde River Basin range from 8.9% to 22.1% (Walters et al. 1993, 1994; Sankovich et al. 1995). These estimates are based on data from parr that were individually tagged with passive integrated transponder (PIT) tags in late summer and were detected at mainstem Snake and Columbia river dams. Before this study was initiated, it was not clear how much mortality occurred during the smolt migration and how much occurred during fall and winter rearing.

The chinook salmon smolt migration from the Grande Ronde basin 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; and Tranquilli et al. 1998) indicate a substantial number of juveniles move out of upper rearing areas during fall and overwinter downstream within the Grande Ronde basin. The proportion of fall migrants in each population, and their survival to Snake and Columbia river dams, varies among years and streams.

Juveniles 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). Therefore winter rearing habitat quantity and quality in the Grande Ronde valley may be important factors limiting chinook salmon smolt production in the Grande Ronde River.

Numerous enhancement activities have been undertaken in an effort to recover spring chinook salmon populations in the Grande Ronde River Basin. 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 in the Grande Ronde River Basin. In addition to our investigations into the in-basin migration timing and abundance of juvenile chinook salmon and their seasonal habitat preference, during the past year we continued work on life-stage-specific survival estimates and the significance of alternative early life histories. The objectives of this study were to: 1) document the annual in-basin migration patterns, including abundance, timing, and duration, of juvenile spring chinook salmon in the upper Grande Ronde River, Catherine Creek, and the Lostine River, 2) estimate and compare survival indices from tagging to smolt detection at mainstem Snake and Columbia River dams for juveniles that leave upper river rearing areas at different times of the year, 3) determine summer and winter habitat utilization and preference of juvenile spring chinook salmon in the upper Grande Ronde River, Catherine Creek, and the Lostine River, 4) estimate and compare smolt detection rates at mainstem Columbia and Snake River dams for migrants from several local, natural populations in the Grande Ronde River and Imnaha River basins, 5) document the annual migration patterns for spring chinook salmon juveniles from several local, natural populations in the Grande Ronde River and Imnaha River basins, 6) determine survival to parr stage for spring chinook salmon in two local, natural populations in the Grande Ronde River Basin, and 7) investigate the significance of alternate life history strategies (precocious maturation in males and seaward migration at age 2+) of spring chinook salmon in two local, natural populations in the Grande Ronde River Basin.

METHODS

In this report, we assume all juvenile chinook salmon captured in traps were downstream "migrants". The term "migration 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 chinook salmon referred to in this report were naturally produced.

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

We used mark-and-recapture and scale-aging techniques to estimate the abundance of immature and mature (male) parr, by age class, in Catherine Creek and the Lostine River in August 1999. We captured, marked, and released parr during the first week in August on Catherine Creek and the second week in August on the Lostine River. We conducted subsequent sampling during the third week in August on Catherine Creek and the fourth week in August on the Lostine River. Our goal on each stream was to mark 1,000 immature parr and as many mature parr as we could capture in 5 d (not to exceed 1,000 parr). During subsequent sampling, our goal was to capture at least 500 immature parr and as many mature parr as possible in 5 d (not to exceed 500 parr). We collected scales from a haphazard sample of approximately 200 immature parr and all but a small portion of the mature parr captured in each stream. We identified mature parr based on body morphology and coloration. Mature parr tend to be longer, deeper-bodied, and more yellowish in color (laterally) than immature parr.

We collected parr for marking either by herding them (while snorkeling) into a seine set perpendicular to the stream flow or by beach seining. 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. The live cages were located near designated marking stations. On both Catherine Creek and the Lostine River, parr were collected (and marked and released) within a reach of stream beginning upstream from the upper-most redd observed in 1998 and ending at a rotary screw trap (see Figure 1 for rotary screw trap locations). These reaches were 22 km (Catherine Creek) and 41 km (Lostine River) in length.

Prior to being marked, fish were anesthetized in an aerated bath containing 40 to 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 Alcian Blue dye. The dye was applied with a tattoo machine, slightly above the anal fin of each fish. Immature parr that were 55 mm FL or greater were either dye-marked or PIT-tagged. PIT tags were injected manually with a modified hypodermic syringe as described by Prentice et al. (1986, 1990) and Mathews et al. (1990, 1992). Syringes were disinfected for 10 min in 70% isopropyl alcohol 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 dye-marked, immature parr. All fish were handled and marked at stream temperatures of 15°C or less and released in the area of capture on the day they were processed.

During subsequent sampling, we collected parr from five randomly selected reaches of approximately 1.6 km each on Catherine Creek and the Lostine River. We used the seining methods outlined above to capture parr. Each fish was inspected for marks and maturity status, and the numbers of mature and immature parr that were unmarked, dye-marked, PIT-tagged, or that had lost their PIT tag (i.e., no tag could be detected, but a PIT-tagging scar was evident) were recorded.

We used the adjusted Petersen estimate (Ricker 1975) to determine the abundance of immature and mature parr in Catherine Creek and the Lostine River. Ninety-five percent confidence intervals were obtained using equation (3.7) and values from Appendix II in Ricker (1975). Estimates of the age composition of groups of immature and mature parr were based on results from scale analyses. Scale impressions were made on acetate slides and inspected on a microfiche reader at 42x magnification. We counted annuli to determine whether parr were age 0+ (no annulus) or 1+(one annulus). We calculated the proportion of immature and mature parr at each age and obtained 95% confidence intervals from table P in Rohlf and Sokal (1995).

Using abundance and age composition estimates from August 1998 (Tranquilli et al. 1998) and 1999, and redd count data from 1997 and 1998, we determined the following regarding chinook salmon populations in Catherine Creek and the Lostine River: 1) the abundance of immature and mature parr, by age class, in August 1999, 2) the percentage of immature, age 0+ parr present in each stream in August 1998 that either matured or did not mature and were present in August 1999, 3) the average number of mature and immature, age 0+ parr (in 1999) produced from each redd constructed in 1998, and 4) the average number of mature and immature age 1+ parr (in 1999) produced from each redd constructed in 1997. We estimated rates of egg-to-parr survival, based on an estimated fecundity of 4,348 eggs/female (mean fecundity of 12 female spring chinook salmon captured at the Lostine River weir and spawned at Lookingglass Hatchery in 1997 and 2000; ODFW files) and the number of redds counted above the trap sites on Catherine Creek and the Lostine River.

In-Basin Migration Timing and Abundance

The seasonal migration timing and abundance of juvenile spring chinook salmon in the upper Grande Ronde River, Catherine Creek and the Lostine River were determined by operating rotary screw traps year round. In the Grande Ronde River subbasin, 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 (Figure 1). A second trap was located in Catherine Creek below spawning and upper rearing areas near the town of Union at rkm 32. Catherine Creek enters the Grande Ronde River at rkm 225 and is a major tributary for spring chinook salmon spawning and rearing. A third rotary screw trap was located in the Grande Ronde River at the lower end of the Grande Ronde Valley near the town of Elgin at rkm 164. At our upper Grande Ronde River trap site, a 1.5 m diameter trap was fished from 2 July through 6 December 1998, and 19 February through 30 June 1999. A 1.5 m diameter trap was fished at the Catherine Creek site from 1 July through 31 December 1998, and 12 January through 30 June 1999. At our lower Grande Ronde River trap site, a 1.5 m diameter trap was fished from 28 September through 30 December 1998. We fished a 2.4 m diameter trap at this site from 25 January through 30 June 1999.

In the Wallowa River subbasin, one rotary screw trap was located below the majority of spawning and rearing areas on the Lostine River near the town of Lostine at rkm 3 (Figure 1). A 1.5 m diameter trap was fished at this site from 21 July 1998 through 14 June 1999. A second rotary screw trap was located on the Wallowa River above the mouth of the Minam River near the town of Wallowa at rkm 27 (Figure 1). This trap was located below spawning and rearing areas of Hurricane, Prairie, Bear, and Parsnip creeks, the upper Wallowa River, and the Lostine River. A 2.4 m diameter trap was fished at this site from 19 August 1998 through 22 June 1999.

The rotary screw traps were equipped with live boxes that safely held hundreds of juvenile spring chinook salmon trapped over 24 to 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. 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 trap efficiency tests throughout each trapping season at each trap site. Trap seasons were defined from catch distributions. Trap efficiency was determined by releasing a known number of paint-marked or PIT-tagged fish above each trap and enumerating recaptures. A Panjet marking instrument (Hart and Pitcher 1969) was used to paint-mark fish by injecting a small amount of non-toxic acrylic paint subcutaneously. Up to 100 juvenile spring chinook salmon were marked and released each week. On days when a trap stopped operating and no marked fish were recaptured, the number of marked fish released the previous day were subtracted from the seasonal total.

Trap efficiency was estimated by

$$\hat{E} = R \;/\; M; \tag{1}$$

where $\hat{E}$ is the estimated seasonal trap efficiency, M is the number of marked fish released upstream, and R is the number of marked fish recaptured.

The abundance of migrants that passed each trap site for each trapping season (summer, fall, winter, and spring) was estimated by

$$\hat{N} = U \;/\; \hat{E}; \tag{2}$$

where $\hat{N}$ is the estimated number of fish migrating past the trap, U is the total number of unmarked fish captured, and $\hat{E}$ is the estimated seasonal trap efficiency.

Variance for each $\hat{N}$ was estimated by the one-sample bootstrap method (Efron and Tibshirani 1986; Thedinga et al. 1994) with 1,000 iterations. Each bootstrap iteration calculated $\hat{N}$ from equations (1 and 2) drawing R and U from the binomial distribution. Confidence intervals

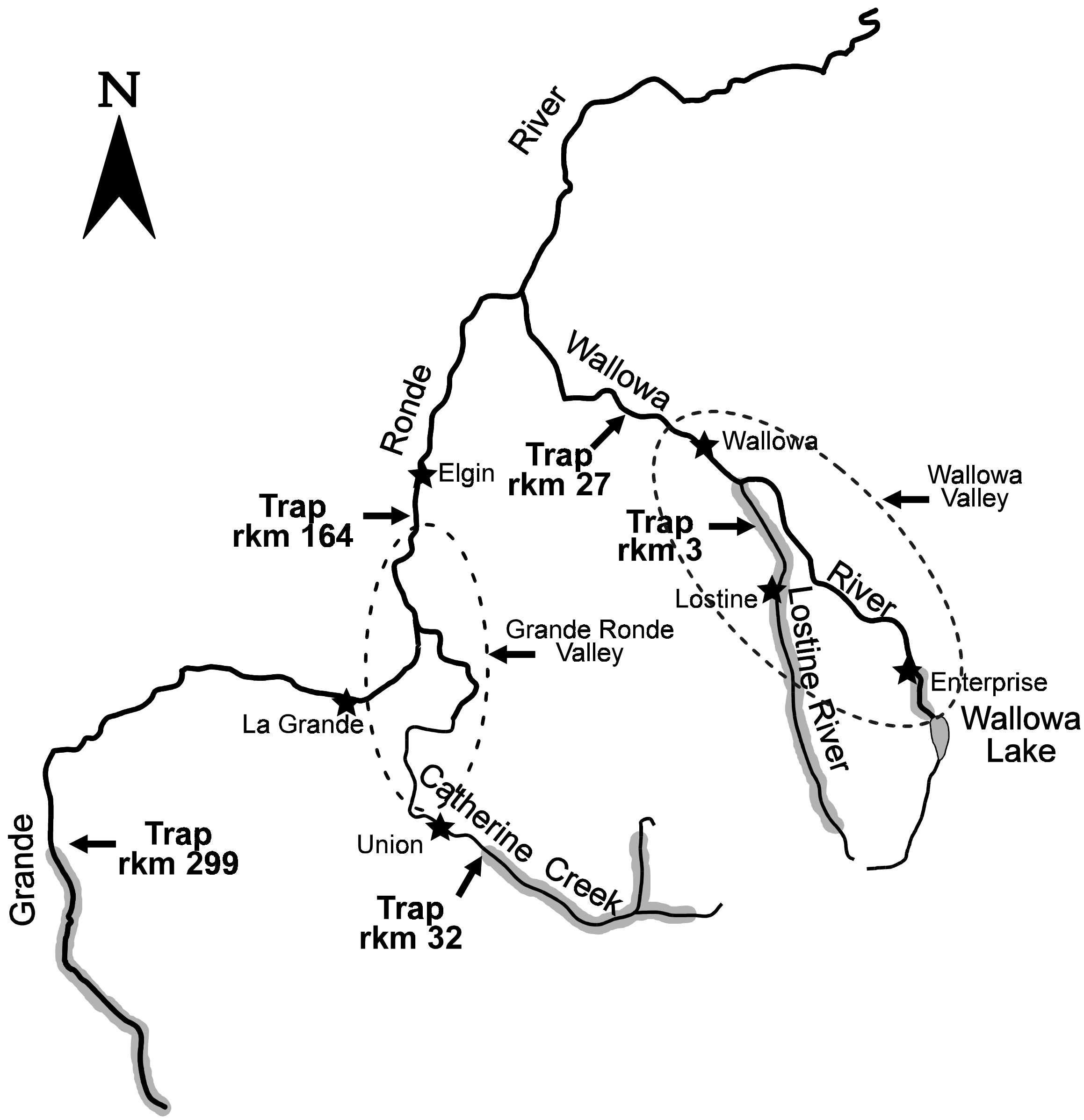

Figure 1. Locations of fish traps in the Grande Ronde River Basin during the study period. Shaded areas delineate spring chinook salmon spawning and upper rearing areas in each study stream. Dashed lines indicate the Grande Ronde River and Wallowa River valleys.

for $\hat{N}$ were calculated by

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

where V is the estimated variance of $\hat{N}$ determined from the bootstrap. Abundance for the total migration past each trap was determined by adding the seasonal estimates. Seasonal variance estimates were summed to obtain estimated variance for the total migration. Migrant fry were able to escape from the trap without detection and, therefore, were not included in migrant abundance estimates. Sexually mature male parr were not included in migrant abundance estimates.

The Grande Ronde Valley trap and the Wallowa River trap were located below hatchery steelhead release sites. It was necessary to monitor these two traps continuously throughout the hatchery steelhead release periods to prevent overcrowding in trap live boxes. A portable fish sorter was designed for each trapping site to separate juvenile spring chinook salmon from larger steelhead migrant. All fish were netted directly from the trap live box to a fish sorter to minimize handling during release periods. Juvenile spring chinook salmon migrants passed through the sorter into a live well. At the Wallowa River trap larger steelhead slid off the sorter directly back into the river. Since there was a desire to closely monitor the natural component of steelhead moving past the Grande Ronde Valley trap, steelhead were collected into large live wells and examined by hand for adipose fin clips.

Hatchery steelhead releases into the Wallowa River during the spring season necessitated modifications to our method of estimating migrant abundance at the Wallowa trap. During low catch periods, the trap was fished continuously throughout a 24 h period. During high catch periods, the trap was fished systematically (each night) for a 4 h interval from 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 chinook salmon catch rates. The interval from 20:00 to 24:00 was chosen because a relatively large proportion of the total daily catch was captured during this 4 h time block. Trap efficiency tests were conducted throughout the spring period whenever we were able to fish the trap continuously. Marked recaptures captured during the systematic sampling interval (20:00 to 24:00) were not included in seasonal totals.

Systematic sampling required us to estimate the proportion of the total daily catch captured during our sampling interval, i.e., during the systematic sampling interval from 20:00 to 24:00 or continuous sampling interval from 08:00 to 08:00 (24 h). We estimated the proportion of the total daily catch captured during the sampling interval by fishing the trap over four 24 h periods through the spring migration period and counting the number of fish trapped during the six successive 4 h intervals within each 24 h period. The proportion of the total daily catch captured during the sampling interval (*i)* was estimated by

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

were $\hat{P}_i$ 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 throughout the six 24 h sampling periods, and C is the total number of fish caught throughout the six 24 h sampling periods.

Abundance during the spring period at the Wallowa trap was estimated for systematic and continuous sampling intervals by

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

where $\hat{N}_s$ is the estimated number of fish migrating past the trap and U_i is the total number of unmarked fish captured during interval *i*. Abundance for the total spring migration at the Wallowa trap was determined by summing the continuous and systematic sampling estimates.

Variance for $\hat{N}_s$ at the Wallowa trap during spring was estimated by the one-sample bootstrap method (Efron and Tibshirani 1986; Thedinga et al. 1994) with 1,000 iterations. Each bootstrap iteration calculated $\hat{N}_s$ from equations (1, 4, and 5) drawing R and S_i from the binomial distribution and U_i from the Poisson distribution. Confidence intervals for the spring period were calculated using equation (3) where V is the estimated variance of $\hat{N}$ (continuous + systematic) determined from the bootstrap.

Migration Timing and Survival to Lower Granite Dam

Juvenile Trapping Studies

PIT tag technology allows fish to be individually marked and subsequently observed without being sacrificed. First-time detections of PIT-tagged fish at Snake and Columbia river dams were used to estimate migration timing and index survival among tag groups. During the 1999 migration 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.

Fish that emigrate from upper rearing areas at different times of the year and overwinter in different habitats are subject to different environmental conditions. Survival may vary among fish exhibiting the different life histories as a result. There is a distinct fall migration from summer rearing areas in the upper Grande Ronde River, Catherine Creek, and the Lostine River to areas downstream where fish overwinter. These fall migrants then migrate out of the basin to the sea the following spring. Other individuals remain in upper rearing areas through fall and winter, and initiate their seaward migration in spring. To determine if there were differences within populations with respect to the survival of juveniles that overwintered in different locations, we planned to tag 500 spring chinook salmon migrants captured in traps during fall and spring and 500 spring chinook salmon that were residing above the traps in winter. For tagging purposes and to be consistent with previous years of this study, we defined the fall migration as downstream movement past our upper trap sites between September and December and the spring migration as downstream movement past our upper trap sites between February and May. These times encompassed a majority of the fall and spring migrations. We also tagged 500 to 1,000 chinook salmon parr on Catherine Creek, and the Imnaha, Lostine, and Minam rivers in late summer 1998 as part of our investigation into parr strategies (Objectives 4-7).

Thus, there are four tag groups used to estimate migration timing and index survival to Lower Granite Dam: summer, fall, winter, and spring. Fish tagged in these groups do not necessarily represent unique life history strategies. For example, the summer tag group includes fish that migrate out of upper rearing areas in fall, winter, or spring, and overwinter in either the upper or lower rearing areas. The summer tag group includes fish that exhibit all possible life histories and, as such, depicts timing and survival for the overall population. PIT-tagged fish were interrogated upon recapture in screw traps and in bypass systems at mainstem dams. All recaptured and interrogated fish were identified by their original tag group, thereby insuring the independence of tag groups for analysis. For example, dam detections of fish that were tagged in summer and were recaptured at a river trap in fall, were analyzed as summer tagged fish.

We estimated migration timing of individual tag groups at Lower Granite Dam 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 pass 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). Kuehl (1986) estimated spill effectiveness at 11, 19, and 35% under 4, 20, and 40% spill conditions, respectively. 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 migrating past Lower Granite Dam by week was calculated by multiplying the number of fish detected each day by a daily expansion factor, which was calculated as:

$$\text{Expansion factor} = (\text{powerhouse flow} + \text{spillway flow})/\text{powerhouse flow}. \qquad (6)$$

Daily products were added and rounded to the nearest integer.

At the completion of the 1999 migration year, we obtained cumulative first-time detection information from PIT tag interrogation sites at Lower Granite, Little Goose, Lower Monumental, McNary, John Day, and Bonneville dams. We calculated survival indices for individual tag groups by dividing the cumulative number of first-time PIT tag detections at these sites by the number of fish released in each tag group and expressed this proportion as a percentage. We did not adjust our data to compensate for tagged fish that may have passed through the hydrosystem without being detected because we are unsure of the most appropriate methods to use at the time of this report. Therefore, the survival indices may only indicate the minimum rate of survival for each tag group. We evaluated relative success of fish that leave upper rearing areas at different times of the year by comparing the survival indices of fall and winter tag groups. Overwinter survival of fish that remained in upper rearing areas was assessed by dividing the survival indices of the winter tag groups by the corresponding index for the spring tag group. This proportion was then expressed as the percentage of fish in upper rearing areas that survived winter. The survival indices for the summer tag groups provided information about the overall population survival from the time of tagging through the following smolt migration.

Parr Studies

In summer 1998 and 1999, we PIT-tagged parr on Catherine Creek, and the Lostine, Minam, and Imnaha rivers in order to monitor their migration timing as smolts at Lower Granite Dam and their rates of detection in hydrosystem. We conducted tagging operations in late summer (Table 1) so that few fish would be too short to tag (<55 mm fork length). Sampling occurred primarily in areas where spawning adults were concentrated the previous year. To collect and PIT tag the parr, we used the methods outlined above previously for the mark-and-recapture experiments (see **Methods**, Egg-to-Smolt Survival, Abundance, and Age Composition of Parr in Summer). In summer 1998, we released from 502 to 1,009 PIT-tagged parr in each stream (Table 1). We released from 499 to 998 PIT-tagged parr in each stream in summer 1999 (Table 1). Information on the migration timing and detection rates of parr PIT-tagged in 1999 will be reported next year.

We estimated the timing with which fish from the different streams migrated through Lower Granite Dam in the same manner as described above for fish in the juvenile trapping studies. To determine if migration timing differed among populations, we performed a Kruskal-Wallis test on the dates of detection, expressed as day of the year, of real and "expanded" fish. When significant differences were found, we used a multiple-comparison procedure (at alpha=0.05; Daniel 1990) to further analyze the data. First-time detection rates of fish from the different streams were calculated in the manner outlined above for fish in the juvenile trapping studies.

Table 1. Dates of tagging and number of spring chinook salmon parr PIT-tagged on various northeast Oregon streams in 1998 and 1999.

Year/Stream	Dates of collection and tagging	Number of parr PIT-tagged and released	Kilometers upstream from Lower Granite Dam
1998			
Catherine Creek	3-7 August	502	354-375
Lostine River	10-13 August	506	274-302
Minam River	17-19 August	1,006	280-284
Imnaha River	24-26 August	1,009	237-243
1999			
Catherine Creek	2-5 August	499	358-374
Lostine River	9-11 August	509	277-301
Minam River	16-18 August	998	279-283
Imnaha River	23-25 August	982	208-241

Habitat Utilization

We assessed habitat utilization for chinook salmon parr during winter and summer on the Lostine River. Rearing distribution was assessed for chinook salmon parr during summer on the Lostine River. Fish were counted by visual observation with two or three persons snorkeling habitat units in an upstream direction. Three counts were made for each habitat unit sampled. Winter counts were made during the night with the use of dive lights, while summer observations were made during the day.

Sampling sites were selected based on redd and rearing distribution surveys from previous years, physical habitat surveys, and accessibility. We surveyed the Lostine River during winter from the Pole Bridge Picnic Area down to the mouth (rkm 23-0). During summer, we surveyed the Lostine River from Turkey Flat Campground to Williamson Campground (rkm 39-30) and from Pole Bridge Picnic Area to the mouth (rkm 23-0).

We identified habitat types using the habitat classification system described in Bisson et al. (1982) and modifications for backwater pools described by Nickelson et al. (1992). Fish of all species were enumerated and the following habitat variables were recorded: habitat type, surface area, depth, cover, substrate composition, water temperature, water velocity, slope, shade, and water visibility. The density of chinook salmon parr in each habitat unit was calculated as the maximum of three fish counts divided by the surface area of each habitat unit.

RESULTS AND DISCUSSION

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

From the information obtained during our mark-and-recapture experiments, we estimated that 735 (95% CI: 490-1,155) mature parr and 22,505 (95% CI: 17,236-29,306) immature parr inhabited Catherine Creek in August 1999 (Table 2). Results from scale analyses indicated 0.5% (1 of 210) of the mature parr sampled for scales were age 0+, while the remainder were age 1+ (Table 3). All of the immature parr sampled were age 0+ (Table 3). Based on these results, we estimated that 731 mature, age 1+ parr; no immature, age 1+ parr; 22,505 immature, age 0+ parr; and 4 mature, age 0+ parr were present in Catherine Creek in early-August 1999. There were 46 and 34 redds counted in the Catherine Creek study area in 1997 and 1998, respectively. Thus, we estimated that an average of 16 mature, age 1+ parr and no immature, age 1+ parr were produced from each redd constructed in 1997. An average of 662 immature, age 0+ parr and 0.1 mature, age 0+ parr were produced from each redd constructed in 1998. Of the 13,222 immature, age 0+ parr estimated to be present in Catherine Creek in August 1998 (Tranquilli et al. 1998), 5.5% were estimated to have matured and been present in August 1999.

We estimated 28,084 (17,926-46,377) immature, age 0+ parr inhabited the Lostine River in August 1999 (Table 2). We were unable to estimate the abundance of mature parr, but their numbers were probably relatively small; only 25 mature parr were captured over nine days of sampling (Table 2). Results from scale analyses indicated that all of the immature and mature parr sampled for scales were ages 0+ and 1+, respectively (Table 3). Based on these results, we estimated that 28,084 immature, age 0+ parr; no mature, age 0+; and no immature age 1+ parr were present in the Lostine River in August 1999. There were 49 and 28 redds counted in the Lostine River study area in 1997 and 1998, respectively. Thus, we estimated that an average of 1,003 immature and no mature, age 0+ parr were produced from each redd constructed in the Lostine River in 1998. Given that at least 25 mature parr were present in the Lostine River in 1999, and that all of the mature parr were estimated to be age 1+, an average of at least 0.5 mature, age 1+ parr and no immature, age 1+ parr were produced from each redd constructed in 1997. At least 0.06% of the immature, age 0+ parr estimated to be present in the Lostine River in 1998 matured and were present in August 1999.

Table 2. Results from mark-and-recapture experiments conducted in Catherine Creek and the Lostine River in August 1999.

Stream/group	Number marked (M)	Number sampled (C)	Number recaptured (R)	Population estimate (N) (95% CI)
Catherine Creek				
immature	1,003	1,187	52	22,505 (17,236-29,306)
mature	117	136	21	735 (490-1,155)
Lostine River				
immature	1,000	504	17	28,084 (17,926-46,377)
mature	10	15	0	--

Table 3. Age composition of immature and mature spring chinook salmon parr sampled in Catherine Creek and the Lostine River in 1999. Age was determined based on analysis of scales.

Stream/group	Number of samples	Percent age 0+ (95% CI)	Percent age 1+ (95% CI)
Catherine Creek			
Immature	204	100.0 (98.2-100.0)	0.0 (0.0-1.8)
Mature	210	0.5 (0.1-6.2)	99.5 (93.8-99.9)
Lostine River			
Immature	201	100.0 (98.1-100.0)	0.0 (0.0-1.9)
Mature	23	0.0 (0.0-14.5)	100.0 (85.5-100.0)

An interesting note regarding chinook salmon in Catherine Creek is that there were an estimated 18 mature male parr for every anadromous female spawner (i.e., redd) in 1999. To our knowledge, it has not been shown whether mature chinook salmon parr are capable of fertilizing eggs and producing viable offspring, as has been demonstrated in Atlantic salmon (Thorpe and Morgan 1980; Hutchings and Myers 1985, 1988). Therefore, we can conclude only that the potential existed for mature male parr to have made significant gametic contributions. Given the continual low abundance of anadromous spawners in northeast Oregon streams, mature male parr may be an important means by which breeding population size is increased.

We estimated egg to parr survival for the 1998 brood year to be 15.2% in Catherine Creek (Table 4) and 23.1% in the Lostine River (Table 5).

Table 4. Estimated abundance of spring chinook salmon in Catherine Creek at several life stages and egg to parr survival rate, 1997–99 broods.

Brood year	Redds[a]	Eggs	Summer parr	Egg to parr survival (%)
1997	45	195,660	13,222	6.8
1998	34	147,832	22,505	15.2
1999	38	165,224	--	--

[a] *Redds counted above rotary screw trap at rkm 32.*

Table 5. Estimated abundance of spring chinook salmon in the Lostine River at several life stages and egg to parr survival rate, 1997–99 broods.

Brood year	Redds[a]	Eggs	Summer parr	Egg to parr survival (%)
1997	47	204,356	40,748	19.9
1998	28	121,744	28,084	23.1
1999	45	195,660	--	--

[a] *Redds counted above rotary screw trap at rkm 3.*

In-Basin Migration Timing and Abundance

The upper Grande Ronde River trap fished for 250 d from 1 July through ice up on 6 December 1998, and from 19 February through 30 June 1999. Distinct fall and spring migrations were evident (Figure 2), while smaller numbers of salmon were captured during summer and winter (Table 6). The date that the median fall migrant passed the trap was 16 November and was similar to timing observed in MY 97. Timing in MY 94, 95, 96, and 98 was somewhat earlier with the median fall migrant moving past our upper trap in October. The date that the median spring migrant moved past the trap was 29 March and was consistent with past observations that ranged from 15 to 31 March.

We estimated a minimum of 13,180 ± 1,558 juvenile spring chinook salmon migrants moved out of the upper Grande Ronde rearing areas during MY 99. This estimate is considerably greater than our estimate of 66 fish in MY 97 and is more consistent with estimates from MY 94 through 96 and 98 that ranged from 1,151 to 30,926. Seasonal trap efficiencies were 75.5 and 28.5% for fall and spring, respectively. Based on these efficiencies, we estimated that approximately 18% (2,325 ± 165) of the migrants moved in fall and 82% (10,822 ± 1,549) migrated in spring. In addition, approximately 0.2% (n = 33) moved in summer but we were not able to accurately estimate their abundance. The trap was not fished during winter. At 18%, the proportion of fall migrants leaving the upper Grande Ronde rearing areas was less than MY 98 (29%), yet greater than the proportion observed in MY 94 (10%), MY 95 (11%), and MY 96 (0.7%). The pattern of a dominant spring migration in the upper Grande Ronde is consistent for all migration years studied to date with the exception of MY 97, when 98% of the migrants moved in fall. It is worth mentioning, however, that MY 97 was exceptional in that only 29 fish were trapped.

The Catherine Creek trap fished for 291 d from 1 July through ice up on 31 December 1997, and from 12 January through 30 June 1998. Migrants were captured during every season the trap was fished (Figure 2). The date that the median migrant passed the trap by season was 19 August, 13 November, 3 February, and 20 March for summer, fall, winter, and spring, respectively (Table 6).

We estimated that a minimum of 15,949 ± 1,211 juvenile spring chinook salmon migrants moved out of the upper Catherine Creek rearing areas during MY 99. This estimate is less than, yet on the same order of magnitude as, estimates from MY 95 (18,680) and is greater than our migrant estimate from MY 96 (6,341), MY 97 (3,951), and MY 98 (8,763). Seasonal trap efficiencies at Catherine Creek were 50.0, 40.7, and 26.5% for fall, winter, and spring, respectively. Based on these efficiencies, 57% (9,102 ± 660) moved in fall, 2% (283 ± 89) moved in winter, and 41% (6,529 ± 346) moved in spring. In addition, approximately 0.2% (n = 35) moved past the trap in summer but we were not able to accurately estimate their abundance. The Catherine Creek population appears to be different from the upper Grande Ronde population with respect to the proportion of fish migrating in spring and fall. The proportion of spring migrants has ranged from 11 to 50% of the total migrant population while the proportion of fall migrants has ranged from 37 to 76%. In contrast, the largest outmigration from the upper Grande Ronde River has consistently been observed in spring.

The lower Grande Ronde River trap fished for 221 d between 28 September 1998 and 30 June 1999. A distinct spring migration was evident; few fish passed the trap in fall and winter (Figure 2). The date that the median migrant passed the trap was 11 May and was similar to timing observed in MY 97. Timing in MY 95, MY 96, and MY98 was somewhat earlier with the median migrant moving past this trap in late April.

We estimated that a minimum of 14,537 ± 2,619 juvenile spring chinook salmon migrants left the Grande Ronde Valley during MY 99. The years estimate is within the same order of magnitude as from MY 94 (28,225) and MY 95 (36,405 ± 2,619), and is one order of magnitude higher than our estimates in MY 96 through MY 98. Seasonal trap efficiency was 13.7% for our 2.4 m trap. Only three fish were captured in fall with our 1.5 m trap and thus we were not able to determine trap efficiency. As in the past five years, more than 99% of the chinook salmon migrants passed our trap during spring. This data indicates that most juvenile spring chinook salmon that left the upper rearing areas during fall overwintered in the valley reaches of the Grande Ronde River. Protection and enhancement of habitat in the Grande Ronde

Valley should be given high priority to maintain or enhance overwinter survival of juvenile spring chinook salmon that reside in the valley during winter.

The Lostine River trap fished for a total of 288 d between 22 July 1998 and 14 June 1999. Distinct fall and spring migrations were evident (Figure 2), while smaller numbers of salmon were captured during summer and winter (Table 6). The date that the median fall migrant passed the trap was 12 November. The date that the median spring migrant moved past the trap was 19 April.

We estimated that a minimum of 31,113 ± 1,801 juvenile spring chinook salmon migrants moved out of the Lostine River during MY 99. Seasonal trap efficiencies were 25% in summer, 32% in fall, 24% in winter, and 40% in spring. Based on these efficiencies, we estimated that approximately 57% (17,592 ± 1,504) of the migrants moved in fall and 36% (11,138 ± 859) migrated in spring. In addition, approximately 4% (1,307 ± 378) moved prior to the start of fall and 3% (1,076 ± 320) moved during winter.

The Wallowa River trap fished for 255 d between 19 September 1998 and 22 May 1999. Distinct fall and spring migrations were evident at this trap (Figure 2). The dates that the median fall and spring migrants passed the trap were 11 November and 20 April, respectively.

We estimated that a minimum of 42,705 ± 4,955 juvenile spring chinook salmon migrants moved past our trap during MY 99. Seasonal trap efficiency was 19 in fall, 27 in winter, and 19% in spring. During the spring period we used systematic sampling methods. The proportion of the total daily catch captured between the 20:00 and 24:00 sampling interval was 35% (total captures 485 fish). Based on these trap efficiencies, 46% (19,841 ± 2,636) of the migrant population moved out of upper rearing areas in fall, 6% (2,603 ± 443) in winter, and 47% (20,261 ± 4,172) in spring.

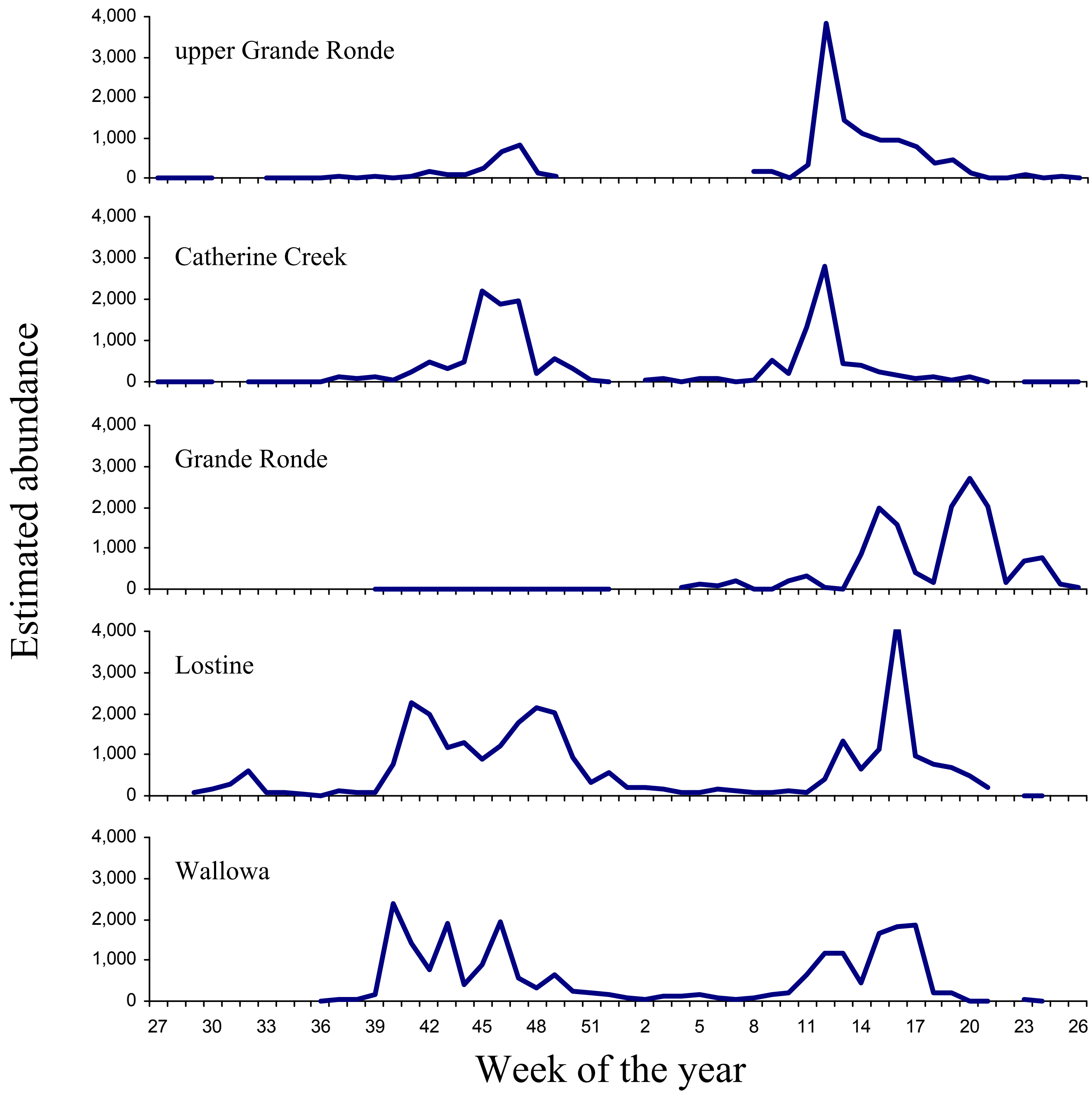

Figure 2. Estimated migration timing and abundance of juvenile spring chinook salmon migrants captured by rotary screw traps. During the 1999 migration year, traps were located at rkm 299 and 164 of the Grande Ronde River, rkm 32 of Catherine Creek, rkm 3 of the Lostine River, and rkm 27 of the Wallowa River.

Table 6. Seasonal catch of juvenile spring chinook salmon at five trap locations in the Grande Ronde River Basin.

Trap site	Season	Migration period	Days fished	Trap catch
Upper Grande Ronde	Summer	1 Jul 98 – 2 Sep 98	48	33
	Fall	3 Sep 98 – 23 Dec 98	91	1,522
	Spring	19 Feb 99 – 30 Jun 99	111	3,089
Catherine Creek	Summer	1 Jul 98 – 2 Sep 98	41	35
	Fall	3 Sep 98 – 23 Dec 98	107	4,551
	Winter	24 Dec 98 – 18 Feb 99	31	115
	Spring	19 Feb 99 – 30 Jun 99	116	1,732
Grande Ronde Valley	Fall	28 Sep 98 – 21 Jan 99	84	3
	Spring	22 Jan 99 – 30 Jun 99	137	1,841
Lostine River	Summer	21 Jul 98- 30 Aug 98	29	323
	Fall	1 Sep 98 - 31 Dec 98	112	5,670
	Winter	1 Jan 99 - 28 Feb 99	55	257
	Spring	1 Mar 99 - 14 Jun 99	92	4,455
Wallowa River Valley	Fall	19 Aug 98 - 31 Dec 98	123	3,732
	Winter	1 Jan 99 - 28 Feb 99	55	702
	Spring	1 Mar 99 - 22 Jun 99	33[a]	832[a]
	Spring	1 Mar 99 - 22 Jun 99	44[b]	1,093[b]

[a] *Continuous trapping.*
[b] *Trapping with 4 h subsampling.*

The pattern of movement at this trap was very similar to that seen upriver at the Lostine trap. Trap-to-trap travel times suggest Lostine River spring chinook salmon use the valley portion of the Wallowa River primarily as a migration corridor and that fall migrants move below the Wallowa River trap site for overwintering. Travel times between the Lostine trap and the Wallowa trap in fall ranged from 1 to 60 d with a mean of 2 d (n = 108).

Mean lengths and weights of juvenile spring chinook salmon captured in the upper Grande Ronde River and PIT-tagged are given in Tables 5 and 6. Mean lengths and weights of juvenile spring chinook salmon captured from Catherine Creek and PIT-tagged are given in Tables 9 and 10. Mean lengths and weights of juvenile spring chinook salmon captured from the Lostine River and PIT-tagged are given in Tables 11 and 12. Length frequency distributions of juvenile spring chinook salmon caught in all traps by migration period are shown in Figures 3 through 7.

Weekly mean lengths of migrants showed trends on increasing over time at each of the traps (Tables 13 – 17). As in previous years, migrants captured at the lower Grande Ronde River trap generally were larger than fish captured at the upper Grande Ronde and Catherine Creek traps in MY 99. Size data collected from fish that were PIT-tagged at the upper traps during fall and spring and recaptured at the lower Grande Ronde trap, 135 km and 100 km downstream from the upper Grande Ronde River and Catherine Creek traps, respectively, show that fish grow before leaving the valley in spring, whether they overwinter in the valley or pass through in the spring (Table 18). Timing and size data collected for Lostine River fish that were PIT-tagged at the trap during fall and spring and recaptured at the Wallowa River trap, 18 km downstream from the Lostine River trap, show that the fish move quickly past the Wallowa Valley trap and do not grow during this time (Table 18).

Table 7. Fork lengths (mm) of juvenile spring chinook salmon collected from the upper Grande Ronde River, fall 1998 to spring 1999. Winter fish were captured with seines or dipnets in the upper Grande Ronde River from rkm 320 to 323. Fall and spring fish were captured with a rotary screw trap at rkm 299. Min. = minimum, Max. = maximum.

	Collected				
Group	*n*	Mean	SE	Min.	Max.
Fall	685	83.4	0.50	55	117
Winter	419	70.7	0.37	57	92
Spring	944	88.5	0.34	62	120
Release	Tagged and released				
group	*n*	Mean	SE	Min.	Max.
Fall	500	85.2	0.55	57	117
Winter	419	70.7	0.37	57	92
Spring	491	91.1	0.50	62	120

Table 8. Weights (g) of juvenile spring chinook salmon collected from the upper Grande Ronde River, fall 1998 to spring 1999. Winter fish were captured with seines or dipnets in the upper Grande Ronde River from rkm 320 to 323. Fall and spring fish were captured with a rotary screw trap at rkm 299. Min. = minimum, Max. = maximum.

	Collected				
Group	*n*	Mean	SE	Min.	Max.
Fall	646	6.69	0.110	1.8	15.0
Winter	419	4.02	0.066	1.9	8.3
Spring	907	7.34	0.080	2.6	17.0
Release	Tagged and released				
group	*n*	Mean	SE	Min.	Max.
Fall	483	7.00	0.124	2.0	15.0
Winter	419	4.02	0.066	1.9	8.3
Spring	485	7.74	0.115	2.6	17.0

Table 9. Fork lengths (mm) of juvenile spring chinook salmon collected from Catherine Creek, fall 1998 to spring 1999. Winter fish were captured with seines or dipnets in Catherine Creek from rkm 42 to 50. Fall and spring fish were captured with a rotary screw trap at rkm 32. Min. = minimum, Max. = maximum.

	Collected				
Group	*n*	Mean	SE	Min.	Max.
Fall	1,208	83.3	0.23	59	110
Winter	495	86.9	0.31	65	104
Spring	678	92.6	0.26	63	118
Release	Tagged and released				
group	*n*	Mean	SE	Min.	Max.
Fall	658	83.0	0.30	59	106
Winter	495	86.9	0.31	65	104
Spring	490	92.8	0.29	73	114

Table 10. Weights (g) of juvenile spring chinook salmon collected from Catherine Creek, fall 1998 to spring 1999. Winter fish were captured with seines or dipnets in Catherine Creek from rkm 42 to 50. Fall and spring fish were captured with a rotary screw trap at rkm 32. Min. = minimum, Max. = maximum.

	Collected				
Group	*n*	Mean	SE	Min.	Max.
Fall	1,158	6.47	0.053	2.4	13.6
Winter	491	6.96	0.075	2.9	11.9
Spring	670	8.42	0.074	2.8	18.3
Release	Tagged and released				
group	*n*	Mean	SE	Min.	Max.
Fall	631	6.38	0.070	2.4	13.6
Winter	491	6.96	0.075	2.9	11.9
Spring	488	8.32	0.079	4.0	15.3

Table 11. Fork lengths (mm) of juvenile spring chinook salmon collected from the Lostine River, fall 1998 to spring 1999. Winter fish were captured with dipnets in the Lostine River from rkm 8 to 31. Fall and spring fish were captured with a rotary screw trap at rkm 3. Min. = minimum, Max. = maximum.

	Collected				
Group	*n*	Mean	SE	Min.	Max.
Fall	984	94.5	0.31	47	141
Winter	499	87.3	0.40	67	128
Spring	702	95.8	0.45	64	147
Release	Tagged and released				
group	*n*	Mean	SE	Min.	Max.
Fall	501	95.6	0.42	69	125
Winter	491	87.3	0.41	67	128
Spring	600	94.9	0.40	70	152

Table 12. Weights (g) of juvenile spring chinook salmon collected from the Lostine River, fall 1998 to spring 1999. Winter fish were captured with dipnets in the Lostine River from rkm 8 to 31. Fall and spring fish were captured with a rotary screw trap at rkm 3. Min. = minimum, Max. = maximum.

	Collected				
Group	*n*	Mean	SE	Min.	Max.
Fall	984	9.87	0.100	1.8	36.5
Winter	499	7.25	0.104	3.0	20.0
Spring	691	10.24	0.173	2.8	35.9
Release	Tagged and released				
group	*n*	Mean	SE	Min.	Max.
Fall	501	10.25	0.143	3.6	23.0
Winter	491	7.26	0.105	3.0	20.0
Spring	598	9.59	0.136	3.8	38.7

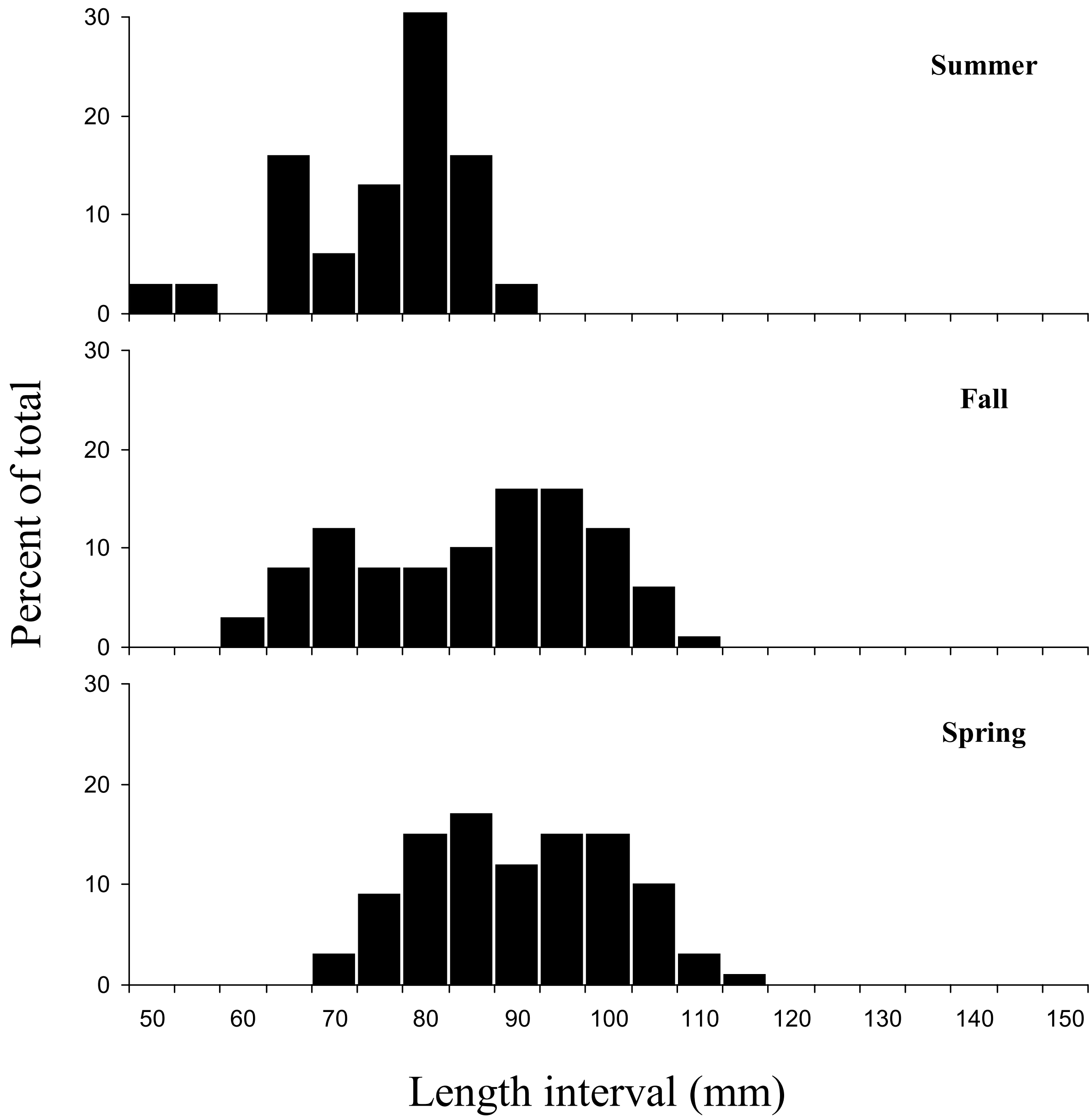

Figure 3. Length frequency distribution (fork length) of juvenile spring chinook salmon migrants captured at the upper Grande Ronde River trap (rkm 299) by seasonal migration period, during the 1999 migration year.

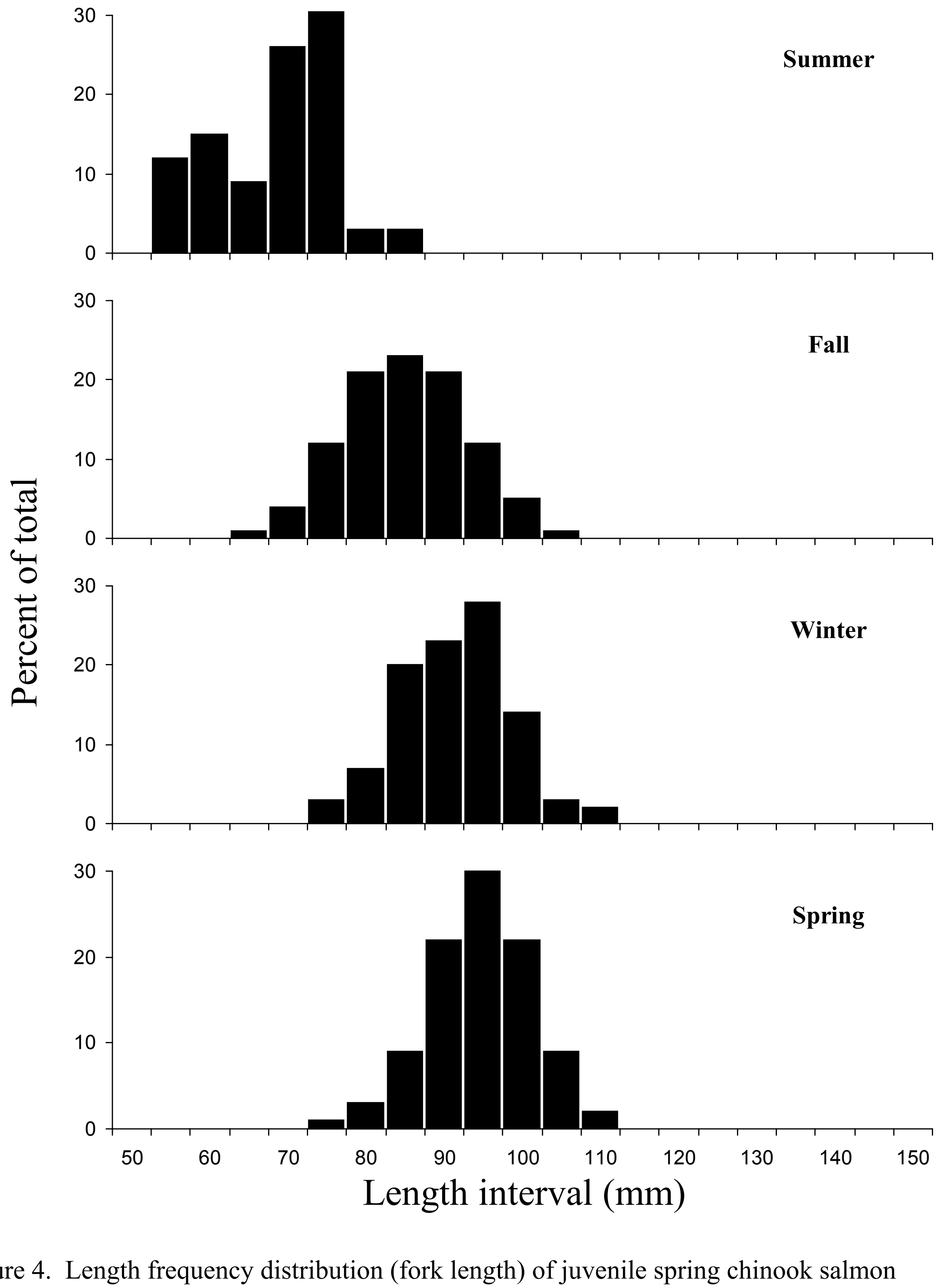

Figure 4. Length frequency distribution (fork length) of juvenile spring chinook salmon migrants captured at the Catherine Creek trap (rkm 32) by seasonal migration period, during the 1999 migration year.

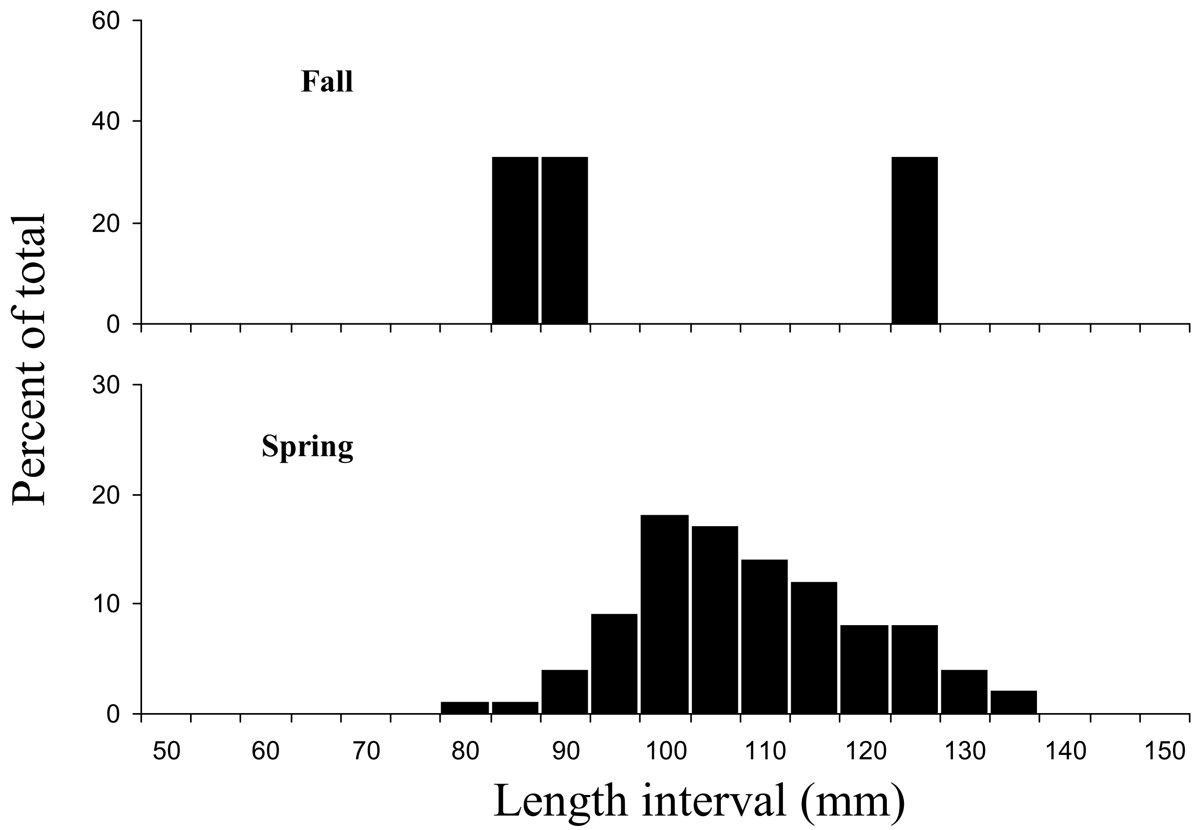

Figure 5. Length frequency distribution (fork length) of juvenile spring chinook salmon migrants captured at the Grande Ronde Valley trap (rkm 164) by seasonal migration period, during the 1999 migration year.

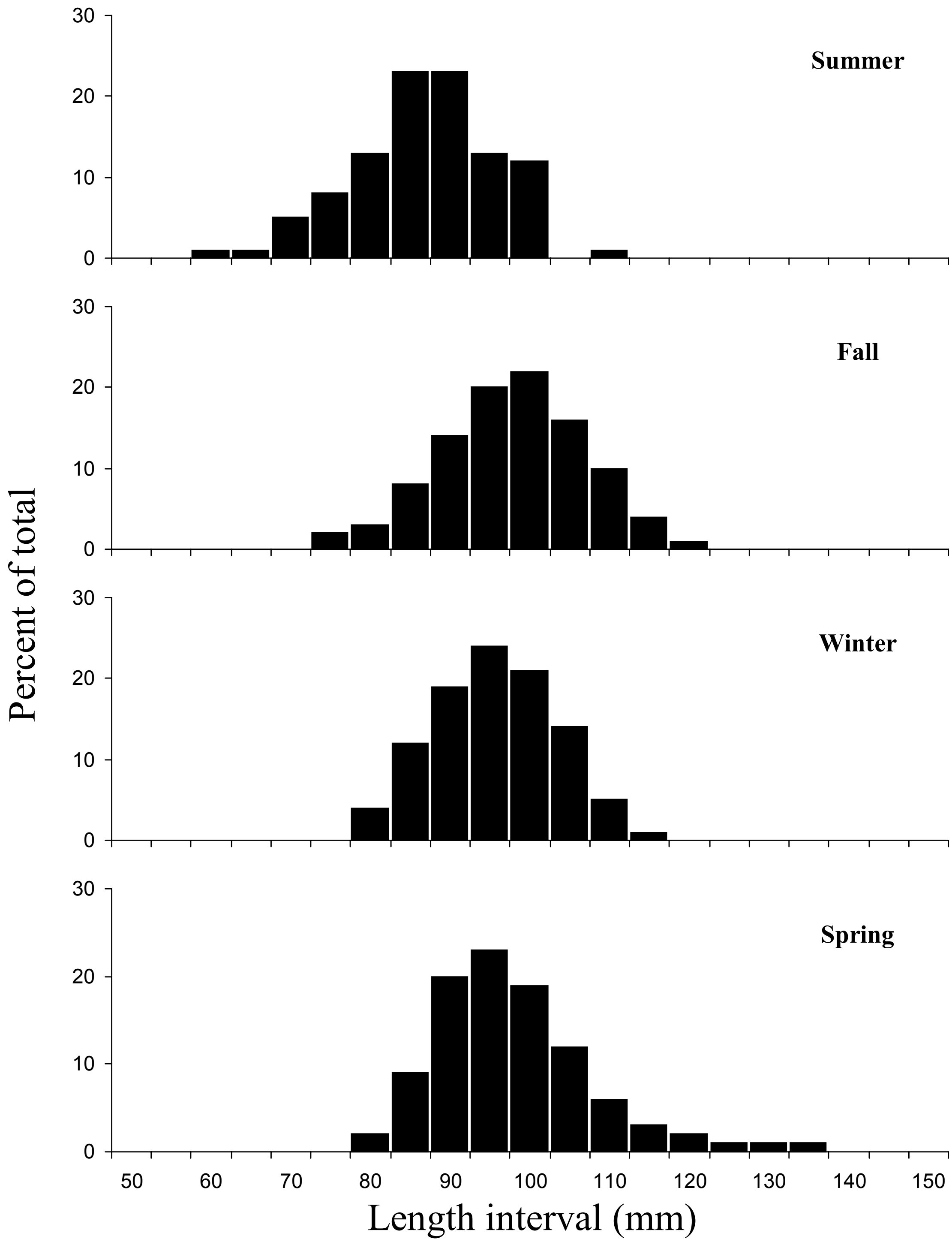

Figure 6. Length frequency distribution (fork length) of juvenile spring chinook salmon migrants captured at the Lostine River trap (rkm 3) by seasonal migration period, during the 1999 migration year.

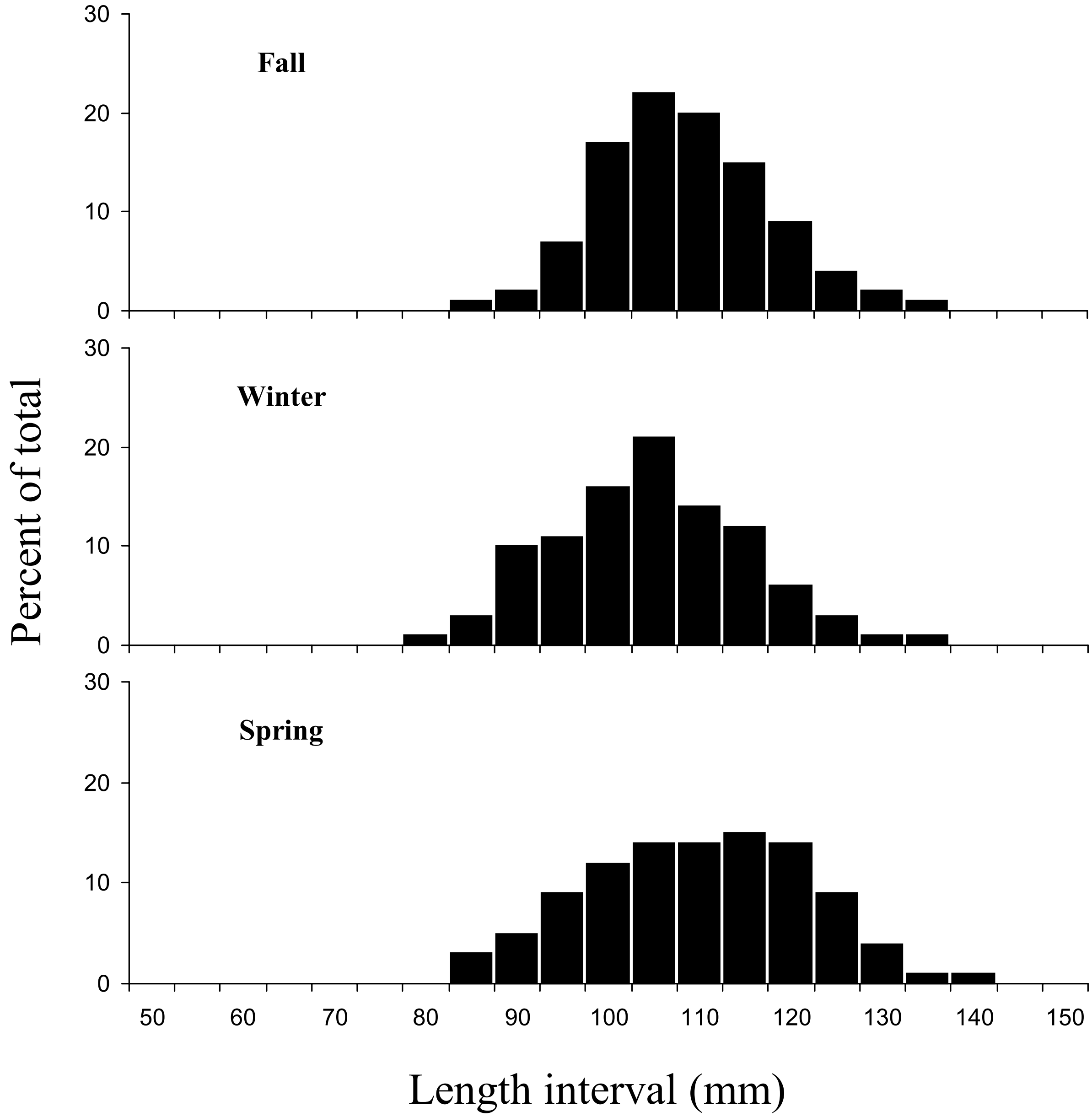

Figure 7. Length frequency distribution (fork length) of juvenile spring chinook salmon migrants captured at the Wallowa Valley trap (rkm 27) by seasonal migration period, during the 1999 migration year.

Table 13. Fork lengths (mm) and weights (g) of juvenile spring chinook salmon captured by a rotary screw trap at rkm 299 of the Grande Ronde River, week 27, 1998 to week 26, 1999.

Year,	Length					Weight				
week	*n*	Mean	SE	Min.	Max.	*n*	Mean	SE	Min.	Max.
1998:										
27	1			51	51	1			1.5	1.5
28	6	67.0	4.16	48	78	6	3.62	0.681	1.3	5.9
29	6	69.7	2.63	61	76	6	4.03	0.510	2.6	5.6
30	11	78.9	0.89	75	85	11	5.67	0.184	4.8	6.7
33	2	72.0	4.95	65	79	2	3.85	0.813	2.7	5.0
34	4	76.0	2.52	70	84	4	5.25	0.563	4.1	7.1
35	1			90	90	1			7.8	7.8
37	11	80.1	3.08	69	100	9	6.18	0.889	3.5	11.5
38	8	83.3	5.61	56	106	5	7.40	1.527	2.1	11.4
39	19	75.2	2.73	57	96	18	4.97	0.553	2.2	9.7
40	4	85.5	5.92	71	104	3	7.87	1.647	5.8	11.9
41	40	76.7	1.69	61	98	30	5.10	0.383	2.4	9.5
42	72	74.1	1.37	55	100	72	4.78	0.256	1.8	11.0
43	51	75.4	1.68	57	98	51	5.01	0.309	2.3	9.5
44	60	84.8	1.62	59	107	60	6.85	0.357	2.0	13.7
45	156	89.2	0.87	59	117	151	7.83	0.196	2.0	15.0
46	147	88.3	1.00	61	110	147	7.61	0.234	2.7	14.7
47	60	79.3	1.41	60	103	44	6.25	0.355	2.5	12.9
48	40	83.4	2.06	59	110	39	6.42	0.456	2.5	14.1
49	17	88.1	2.74	64	101	17	7.23	0.605	2.9	11.5
1999:										
8	30	97.8	1.27	71	107	30	9.30	0.279	4.1	11.9
9	37	99.1	1.10	82	116	36	9.39	0.279	5.4	13.2
11	64	96.4	1.23	70	113	63	8.98	0.318	3.5	15.2
12	332	90.4	0.61	62	120	330	7.55	0.140	2.6	17.0
13	31	85.0	1.80	69	104	30	6.42	0.360	3.6	10.2
14	65	84.8	1.12	70	106	65	6.42	0.258	3.5	12.7
15	138	84.4	0.79	66	110	127	6.55	0.194	3.0	13.3
16	40	83.6	1.25	72	101	40	6.29	0.280	4.0	10.8
17	66	82.5	0.94	68	104	65	6.26	0.218	3.5	12.3
18	59	84.1	1.14	64	110	59	6.75	0.271	2.8	14.0

Table 13. Continued.

Year,	Length					Weight				
week	*n*	Mean	SE	Min.	Max.	*n*	Mean	SE	Min.	Max.
1999:										
19	46	85.3	1.20	68	106	26	6.43	0.288	3.3	9.2
22	3	87.0	4.11	77	93	3	7.50	0.980	5.1	8.7
23	22	91.3	1.20	82	99	22	8.70	0.360	6.1	11.2
24	4	94.8	1.43	91	98	4	9.98	0.640	8.6	11.7
25	6	90.2	2.86	81	98	6	8.95	0.800	6.6	11.9
26	1			102	102	1			8.8	8.8

Table 14. Fork lengths (mm) and weights (g) of juvenile spring chinook salmon captured by a rotary screw trap at rkm 32 of Catherine Creek, week 27, 1998 to week 25, 1999.

Year,	Length					Weight				
week	*n*	Mean	SE	Min.	Max.	*n*	Mean	SE	Min.	Max.
1998:										
27	7	58.0	1.93	53	68	7	2.50	0.262	1.8	4.1
30	5	64.4	2.99	55	72	5	3.34	0.533	1.8	5.1
32	1			76	76	1			5.0	5.0
33	8	66.8	2.19	57	73	8	3.24	0.252	2.0	4.0
34	8	71.9	2.85	56	85	7	4.87	0.453	3.4	7.5
35	5	69.8	1.16	66	73	5	3.66	0.180	3.1	4.2
36	5	75.6	1.75	70	81	4	5.30	0.146	5.1	5.8
37	55	73.5	1.09	61	110	53	4.40	0.215	2.4	11.6
38	33	75.0	1.25	62	92	30	5.16	0.306	3.3	10.8
39	55	76.3	0.82	65	94	55	4.94	0.174	2.9	9.4
40	24	76.4	1.80	59	95	18	5.54	0.375	2.4	9.1
41	97	82.0	0.64	67	99	91	6.24	0.138	3.2	11.2
42	207	81.4	0.46	67	103	207	5.99	0.109	3.4	11.1
43	140	83.4	0.60	62	102	138	6.47	0.138	3.1	11.9
44	91	87.5	0.77	69	109	91	7.42	0.205	3.4	12.2

Table 14. Continued.

Year,	Length					Weight				
week	*n*	Mean	SE	Min.	Max.	*n*	Mean	SE	Min.	Max.
1998:										
45	170	86.3	0.53	71	106	156	7.06	0.142	3.6	13.6
46	101	85.3	0.65	70	104	101	6.83	0.161	3.9	12.3
47	86	87.8	0.75	71	105	76	7.44	0.200	3.9	13.1
48	27	83.7	1.21	75	101	27	6.33	0.287	4.0	10.8
49	75	86.6	0.67	75	101	75	7.08	0.156	4.8	11.1
50	22	85.9	1.21	78	96	16	7.28	0.337	5.1	9.5
51	20	90.7	1.27	77	100	20	8.43	0.361	5.8	11.5
1999:										
2	9	90.8	1.26	86	95	9	7.91	0.407	6.5	9.5
3	37	87.8	1.28	72	108	37	7.32	0.297	3.6	12.2
4	1			80	80	1			5.2	5.2
5	22	90.0	1.63	76	102	22	7.45	0.398	4.4	10.9
6	35	90.7	1.13	74	108	34	7.43	0.269	4.6	12.6
7	5	91.4	3.19	84	102	5	7.94	0.608	6.0	10.2
8	8	91.4	1.85	86	99	8	8.03	0.433	6.2	9.7
9	76	93.2	0.70	80	110	76	8.33	0.193	5.2	13.9
10	57	91.6	0.82	75	105	57	7.79	0.221	4.3	11.4
11	95	93.0	0.66	78	106	93	8.37	0.183	4.6	12.8
12	192	93.3	0.46	73	114	192	8.48	0.127	4.0	15.3
13	57	91.7	0.81	77	105	57	8.19	0.225	4.6	12.6
14	54	91.6	0.97	75	106	54	8.07	0.233	4.7	12.5
15	53	92.0	0.86	81	106	52	8.68	0.246	5.4	13.0
16	25	93.2	1.35	80	106	25	8.81	0.398	6.0	13.6
17	11	94.4	3.16	75	113	11	9.55	0.956	4.5	16.6
18	21	96.8	1.67	84	118	16	10.78	0.680	6.8	18.3
19	4	89.8	6.57	73	104	4	8.48	1.552	4.2	12.7
20	21	89.8	2.10	73	106	21	8.52	0.578	4.4	14.3
23	1			63	63	1			2.8	2.8
25	3	86.7	11.26	73	109	3	8.43	3.655	5.7	13.6

Table 15. Fork lengths (mm) and weights (g) of juvenile spring chinook salmon captured by a rotary screw trap at rkm 164 of the Grande Ronde River, week 47, 1998 to week 26, 1999.

Year,	Length					Weight				
week	*n*	Mean	SE	Min.	Max.	*n*	Mean	SE	Min.	Max.
1998:										
47	1			87	87	1			6.6	6.6
50	2	104.5	13.79	85	124	2	13.75	3.288	9.1	18.4
1999:										
4	3	97.7	1.78	95	102	3	9.90	0.942	8.2	12.1
5	16	99.3	2.01	88	120	16	10.12	0.906	6.6	21.2
6	9	96.9	1.08	92	102	4	9.95	0.610	8.1	11.5
7	26	97.3	1.36	83	110	25	9.23	0.406	5.1	12.5
8	2	83.5	8.84	71	96	2	6.35	1.803	3.8	8.9
10	19	102.6	2.34	73	120	18	10.58	0.752	4.0	19.1
11	32	99.0	1.04	86	117	31	9.33	0.249	6.4	12.1
12	4	100.3	2.22	95	107	4	10.00	0.626	8.7	11.7
14	91	100.0	0.79	77	129	90	10.52	0.296	5.3	23.9
15	235	101.7	0.67	69	133	234	11.13	0.229	3.2	26.6
16	74	107.5	1.02	84	127	74	13.43	0.384	7.2	21.0
17	31	110.3	1.59	90	126	30	14.44	0.696	8.0	23.3
18	16	104.9	2.52	90	125	16	12.43	0.970	8.0	20.5
19	100	113.8	1.11	86	137	99	16.64	0.476	6.9	28.8
20	102	113.9	0.96	92	136	91	16.81	0.455	8.1	29.1
21	87	109.6	1.14	93	132	87	15.67	0.451	8.8	25.9
22	12	102.4	2.77	84	122	12	12.93	0.946	7.6	20.1
23	61	114.2	1.58	87	138	60	16.68	0.737	6.6	30.5
24	55	113.8	1.69	92	139	54	16.25	0.734	8.6	27.3
25	13	114.2	2.87	96	132	13	19.12	1.416	12.3	27.9
26	3	117.7	5.26	105	126	3	18.67	3.394	10.5	24.1

Table 16. Fork lengths (mm) and weights (g) of juvenile spring chinook salmon captured by a rotary screw trap at rkm 3 of the Lostine River, week 20, 1998 to week 21, 1999.

Year,	Length					Weight				
week	*n*	Mean	SE	Min.	Max.	*n*	Mean	SE	Min.	Max.
1998:										
20	20	48.8	2.20	33	76	20	1.49	0.239	0.3	5.1
21	0					0				
22	13	58.5	1.71	42	68	13	2.62	0.244	1.0	4.4
23	21	60.0	2.13	35	71	21	2.76	0.260	0.3	4.5
24	7	56.9	2.70	45	67	7	2.43	0.282	1.1	3.5
25	42	56.9	1.44	40	83	42	2.37	0.193	0.8	7.1
26	28	60.2	1.55	43	81	28	2.74	0.211	0.9	6.2
27	2	63.5	5.50	58	69	2	3.15	0.850	2.3	4.0
28	0					0				
29	16	73.7	2.40	55	93	16	5.26	0.529	2.5	10.2
30	35	80.4	1.50	62	98	35	6.84	0.367	3.1	11.9
31	51	83.9	0.88	70	96	51	7.46	0.244	4.7	11.3
32	69	86.7	0.93	70	105	69	8.42	0.280	4.1	14.7
33	17	91.5	1.51	78	99	17	9.49	0.486	5.8	12.2
34	18	85.7	1.80	70	106	18	8.16	0.546	4.1	14.8
35	7	76.6	3.52	61	87	7	5.76	0.731	2.6	8.1
36	0					0				
37	38	82.4	2.63	64	141	38	7.57	1.056	3.1	36.5
38	25	86.2	2.74	47	104	25	8.19	0.650	1.8	13.3
39	30	88.6	1.69	71	108	30	8.47	0.495	4.3	15.5
40	131	96.5	0.82	62	111	131	10.96	0.263	3.2	16.8
41	170	94.9	0.73	69	116	170	10.27	0.248	3.5	19.0
42	126	94.7	0.83	73	125	126	9.99	0.276	4.5	23.0
43	102	95.2	0.89	75	127	102	10.06	0.302	4.6	23.2
44	105	95.8	0.77	77	120	105	10.26	0.260	4.7	19.6
45	123	94.1	0.73	70	121	123	9.62	0.223	3.8	19.8
46	123	95.4	0.96	75	127	123	10.02	0.339	2.3	22.8
47	112	95.9	0.96	75	121	112	10.08	0.331	4.5	19.3
48	126	97.6	0.76	75	118	126	10.40	0.243	4.6	19.1
49	77	96.9	0.99	76	120	77	10.42	0.334	4.9	18.5

Table 16. Continued.

Year,	Length					Weight				
week	*n*	Mean	SE	Min.	Max.	*n*	Mean	SE	Min.	Max.
1998:										
50	98	94.4	0.83	70	114	98	9.73	0.244	3.6	15.8
51	36	96.3	1.48	80	122	36	10.04	0.494	5.6	19.1
52	65	94.3	0.82	80	112	65	9.28	0.238	5.5	14.4
1999:										
1	51	93.1	0.92	80	109	51	8.70	0.256	5.1	12.6
2	44	91.2	1.17	77	108	44	8.50	0.318	4.5	13.9
3	32	90.6	1.33	78	108	32	8.06	0.406	5.0	16.3
4	15	93.3	1.73	84	103	15	8.73	0.459	6.0	11.8
5	19	93.0	1.64	83	106	19	8.74	0.499	5.8	12.5
6	36	94.8	1.56	76	112	36	9.56	0.457	4.1	14.7
7	28	92.8	1.47	78	108	28	8.83	0.389	5.3	12.7
8	15	92.1	1.66	83	103	15	8.44	0.408	6.1	12.1
9	28	92.8	1.29	76	108	28	8.83	0.365	4.6	14.7
10	46	93.6	1.05	81	111	46	8.79	0.291	5.3	14.1
11	23	91.8	1.69	78	110	23	8.52	0.478	5.2	14.3
12	110	97.2	1.04	77	128	110	10.58	0.331	5.2	21.1
13	173	95.6	0.66	73	122	173	9.87	0.194	4.5	18.4
14	145	93.8	0.75	78	128	145	9.09	0.219	5.2	22.6
15	131	94.6	0.79	76	119	131	9.39	0.216	5.2	15.5
16	141	94.1	0.80	76	134	141	9.90	0.261	4.9	26.5
17	105	92.3	0.90	77	125	105	9.05	0.305	5.0	22.2
18	132	95.5	1.13	70	135	132	9.98	0.408	3.8	27.9
19	105	100.0	1.56	70	142	105	11.63	0.641	3.6	31.4
20	128	98.0	1.23	64	152	117	11.09	0.586	2.8	38.7
21	31	96.7	2.74	79	137	31	11.01	1.128	6.3	29.7

Table 17. Fork lengths (mm) and weights (g) of juvenile spring chinook salmon captured by a rotary screw trap at rkm 27 of the Wallowa River, week 40, 1998 to week 20, 1999.

Year,	Length					Weight				
week	*n*	Mean	SE	Min.	Max.	*n*	Mean	SE	Min.	Max.
1998:										
40	83	104.4	0.96	77	130	83	14.63	0.438	5.5	28.8
41	114	98.9	0.84	83	119	114	11.75	0.366	4.2	29.0
42	89	102.2	1.43	71	132	89	13.42	0.553	4.1	29.6
43	97	102.9	1.10	77	129	97	13.15	0.461	5.1	26.8
44	94	101.8	1.04	76	127	94	12.72	0.393	5.5	24.7
45	112	104.1	0.97	77	129	112	13.23	0.377	4.7	24.8
46	104	100.0	1.11	74	127	104	11.54	0.408	4.2	22.9
47	106	100.3	1.11	78	133	106	11.79	0.448	4.9	29.2
48	90	101.8	1.05	77	130	90	12.04	0.407	4.7	24.7
49	101	102.3	0.99	83	129	101	12.58	0.391	6.5	25.8
50	104	100.6	1.04	77	132	104	11.70	0.379	5.4	24.9
51	37	100.6	2.00	74	142	37	11.44	0.683	4.2	26.4
1999:										
1	118	101.1	1.03	77	124	118	11.63	0.349	5.0	21.0
2	90	101.7	1.12	79	131	90	12.15	0.399	5.8	24.5
3	39	100.3	1.60	79	125	39	11.11	0.556	5.7	21.2
4	51	97.7	1.32	80	128	51	10.42	0.418	5.9	22.0
5	45	99.6	1.69	85	129	45	10.79	0.591	5.4	22.3
6	14	101.9	2.42	89	115	14	11.47	0.751	7.3	16.8
7	60	103.5	1.20	85	129	60	12.09	0.441	6.6	24.1
8	66	103.6	1.29	79	134	66	12.01	0.496	5.2	28.8
9	34	104.5	1.50	84	122	34	12.52	0.533	6.5	20.0
10	82	104.8	1.15	85	131	82	12.60	0.433	6.3	25.1
11	53	106.8	1.77	78	139	53	13.81	0.753	5.3	31.3
12	87	102.2	1.22	79	126	87	12.15	0.430	5.6	23.8
13	138	103.8	1.01	73	129	138	12.88	0.359	3.9	22.8
14	161	109.3	0.79	80	139	161	14.81	0.332	5.8	28.8
15	78	106.3	1.33	82	135	78	13.95	0.547	6.0	27.3

Table 17. Continued.

Year,	Length					Weight				
week	*n*	Mean	SE	Min.	Max.	*n*	Mean	SE	Min.	Max.
1999:										
16	19	105.7	2.22	89	124	19	13.24	0.760	8.1	20.7
17	127	107.0	1.18	79	142	127	14.71	0.476	6.1	32.9
18	117	108.0	1.18	84	140	117	15.06	0.481	7.0	32.5
19	82	109.8	1.30	82	134	82	15.93	0.554	5.7	29.4
20	45	108.3	1.76	80	132	45	15.45	0.715	6.2	25.7

Table 18. Mean fork lengths (mm) by tag group of juvenile spring chinook salmon PIT-tagged on the upper Grande Ronde River, Catherine Creek, and Lostine River and recaptured at the Grande Ronde Valley or Wallowa Valley traps during spring 1999. Standard errors are in parentheses.

Trap site of tagging,	Mean fork length		
tag group	*n*	Tagging	Recapture
Upper Grande Ronde			
Fall	19	90.2 (2.40)	99.2 (2.35)
Spring	33	89.6 (1.78)	98.5 (1.48)
Catherine Creek			
Fall	8	86.4 (3.44)	117.9 (3.94)
Spring	20	93.9 (1.16)	113.8 (1.62)
Lostine River			
Fall	108	95.3 (0.87)	95.3 (0.87)
Spring	79	95.3 (0.96)	96.2 (1.00)

Migration Timing and Survival to Lower Granite Dam

Juvenile Trapping Studies

At the upper Grande Ronde River trap, we PIT-tagged 500 fall- and 535 spring-migrating chinook salmon juveniles that were not previously tagged. At the Catherine Creek trap, we PIT-tagged 656 fall- and 502 spring-migrating spring chinook salmon juveniles that were not previously tagged. During winter, we captured and PIT-tagged an additional 420 and 494 juveniles from rearing areas upstream for the upper Grande Ronde River and Catherine Creek traps, respectively. At the Lostine River trap, we PIT-tagged 504 fall- and 600 spring-migrating juvenile chinook salmon that were not previously tagged. During winter, we captured and PIT-tagged an additional 491 juveniles from rearing areas above the trap.

PIT-tagged fish from the upper Grande Ronde River (*n* = 138) were detected at Lower Granite Dam from 31 March to 20 June 1999, with 50% of the fish passing the dam by 5 May 1999 (Figure 8). PIT-tagged fish from Catherine Creek (*n* = 130) were detected at Lower Granite Dam from 19 April to 9 July 1999, with 50% of the fish passing the dam by 24 May 1999 (Figure 9). These dates are within the migration windows observed for fish from the upper Grande Ronde and Catherine Creek in past years. PIT-tagged fish from the Lostine River (*n* = 167) were detected at Lower Granite Dam from 31 March through 8 July 1999, with 50% of the fish passing the dam by 4 May 1999 (Figure 10).

Travel times to Lower Granite Dam for fish tagged during the spring migration at the upper Grande Ronde River trap ranged from 16 to 92 d with a mean of 43.7 d (*n* = 83). Travel times for fish tagged at the Catherine Creek trap ranged from 21 to 90 d with a mean of 60.8 d (*n* = 54). Travel times for fish tagged at the Lostine River trap ranged from 5 to 61 d with a mean of 27.9 d (*n* = 88). Data from the past three years indicate travel times have remained relatively constant for fish from these three populations. Fish from the Grande Ronde River population have exhibited the most variation, with means ranging from 44 to 57 d.

Median arrival dates at Lower Granite Dam for fish PIT-tagged at the upper Grande Ronde River trap during fall, winter, and spring were 29 April, 27 May, and 4 May 1999, respectively (Figure 8). Medians for fish PIT-tagged at the Catherine Creek trap during fall, winter, and spring were 23 May, 29 May, and 21 May 1999, respectively (Figure 9). Medians for fish PIT-tagged at the Lostine River trap during fall, winter, and spring were 26 April, 10 May, and 12 May, respectively (Figure 10). As in past years, the earliest of the upper Grande Ronde River, Catherine Creek, and Lostine River fish to be detected were those that were tagged during fall and overwintered in lower rearing areas. Unlike past years, there was little difference in the time of detection at Lower Granite dam between seasonal tag groups originating from Catherine Creek. Although the earliest fish detected from Catherine Creek was a fall migrant, only one day separated it from the earliest spring migrant detected at Lower Granite dam. Additionally, the median arrival date for spring migrants occurred one day earlier than fall migrants originating from Catherine Creek (Figure 9).

Detection rates by tag group for upper Grande Ronde River fish ranged from 10% for fish tagged during winter to 50% for fish tagged during the spring migration (Table 19). We anticipated that spring-tagged fish would have the highest detection rate since this group is the only tag group not subject to overwinter mortality after tagging. Fall-tagged fish from the upper Grande Ronde were detected at a higher rate than winter-tagged fish ($\chi^2 = 38.44$, $P < 0.001$), indicating better overwinter survival for fish that moved out of the upper rearing areas and overwintered in the Grande Ronde Valley habitat. This finding is consistent with past years when we have been able to compare fall- and winter-tagged fish. A comparison of the detection rates of winter- and spring-tagged fish from the upper Grande Ronde indicated that overwinter survival of fish remaining in upper rearing areas was approximately 20% for BY 97. This rate is comparable to past estimates that have ranged from 22 to 33%.

Detection rates by tag group for Catherine Creek fish ranged from 17% for fish tagged during fall to 36% for fish tagged during the spring migration (Table 19). Fall-tagged fish were detected at a lower rate than winter-tagged fish ($\chi^2 = 6.56$, $P = 0.01$), indicating better overwinter survival for fish that remained in upper rearing areas than those that overwintered in the Grande Ronde Valley. There appears to be no distinct pattern for survival advantage among Catherine Creek fish. In some years it appears to be a better strategy to overwinter in upper rearing areas, in other years the opposite is true, and in still others, there appears to be no difference in the survival of fish overwintering in upper versus lower rearing areas. Comparing detection rates of winter- and spring-tagged fish from Catherine Creek indicates that overwinter survival of fish remaining in the upper rearing areas was approximately 65% for BY 97. This rate is greater than any observed previously during the study (BY 93: 53%; BY 94: 32%; BY 95: 19%; and BY 96: 50%).

Detection rates by tag group for Lostine River fish ranged from 28% for fish tagged during winter to 61% for fish tagged during the spring migration (Table 19). Detection rates of fall and winter tag groups from the Lostine River were not different ($\chi^2 = 2.93$, $P > 0.05$), indicating there was no difference in overwinter survival between fish remaining in the upper rearing areas of the Lostine River and those leaving the Lostine River in the fall to overwinter in areas downstream. Comparing detection rates of winter- and spring-tagged fish from the Lostine River indicates that overwinter survival of fish remaining in the upper rearing areas was approximately 47% for BY 97. This rate is within the range observed during the two previous years of the study for the Lostine River (BY 95: 53% and BY 96: 44%).

In all populations, fish that leave upper rearing areas in fall arrive at Lower Granite Dam earlier than fish that leave in spring. As environmental conditions in the Snake and Columbia rivers vary from year to year, the survival rates of fish utilizing the different early life history strategies may vary as fish arrive at the dams during different periods of the migration season. These differences point out the need to maintain the diversity of life history strategies observed in the spring chinook salmon of the Grande Ronde River Basin.

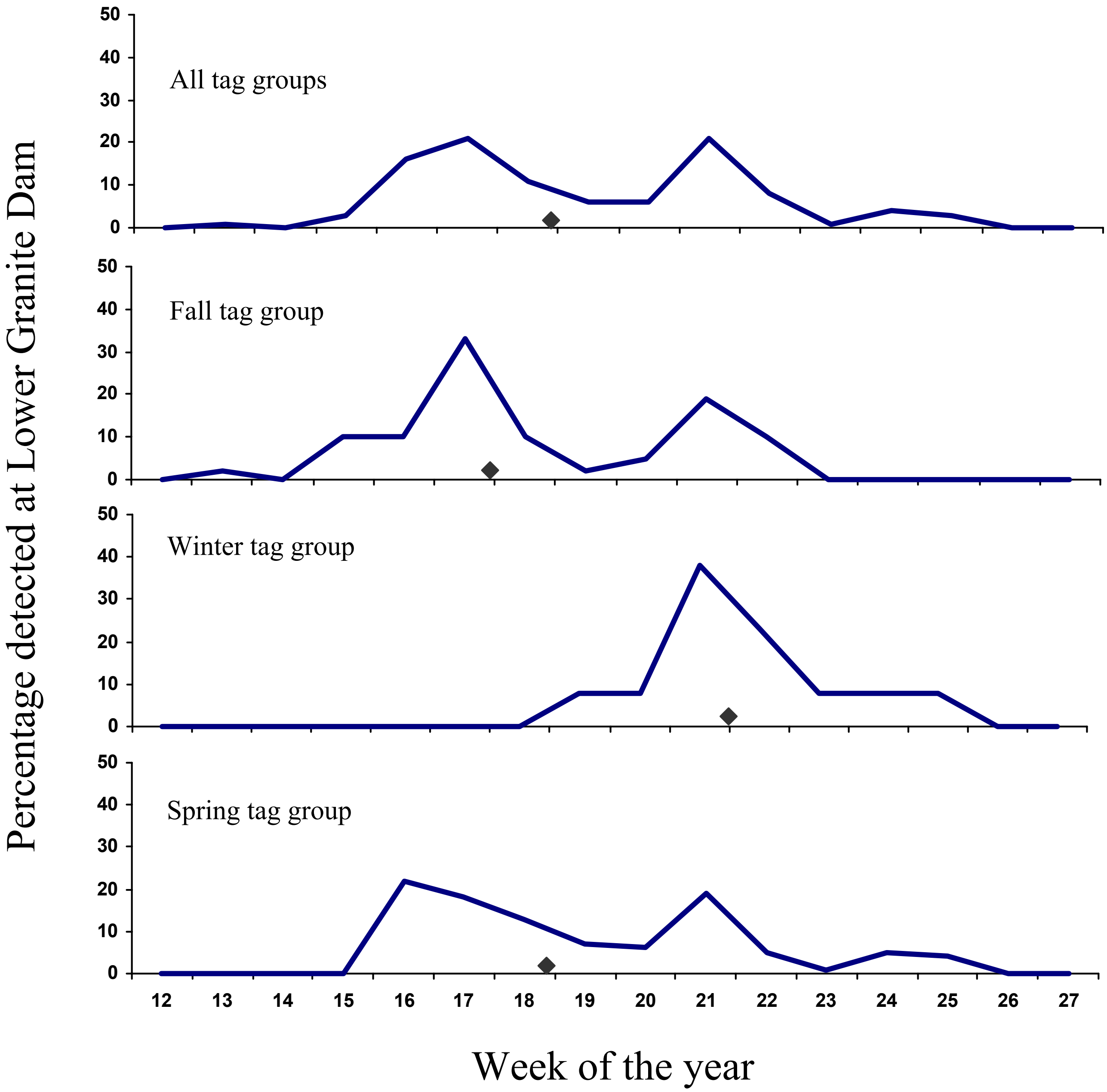

Figure 8. Migration timing at Lower Granite Dam for juvenile spring chinook salmon PIT-tagged on the upper Grande Ronde River by tag group, during the 1999 migration year. ◆ = median arrival date. Data were expanded for spillway flow.

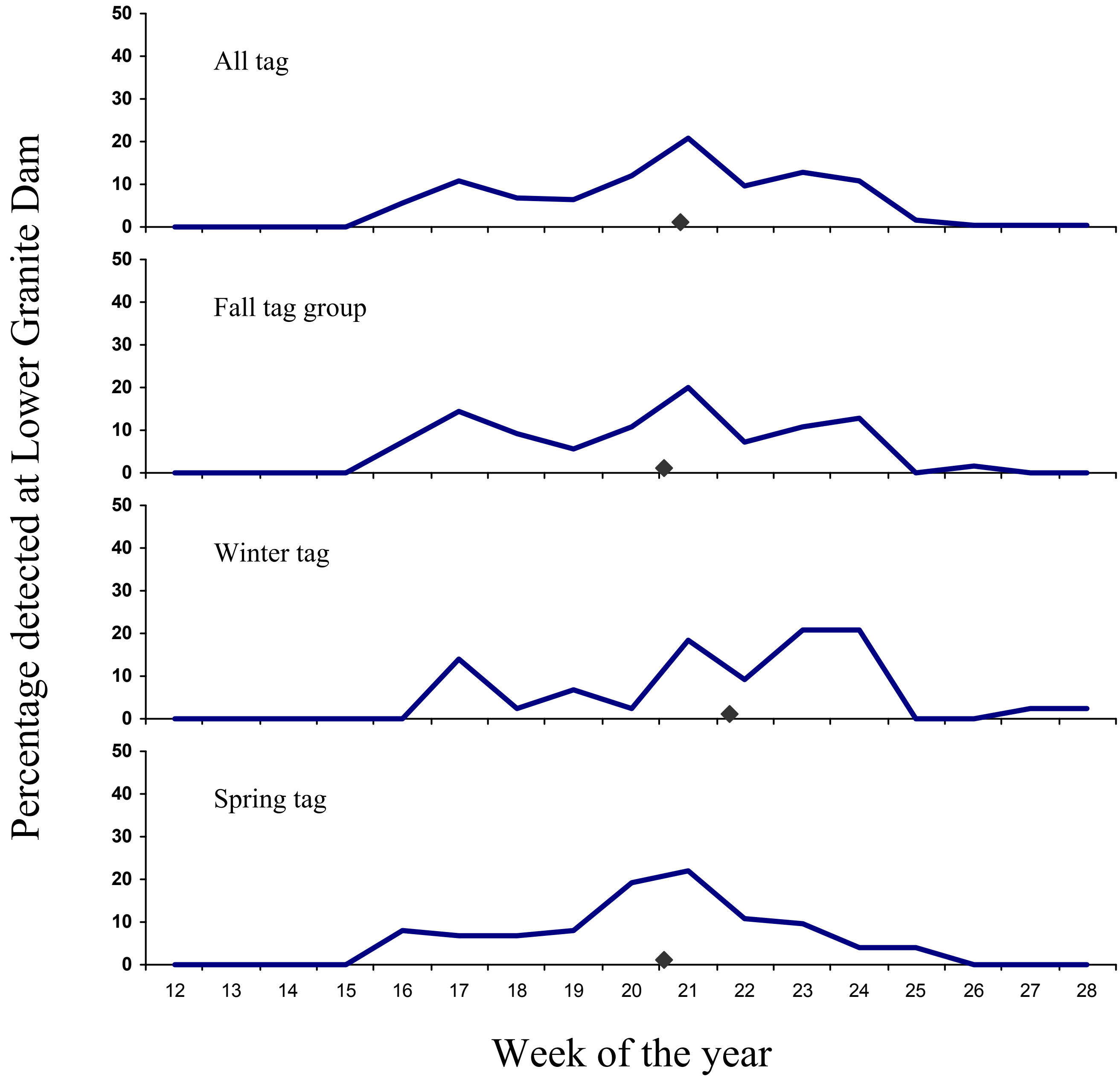

Figure 9. Migration timing at Lower Granite Dam for juvenile spring chinook salmon PIT-tagged on Catherine Creek by tag group, during the 1999 migration year. ◆ = median arrival date. Data were expanded for spillway flow.

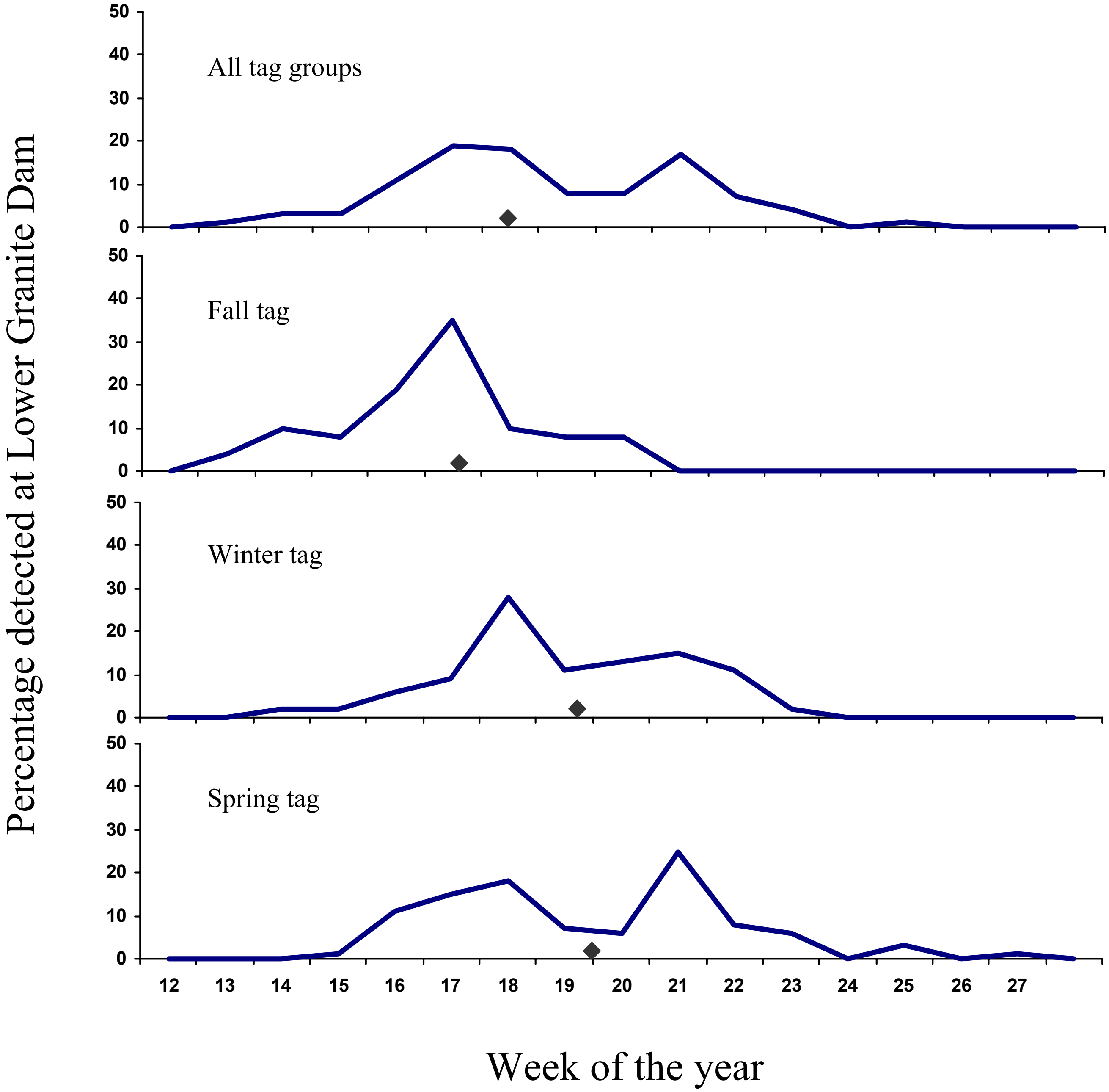

Figure 10. Migration timing at Lower Granite Dam for juvenile spring chinook salmon PIT-tagged on the Lostine River by tag group, during the 1999 migration year. ◆ = median arrival date. Data were expanded for spillway flow.

Table 19. Detection rates of spring chinook salmon PIT-tagged on the upper Grande Ronde River, Catherine Creek, and the Lostine River by group and dam site during the 1999 migration year. Detection rates are presented as a percentage of the total fish released.

Stream and group	Number released	Lower Granite	Little Goose	Lower Mon.	McNary	John Day	Bonn.	Total
Grande Ronde River								
Fall	500	8.4	9.8	4.4	2.2	1.0	0.2	26.0
Winter	420	3.1	4.0	2.1	0.5	0.0	0.2	10.0
Spring	535	15.5	22.1	7.7	2.2	2.2	0.7	50.5
Catherine Creek								
Fall	656	6.3	7.2	2.0	1.1	0.6	0.3	17.4
Winter	494	7.1	9.3	5.3	0.8	1.0	0.0	23.5
Spring	502	10.8	15.5	6.6	1.8	0.6	0.8	36.1
Lostine River								
Fall	501	8.0	16.6	5.8	2.0	0.8	0.2	33.3
Winter	491	7.9	14.1	4.7	0.8	0.6	0.2	28.3
Spring	600	14.7	30.3	10.7	3.0	1.0	0.8	60.5

Parr Studies

Chinook salmon parr that were captured with seines and PIT-tagged on Catherine Creek and the Imnaha, Lostine, and Minam rivers in summer 1998 were detected at Lower Granite Dam over a 90 d period from 29 March to 26 June 1999 (Figure 11). The migratory period of individual populations ranged from 48 d (Imnaha River) to 64 d (Minam River) in length. Median dates of migration ranged from 29 April (Minam River) to 29 May (Catherine Creek). Migration timing differed significantly among populations ($P < 0.001$). Fish from the Imnaha and Minam rivers passed Lower Granite Dam significantly earlier than fish from Catherine Creek. There were no significant differences among fish from the Imnaha, Lostine, and Minam rivers, or between fish from the Lostine River and Catherine Creek.

Our findings in 1999 were generally consistent with past observations (Sankovich et al. 1996, Walters et al. 1997; Tranquilli et al. 1998). For each population except that from Catherine Creek, the median date of migration in 1999 fell within the range in medians observed from 1993 to 1998. The median for the Catherine Creek population was 6 d later than the latest median observed previously. Comparisons of timing between populations yielded results that had been obtained in the past, except that in each year prior to 1999, there were significant differences between the Lostine River and Catherine Creek populations. That timing has and continues to differ among 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. Maintenance of the remaining populations, their specific life histories, and unique genetic characteristics is critical to the continued persistence of chinook salmon in northeast Oregon and elsewhere in the Snake River basin.

Of the parr PIT-tagged on Catherine Creek and the Imnaha, Lostine, and Minam rivers in 1998, 14.1, 14.2, 17.2, and 17.1% were detected in the hydrosystem in 1999 (Table 20). These detection rates tended to fall within the mid-range of detection rates observed for each population in past years.

During the 1999 migration, there were no detections of any age 2+ smolts that had been PIT-tagged as parr on Catherine Creek and the Imnaha and Minam rivers in summer 1997 (Sankovich et al. 1997). We estimated previously that there were no immature, age 1+ parr (i.e., fish that would presumably become age 2+ smolts) in Catherine Creek in summer 1998 (Tranquilli et al. 1998). To date, the information we have gathered regarding age 2+ smolts indicates this life history is rare among northeast Oregon chinook salmon. Of 27,250 parr PIT-tagged on Catherine Creek and the Grande Ronde, Imnaha, Lostine, Minam, and Wenaha rivers from 1992 to 1997 (Walters et al. 1992, 1997; Sankovich et al. 1996, 1997), only 11 (0.04%) were detected in the hydrosystem as age 2+ smolts. Eight of these fish originated in the upper Grande Ronde River and all but one were detected in 1995. This may indicate that the age 2+ smolt life history is expressed at varying levels among populations and is dependent upon conditions which occur infrequently. Further investigation will be required to address these issues.

Another question that needs to be resolved regarding age 2+ smolts is whether they arise from immature or mature, age 1+ parr, or both. We assumed they arise from immature, age 1+ parr and, therefore, assessed the frequency of the age 2+ smolt life history in part by determining the abundance of immature, age 1+ parr in Catherine Creek and the Lostine River. Our research indicated that there were no immature, age 1+ parr in those streams in 1998 or 1999 (Tranquilli et al. 1998; see **Results and Discussion**, Egg-to-parr Survival, Abundance, and Age Composition of Parr in Summer in this report). These results are not surprising given the apparent rarity of the age 2+ smolt life history. However, the question that arises is this: Can we conclude from our findings that no age 1+ parr were on a course to become age 2+ smolts, or, to do so, would information on the fate of mature, age 1+ parr also be required? Ricker (1972), who cited two studies (Gebhards 1960 and Burck 1967), suggested that maturation of age 1+ parr is always followed by death. It is conceivable, however, that some mature, age 1+ parr recondition and migrate seaward the following spring. This has been shown to occur for mature, age 0+ parr (Ricker 1972). Furthermore, at our upriver traps, we regularly capture mature, age 1+ parr that appear outwardly to be in excellent condition, weeks after the spawning season. In the future it may be prudent to attempt to determine the fate of these fish.

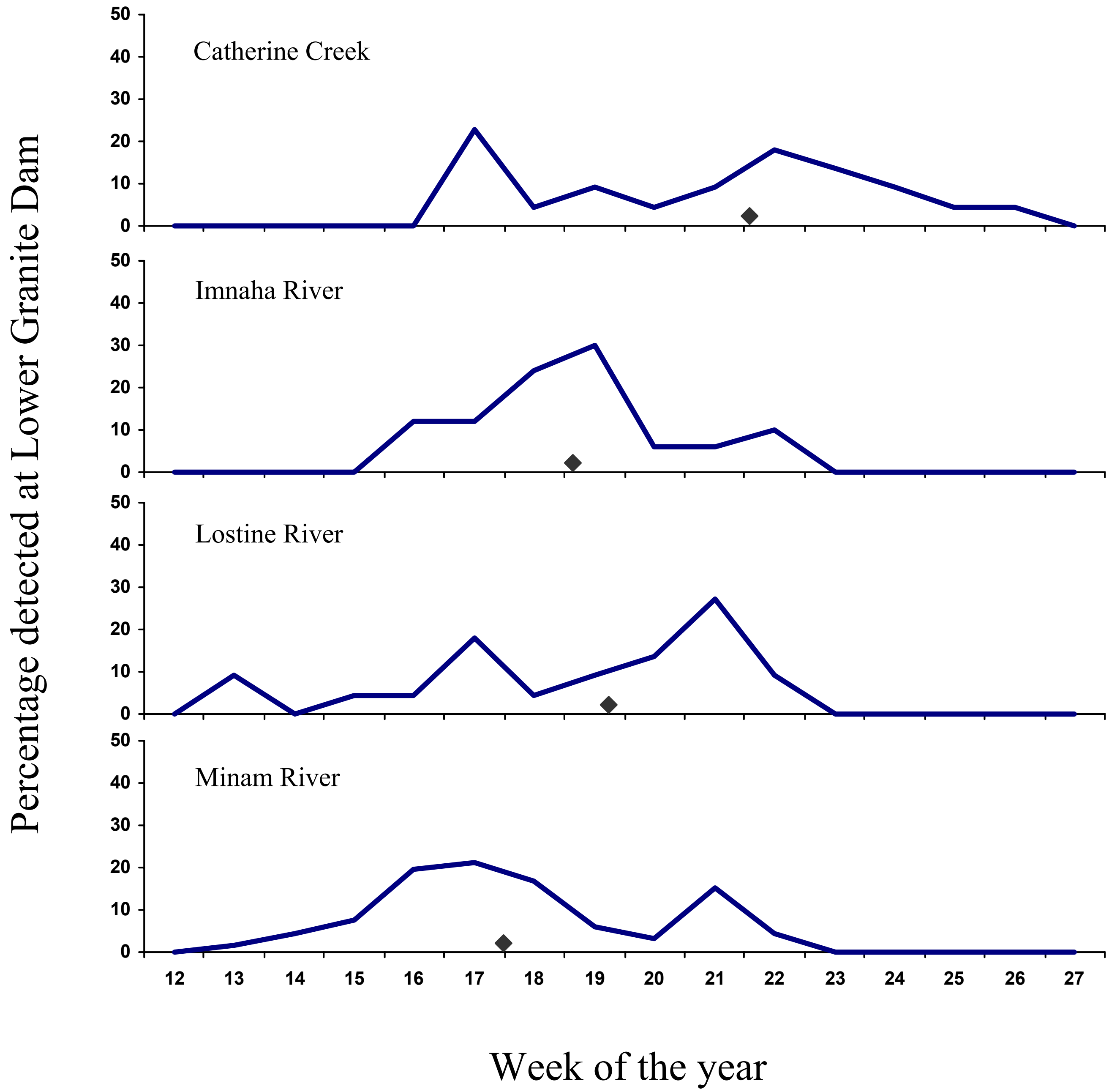

Figure 11. Migration timing at Lower Granite Dam for juvenile spring chinook salmon PIT-tagged as parr on Catherine Creek and the Imnaha, Lostine, and Minam rivers during summer 1998. ◆ = median arrival date. Data were expanded for spillway flow.

Table 20. Detection rates in 1999 of spring chinook salmon PIT-tagged as parr on Catherine Creek and the Imnaha, Lostine, and Minam rivers in 1998.

Stream	Number released	Lower Granite	Little Goose	Lower Mon.	McNary	John Day	Bonn.	Total
Catherine Cr.	502	4.0	5.8	3.4	0.6	0.2	0.2	14.1
Imnaha R.	1,009	4.1	6.8	1.9	1.1	0.3	0.0	14.2
Lostine R.	506	3.8	8.9	2.6	1.0	1.0	0.0	17.2
Minam R.	1,006	5.0	7.7	3.5	0.6	0.2	0.1	17.1

Habitat Utilization

We surveyed 78 habitat units in 23 rkm during winter surveys on the Lostine River and observed 262 spring chinook salmon parr from Pole Bridge Picnic Area to the mouth (rkm 23-0). Parr were most abundant in dammed, alcove, and backwater pools and were generally found in low velocity habitat types (Table 21). We surveyed 115 habitat units in 32 rkm of the Lostine River during summer surveys and observed 2,219 spring chinook salmon parr rearing from Turkey Flat Campground to Williamson Campground (rkm 39-30) and from Pole Bridge Picnic Area to the mouth (rkm 23-0). Parr were observed in all habitat types and were most abundant in alcove and backwater pools (Table 22). Parr were generally found in low velocity habitat types.

Chinook salmon parr were more abundant in pools than glides or riffles during both summer and winter surveys. Maintenance and/or enhancement of existing pool habitat should be given priority in habitat restoration programs. In addition, increasing habitat diversity should be an important component of habitat management for threatened chinook salmon populations in northeast Oregon streams.

Table 21. Density (fish/100 m^2) of spring chinook salmon parr in the Lostine River (rkm 0-23) and mean water velocity (m/s) by habitat type during winter 1999.

Habitat type	*n*	Density	Water velocity
Pools:			
Alcove	2	29.72	0.000
Backwater	18	7.78	0.020
Dammed	1	46.23	0.113
Isolated	2	0.95	0.000
Lateral scour	12	1.31	0.284
Plunge	4	1.35	0.183
Straight scour	10	2.93	0.266
Glide	10	1.14	0.272
Rapid with boulders	5	0.00	0.653
Riffle	6	0.00	0.619
Riffle with pockets	8	0.21	0.439

Table 22. Density (fish/100 m^2) of spring chinook salmon parr in the Lostine River (rkm 0-23 and rkm 30-39) and mean water velocity (m/s) by habitat type during summer 1999.

Habitat type	*n*	Density	Water velocity
Pools:			
Alcove	5	153.18	0.040
Backwater	26	46.69	0.077
Isolated	5	6.71	0.136
Lateral scour	20	9.52	0.368
Plunge	6	4.80	0.746
Straight scour	13	4.53	0.550
Glide	5	2.71	0.389
Rapid with boulders	8	0.21	0.826
Riffle	13	1.40	0.783
Riffle with pockets	14	0.50	0.318

Future Directions

We will continue this early life history study of spring chinook salmon in Catherine Creek and the upper Grande Ronde, Lostine, and Wallowa rivers. In MY 2000, we will begin to piece together the components to build a life history model for spring chinook salmon in our study streams. In addition, we will begin to investigate the life history of summer steelhead in the Grande Ronde River Basin.

REFERENCES

Bisson, P. A., J. L. Neilson, R. A. Palmason, and L. E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low stream flow. Pages 62-73 *in* N. B. Armantrout, editor. Acquisition and utilization of aquatic habitat inventory information. American Fisheries Society, Bethesda, MD.

Bryson, D. 1993. Northeast Oregon Hatchery Grande Ronde River Management Plan. Final Report. Bonneville Power Administration, Portland, OR.

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

Burck, W. A. 1967. Mature stream-reared spring chinook salmon. Oregon Fish Commission Research Briefs 13(1):128.

Daniel, W. W. 1990. Applied Nonparametric Statistics, 2nd edition. PWS-Kent Publishing Company, Boston.

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

Gebhards, S. V. 1960. Biological notes on precocious male chinook salmon in Salmon River drainage. Progressive Fish-Culturist 22(3):121-123.

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

Hart, P. J. B., and T. J. Pitcher. 1969. Field trials of fish marking using a jet inoculator. Journal of Fish Biology 1:383-385.

Hutchings, J. A., and R. A. Myers. 1985. Mating between anadromous and nonanadromous Atlantic salmon, *Salmo salar*. Canadian Journal of Zoology 63:2219-2221.

Hutchings, J. A., and R. A. Myers. 1988. Mating success of alternative maturation phenotypes in male Atlantic salmon, *Salmo salar*. Oecologia (Berl.) 75:169-174.

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

Jonasson, B. C., R. W. Carmichael, and M. Keefe. 1996. Investigations into the early life history of naturally produced spring chinook salmon in the Grande Ronde River Basin. . Annual Progress Report. Bonneville Power Administration, Portland, OR.

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

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

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

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

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

Matthews, G. M., S. Achord, J. R. Harmon, O. W. Johnson, D. M. Marsh, B. P. Sandford, N. N. Paasch, K. W. McIntyre, and K. L. Thomas. 1992. Evaluation of transportation of juvenile salmonids and related research on the Columbia and Snake rivers, 1990. Report of the U.S. Army Corps of Engineers, Contract DACW68-84-H0034. National Marine Fisheries Service, Seattle.

Nickelson, T. E., J. D. Rodgers, S. L. Johnson, and M. F. Solazzi. 1992. Seasonal changes in habitat use by juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 49:783-789.

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

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

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

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

Ricker, W. E. 1972. Heredity and environmental factors affecting certain salmonid populations. Pages 19-160 *in* R.C. Simon and P.A. Larkin, editors. The stock concept in Pacific salmon. H. R. MacMillan lectures in fisheries, University of British Columbia, Vancouver.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Rodgers, J. D., M. F. Solazzi, S. L. Johnson, and M. A. Buckman. 1992. Comparison of three techniques to estimate juvenile coho salmon populations in small streams. North American Journal of Fisheries Management 12:79-86.

Rohlf, F. J. and R. R. Sokal. 1995. Statistical Tables, 3rd edition. W. H. Freeman and Company, New York.

Sankovich, P., R. W. Carmichael, and M. Keefe. 1995. Smolt migration characteristics and mainstem Snake and Columbia River detection rates of Grande Ronde and Imnaha River naturally produced spring chinook salmon. Annual Progress Report. Bonneville Power Administration, Portland, OR.

Sankovich, P. M., R. W. Carmichael, and M. Keefe. 1996. Smolt migration characteristics and mainstem Snake and Columbia river detection rates of PIT-tagged Grande Ronde and Imnaha river naturally produced spring chinook salmon. Annual Progress Report. Oregon Department of Fish and Wildlife, Portland, OR.

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

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

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

Thorpe, J. E., and R. I. G. Morgan. 1980. Growth-rate and smolting-rate of progeny of male Atlantic salmon parr, *Salmo Salar* L. Journal of Fish Biology 17:451-459.

Tranquilli, J. V., P. Sankovich, E. Van Dyke, B. C. Jonasson, M. Keefe, and R. W. Carmichael. 1998. Investigations into the early life history of naturally produced spring chinook salmon in the Grande Ronde River Basin. Annual Progress Report. Bonneville Power Administration, Portland, OR.

USACE (United States Army Corps of Engineers). 1975. Lower Snake River Fish and Wildlife Compensation Plan Special Report. U. S. Army Corps of Engineers, Walla Walla, WA.

USFS (United States Forest Service) and six co-author agencies. 1992. Upper Grande Ronde River Anadromous Fish Habitat Restoration and Monitoring Plan. U. S. Forest Service, Wallowa-Whitman National Forest, Baker, OR.

Walters, T. R., R. W. Carmichael, and M. Keefe. 1992. Smolt migration characteristics and parr-to-smolt survival of naturally produced spring chinook salmon in the Grande Ronde and Imnaha river subbasins. Annual Progress Report, Oregon Department of Fish and Wildlife, Portland, OR.

Walters, T. R., R. W. Carmichael, and M. Keefe. 1993. Smolt migration characteristics and mainstem Snake and Columbia River detection rates of Grande Ronde and Imnaha River naturally produced spring chinook salmon. Annual Progress Report, Oregon Department of Fish and Wildlife, Portland, OR.

Walters, T. R., R. W. Carmichael, and M. Keefe. 1994. Smolt migration characteristics and mainstem Snake and Columbia river detection rates of PIT-tagged Grande Ronde and Imnaha river naturally produced spring chinook salmon. Annual Progress Report. Oregon Department of Fish and Wildlife, Portland, OR.

Walters, T. R., R. W. Carmichael, M. Keefe, and P. Sankovich. 1997. Smolt migration characteristics and mainstem Snake and Columbia River detection rates of Grande Ronde and Imnaha River naturally produced spring chinook salmon. Annual Progress Report 1993, 1994, and 1995. Bonneville Power Administration, Portland, OR.