INFLUENCE OF WINTER CONCEALMENT HABITAT ON THE BEHAVIOR OF JUVENILE SPRING CHINOOK SALMON IN THE GRANDE RONDE RIVER BASIN, OREGON

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ABSTRACT

The goal of the project was to characterize the quality, quantity, and use of winter concealment habitat by juvenile spring Chinook salmon *Oncorhynchus tshawytscha* in hatching areas of the Grande Ronde River Basin, Oregon. The objectives of the project were to 1) assess the relationships between quality and quantity of winter concealment habitat, fish density and size of juvenile fish; and 2) determine when the juveniles shift to winter concealment behavior and identify the factors influencing that shift.

Most tagged fish that were redetected in the hatching areas of Catherine Creek (98%), Lostine (99%) and upper Grande Ronde (96%) rivers were in their original pool of capture. Catherine Creek and Lostine River pools generally contained densities less than two fish/m^2, and fish densities in upper Grande Ronde River pools were less than one fish/m^2. Monthly fish densities did not follow a regular trend in Catherine Creek, and increased September through January in Lostine and upper Grande Ronde rivers. Fish densities were significantly greater in Catherine Creek and Lostine River pools with the best winter concealment ranking (ANOVA; P = 0.0049 and 0.0378), but best and worst winter concealment pools did not differ significantly in the upper Grande Ronde River (ANOVA; P = 0.0623).

In the hatching areas, mean fork length increased each month in Catherine Creek and Lostine River and were similar each month in the upper Grande Ronde River, while specific growth rate decreased sharply by November-December in all three subbasins. Specific growth rate of tagged fish differed significantly among monthly growth periods in Catherine Creek (ANOVA; P = 0.0256), Lostine (ANOVA; P = 0.0012), and upper Grande Ronde rivers (ANOVA; P = 0.0063). However, differences were only confirmed when comparing earlier months to later months (Tukey's Studentized Range test; P < 0.05).

As in 2002, shorter less robust fish migrated out whereas longer more robust fish remained in the hatching areas of Catherine Creek. Mean fork length was significantly larger for fish that remained to overwinter in the hatching areas of Catherine Creek (ANOVA; P = 0.0188), but specific growth rate did not differ significantly (ANOVA; P = 0.2589). We were not able to complete this analysis for Lostine River because the trap was not operated and too few fish migrated out of the hatching area in the upper Grande Ronde River.

Weekly mean temperatures were similar across all Catherine Creek pools, and weekly mean temperatures fell below 1° C in seven of 20 weeks. In the Lostine River only pools 43 and 45 exceeded 10° C (two of 20 weeks) and dropped below 1° C (ten of 20 weeks) during sampling. Weekly mean temperatures were similar across all upper Grande Ronde River pools, and weekly mean temperatures fell below 1° C in twelve of 20 weeks. Week ending 4 November 2003 marked a noticeable decrease in weekly mean water temperature in all three subbasins.

Nocturnal index (NI > 50) indicated that fish shifted from primarily being active during the day to favoring night by November in Catherine Creek and the Lostine River, and by October in the upper Grande Ronde River. However, fish were observed during daytime snorkel surveys every month, even when daily mean water temperatures were less than 1° C. Cumulative detections of concealed fish increased October through December in all three subbasins.

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Objectives

1.   Assess the relationships between quality and quantity of winter concealment habitat, fish density and size of juvenile spring Chinook salmon *Oncorhynchus tshawytscha* in the Grande Ronde River Basin.

2.   Determine when juvenile spring Chinook salmon shift to winter concealment behavior, and identify the factors including water temperature, fish density and fish size, influencing the shift.

Accomplishments

We accomplished all of our objectives.

Findings

Initial habitat inventories identified 34 pooled habitats within the designated hatching areas of Catherine Creek, 30 in the Lostine River and 73 in the upper Grande Ronde River. Median pool surface areas were 158.5, 170.94 and 119.3 m^2 in each of the aforementioned subbasins, respectively. Median percentage of substrates larger than cobble was visually estimated to be 38% in Catherine Creek, 21% in the Lostine River and 10% in the upper Grande Ronde River. Median percentage of instream cover was visually estimated to be < 15% in each of the three subbasins. On average pool substrates larger than 10 cm diameter were estimated to be low to moderately embedded, and stream banks were primarily covered by vegetation and rock materials that provided poor resistance to erosion in all three subbasins.

Winter concealment habitat was measured in six randomly selected pools within designated hatching areas of Catherine Creek, Lostine and upper Grande Ronde rivers. Ranked winter concealment features in Catherine Creek generally achieved moderate to high scores (≥3) in every category except mean depth and the number of substrate pieces 10 to 24.9 cm/m2, which varied widely (scores 1 to 5), and percent instream cover, which was less than five percent of the entire pool area in four of the six pools measured. In the Lostine River, ranked winter concealment features for depth and velocity scored the highest ranking (5) 10 of 12 times while percent of instream cover scored low (1 or 2) in five of six pools. Although Lostine River pools were characterized as containing areas with high percentages of substrates < 6.3 cm in diameter, over 50% of the areas where substrates 10-24.9 cm diameter were present generally achieved embeddedness ratings that were 4 or 5. Upper Grande Ronde River typically exhibited high scores (4 or 5) for velocity features, but physical habitat and embeddedness typically scored low (1 or 2).

The total number of unique PIT-tagged juvenile spring Chinook salmon that were redetected in their original pool of capture in the hatching area was 265 of 698 in Catherine Creek, 272 of 675 in the Lostine River and 274 of 412 in upper Grande Ronde River. The corresponding total number of unique tagged fish redetected in pools other than their original

pool of capture was six, four and 12. Over 95% of the tagged fish observed outside of their original pool of capture in Catherine Creek were detected leaving the hatching area. Only one PIT-tagged fish was detected leaving the hatching area in the upper Grande Ronde River, and no fish were observed leaving the hatching area in the Lostine River because the trap was not operated September 2003 to January 2004. Estimates generated from redetections of tagged fish in rotary screw traps indicated that 271 ± 38 of 698 left the hatching areas of Catherine Creek and 2 ± 3 of 435 left the hatching areas of the upper Grande Ronde River by 31 January, 2003.

Juvenile spring Chinook salmon densities in pools in the hatching areas of Catherine Creek and the Lostine River were generally less than two fish/m^2, but densities in the upper Grande Ronde River never exceeded 0.75 fish/m^2. In Catherine Creek, fish densities in pools decreased as early as October, and all decreased by December. Fish densities in the Lostine River increased September through January, and in the upper Grande Ronde River fish densities increased September through December. Both Catherine Creek and the Lostine River contained fish densities in pools with the best winter concealment ranking that were significantly greater than fish densities in the worst ranked pools (ANOVA; P = 0.0049 and P = 0.0378), but in the upper Grande Ronde River fish densities were not significantly different (ANOVA; P = 0.0623).

Mean fork lengths of tagged fish subsequently recaptured in pools in the hatching area of Catherine Creek, Lostine and upper Grande Ronde rivers were shorter than untagged fish in most months. However, monthly mean fork length of tagged and untagged fish did not differ significantly (ANOVA; P = 0.0641, 0.1016 and 0.9857). The influences of tag group and month on mean fork length were not significant in Catherine Creek (Factorial ANOVA; P = 0.2546), Lostine (Factorial ANOVA; P = 0.1447), or upper Grande Ronde rivers (Factorial ANOVA; P = 0.9983).

Tagged fish that reared in hatching areas of Catherine Creek, Lostine and upper Grande Ronde rivers had positive growth rate during all individual growth periods. Specific growth rate generally deceased through December in each subbasin. Specific growth rate differed significantly among months in Catherine Creek (ANOVA; P = 0.0256), Lostine (ANOVA; P = 0.0012), and upper Grande Ronde rivers (ANOVA; P = 0.0063).

Mean fork lengths of tagged fish present in the hatching areas of Catherine Creek were significantly longer than tagged fish that migrated out of the hatching areas during the same month (ANOVA; P = 0.0188). The influences of migrant group and month on mean fork length were significant (Factorial ANOVA; P = 0.0017). This analysis could not be conducted for the other two subbasins because the Lostine trap was not operated, and only one fish migrated out of the hatching area in the upper Grande Ronde River September through January 2004.

Tagged fish captured in the hatching areas of Catherine Creek had a higher mean specific growth rate than tagged fish that migrated out of the hatching areas. Mean specific growth rate declined October to December for fish that reared in the hatching area, and did not follow a consistent pattern for fish that migrated. Specific growth rate did not differ significantly among tagged fish that remained in the hatching areas and those that migrated out for all growth periods (ANOVA; P = 0.2172).

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Water temperatures were logged 15 September 2003 through 31 January 2004 in Catherine Creek, Lostine and upper Grande Ronde rivers. Weekly mean water temperatures exceeded 10° C prior to week ending 4 October 2003 in all six pools in Catherine Creek, in pools 43 and 45 of the Lostine River during weeks ending 30 September and 4 October 2003, and did not exceeded 10° C during any week in the upper Grande Ronde River. Weekly mean water temperatures were < 1° C in seven of the 20 weeks that we sampled in Catherine Creek, 12 of 20 weeks in upper Grande Ronde River, and only pools 43 and 45 in the Lostine River ever achieved weekly mean water temperatures < 1° C (ten of 20 weeks).

Fish began to favor being active at night in November (Nocturnal Index ≥ 50), and were most active in pools at night by January in Catherine Creek. Fish began to favor being active at night in October, and were most active at night in December in Lostine and upper Grande Ronde rivers. However, we observed fish during daytime snorkel counts in every month that we sampled. We detected 20, 69 and 41 PIT-tagged fish concealed under cobbles, macrophytes and wood or root wad structure in Catherine Creek, Lostine and upper Grande Ronde rivers, respectively. Detections of concealed fish increased October through December in Catherine Creek and upper Grande Ronde River, and October through January in Lostine River.

Management Implications and Recommendations

The majority of the pools sampled in the Grande Ronde Basin scored low in terms of available physical habitat within the wetted channel and embeddedness. Many other investigations (Lister and Genoe 1970; Rimmer et al. 1983; Hillman et al. 1987) have observed increased use of physical habitat by juvenile spring Chinook salmon that rear where it is available. Introducing substrate pieces (> 10 cm diameter), root wad or overhanging bush structures that remain adequately scoured within the wetted channel, could enhance rearing conditions in the basin. Since juvenile spring Chinook salmon frequented shallow (20-60 cm) lower velocity (< 0.25 m/s) habitats, reestablishing instream structures that promote and maintaining these conditions could enhance the quality and quantity of pools in the basin.

Most of the PIT-tagged juvenile spring Chinook salmon recaptured between September and January remained in their original pool of tagging. This indicates that some fish in the Grande Ronde Basin utilize the same pool during late summer, fall and winter. Pool features that juvenile spring Chinook salmon were observed using included depth (> 40 cm) and velocity (< 0.5 m/s) for summer drift and feeding stations, physical structure (e.g. root wads, live-overhanging vegetation, beaver dens) that accommodated shifts in behavior associated with decreasing water temperatures, shallow (20-60 cm) low velocity (< 0.25 m/s) areas, and substrates (> 10 cm diameter) that provided interstitial spaces for concealment opportunities. Therefore, future enhancement projects that incorporate these features could help to maintain and provide habitats that may accommodate fish during multiple rearing phases.

Juvenile spring Chinook salmon that remained in the hatching areas of Catherine Creek were significantly larger than those that left to overwinter elsewhere. The relationship between fish biomass and density resembled the theoretical principle of self-thinning (Bolin et al. 1994; Fréchette et al. 1995) suggesting that competition driven mechanisms may be regulating fish populations in hatching areas of Catherine Creek at a predictable level. This may indicate that

present hatching area habitats are reaching carrying capacity and would not be able to sustain increases in population densities. Therefore, achieving basin wide enhancement goals may require implementing research and monitoring that identifies ecological relationship related to space and foraging behavior, as well as enhancement projects that create habitat features used by fish during all rearing phases. Conducting mass-density analysis that involves other aquatic species may provide information relative to ecosystem relationships and thus more effectively guide enhancement activities in the subbasin.

INTRODUCTION

Many researchers have reported distinct annual patterns of emigration exhibited by juvenile Chinook salmon *Oncorhynchus tshawytscha* fry, pre-smolts and smolts. Fall-run (ocean-type) Chinook salmon migrate seaward during their first year of life, whereas spring-run (stream-type) Chinook salmon reside in freshwater for more than a year before moving seaward (Healey 1991). Although spring Chinook salmon do not migrate to the ocean immediately, their movement patterns within freshwater habitats differ within and among populations and basins.

In Catherine Creek, the Lostine River and upper Grande Ronde River, Oregon (all subbasins within the Grande Ronde River basin) some juvenile spring Chinook salmon overwinter in hatching areas whereas others migrate downstream to lower river habitats well before their seaward migration (Jonasson et al. 1999). The factors that influence whether presmolt spring Chinook salmon remain in hatching areas or leave to overwinter in lower river habitats have not been extensively evaluated.

When salmonid fry emerge from the gravel, their first movements are typically downstream. This downstream movement may result from the influence of flow or from an innate tendency to migrate (Chapman 1962; Mason and Chapman 1965; Reimers 1970). Their small size and weak swimming capability may limit their ability to hold position in a stream, so they tend to move with the current until they encounter suitable habitat. Fry typically reside on stream margins in low velocity habitat (Chapman 1962; Everest and Chapman 1972).

As spring Chinook salmon fry grow larger, they move from stream margins to deeper waters with higher velocities and larger substrates, often further from cover (Lister and Genoe 1970; Everest and Chapman 1972; Hillman et al. 1987). This foraging adaptation positions them where invertebrate drift is readily available (Everest and Chapman 1972).

As winter approaches, juvenile salmonids and pre-smolts remaining in freshwater shift from actively feeding during the day to concealing their position during the day and emerging to feed at night (Hartman 1965; Chapman and Bjornn 1969; Bustard and Narver 1975; Hillman et al. 1987; Cunjak 1988; Contor 1989; Riehle and Griffith 1993). This shift typically begins in September and October (Riehle and Griffith 1993), but can be earlier or later depending on climatic factors and river water temperatures. In Catherine Creek, the Lostine River and the upper Grande Ronde River, subyearling spring Chinook salmon have completed this shift sometime before December (Jonasson et al. 1999).

Several studies indicate that water temperature is a key factor influencing a shift to winter concealment by presmolt spring Chinook salmon. Although temperatures associated with the shift have been found to vary among populations and species (Bustard and Narver 1975; Rimmer et al. 1983; Chisholm et al 1987; Hillman et al. 1987; Taylor 1988; Jakober et al. 1998; Meyer and Gregory 2000), most shifts have occurred at water temperatures < 10° C. A number of researchers have associated daily mean temperatures between 4 and 10° C with a shift from an active pattern during warm periods to a daytime concealment pattern during cold periods (Hartman 1965; Chapman and Bjornn 1969; Campbell and Neuner 1985; Hillman et al. 1987; Contor 1989; Riehle and Griffith 1993). Bustard and Narver (1975) reported that as

temperatures fell from 9° C to 2° C, coho *Oncorhynchus kisutch* and steelhead *Oncorhynchus mykiss* moved closer to cover.   This shift has been shown to occur in September in other Snake River systems (Bjornn 1971; Riehle and Griffith 1993). Taylor (1988) found that coho salmon and Chinook salmon in laboratory stream troughs were more commonly associated with cover at water temperatures of 2° C than at 12° C, and concluded that decreasing water temperatures in fall stimulated the shift. Riehle and Griffith (1993) observed that rainbow trout *Oncorhynchus mykiss* in Silver Creek, Idaho shifted from actively feeding in mid-channel habitats during the day to concealing their position during the day and coming out to feed at night even though chironomids were abundant in the daytime drift.

Emigration from hatching areas is often associated with movement to overwintering habitats downstream. Bjornn (1971, 1978) reported that habitats in upper stream sections of Big Spring Creek, a tributary to the Lemhi River, Idaho, had a higher holding capacity in summer than winter. He reported that 80% of the spring Chinook salmon in Big Spring Creek migrated downstream in fall as presmolts, suggesting that they were destined for overwinter habitats in the Lemhi River (Bjornn 1978).   In the Grande Ronde Basin, the proportion of fall migrants varied among years for each subbasin population. In the upper Grande Ronde the proportion of spring Chinook salmon that migrated in fall 1994-1999 ranged from 1 to 29% (mean, 13.7%), but fish that migrated in fall survived at a significantly higher rate than fish that remained to overwinter in hatching areas (paired t-test: T= 7.09, $P = 0.001$ df = 4). In the Lostine River (1998-2001), the proportion of fish that migrated in fall ranged from 57 to 80% (mean, 66.0%), and they survived at a significantly higher rate than fish that remained to overwinter in hatching areas (paired t-test: T= 7.98, $P = 0.002$ df = 3). In Catherine Creek (1995-1999), the proportion of fish that migrated in fall ranged from 49 to 76% (mean, 61.2%), but there was no consistent survival advantage between overwintering strategies (paired t-test: T= 0.83, $P = 0.222$ df = 5) (ODFW unpublished). In view of these observed differences in emigration patterns among subbasins, further investigation is needed on the qualitative and quantitative factors that influence whether pre-smolts overwinter in hatching areas or emigrate.

The quality and quantity of available winter concealment habitat within hatching areas may be a critical factor in the decision of whether to remain or emigrate. Optimal winter habitats for juvenile spring Chinook salmon require concealment cover (Hillman et al. 1987; Riehle and Griffith 1993). Fish utilize a variety of cover types for overwintering habitat, including interstial spaces amid the substrate (Hillman et al. 1987; Cunjak 1988), woody debris, root wads (Bustard and Narver 1975), submerged sedges, overhanging banks and vegetation (Hillman et al. 1987). Cunjak (1988) found that Atlantic salmon *Salmo salar* were consistently found hiding beneath rocks between 16.8 and 23.0 cm mean diameter. Griffith and Smith (1993) found cutthroat *Oncorhynchus clarki* and brown trout *Salmo trutta* were found amid cobble substrates >20 cm in diameter and were less abundant in areas heavily embedded with fine sediment. Meyer and Griffith (1997b) used cobbles 20-40 cm in diameter to assess use by steelhead in varying concealment habitat quality and found that significantly more steelhead remained in wire-mesh enclosures when more concealment cover was available. Hillman et al. (1987) introduced cobble habitat to a highly sedimented Idaho stream and found that significantly more spring Chinook salmon subsequently used the habitat in winter. Gregory and Griffith (1996a) used simulated interstitial spaces within enclosures in a stream and found that rainbow trout did not conceal themselves in spaces that were narrower than the width of test fish with extended pectoral fins,

and taller than the height of the fish with an extended dorsal fin. Several researchers have defined similar relationships between winter concealment habitat for other salmonid species, both in the field and in quasi-natural laboratory studies (Bustard and Narver 1975; Rimmer et al. 1983; Cunjak and Power 1986; Chisholm et al. 1987; Cunjak 1988; Griffith and Smith 1993; Heggenes et al. 1993; Riehle and Griffith 1993; Smith and Griffith 1994; Gregory and Griffith 1996a, 1996b; Erkinaro and Gibson 1997; Meyer and Griffith 1997a, 1997b; Jakober et al. 1998; Simpkins et al. 2000).

If overwintering habitat is limited, one factor that would influence the decision to overwinter or emigrate is density of fish in relation to the carrying capacity of the habitat. High densities of juvenile salmonids have been shown to result in the increase of emigration from rearing habitats (Chapman 1962; Mason and Chapman 1965; Bjornn 1971; Everest and Chapman 1972; Hillman et al. 1987; Keeley 2001). Chapman and Bjornn (1969) suggested that social interaction was an important mechanism for distributing individuals of nearly equal size in available habitats. Lister and Genoe (1970), however, found differences in spawning and emergence timing played an important role in segregation among similar species. Bjornn (1971) suggested that density only modified basic migration patterns rather than causing the movement, because some fish moved downstream no matter what fish densities existed. Similarly, Mason and Chapman (1965) found that early emerging coho salmon were larger and tended to remain in an artificial stream channel, but suggested factors other than size, aggressive behavior and food availability determined residency since very large fish migrated out of stream channels. Keeley's (2001) research with artificial stream channels indicated that food and space were important factors shaping demographic changes in salmonid populations, but that neither exclusively limited abundance.

Two other factors that may influence a decision to overwinter in the hatching area or emigrate are fish size and growth rate. Results of studies relating growth and size of fish to tendency to emigrate have been sometimes seen as contradictory and confusing, in part because of the different responses of pre-smolts and smolts, and in part because of the influence of other factors such as habitat quality and fish density. Reimers and Loeffel (1967) found that slower-growing fall Chinook salmon remained in the stream longer than faster-growing fish. Similarly, Major and Mighell (1969) observed that within the same year the average size of yearling smolts migrating downstream in the Yakima River decreased with time and suggested that larger smolts migrated first. In contrast, Bell (1958) observed that the larger fish of one group of smolts in the Snake River were caught later than smaller fish. Mains and Smith (1964) found no systematic change in smolts size with time. Keeley (2001) found that steelhead that migrated from stream channels were more likely to be smaller and in poorer health than fish that remained. The differences reported in these studies may have been influenced by the size of the system that these fish originated from, the quality and quantity of available habitat, fish density, and other factors.

Spring Chinook salmon in the Grande Ronde Basin have declined precipitously from historic levels, and thus were included with other Snake River populations to be listed as threatened under the Endangered Species Act (October 1992). Poor overwinter survival due to degraded habitat complexity has been implicated as one cause for the decline in the basin. It has been estimated that 80% of historic anadromous salmonid habitat in the upper Grande Ronde

River has been degraded (USFS 1992). Bryson (1993) identified sedimentation, poor thermal buffering, riparian degradation and loss of pool habitats as problems confronting salmon recovery efforts in the Grande Ronde Basin. The proposed research seeks to better understand critical relationships between these problems in basin hatching areas and juvenile spring Chinook salmon overwintering behavior.

GOAL AND OBJECTIVES

The goal of the project was to determine the quality and quantity of winter concealment habitat in selected spring Chinook salmon upper rearing areas, and quantify and characterize its use by juvenile spring Chinook salmon in the Grande Ronde subbasin. The objectives were to 1) assess the relationships between quality and quantity of winter concealment habitat, fish density and size of fish in the Grande Ronde Basin, and 2) determine when juvenile fish shifted to winter concealment behavior, and identify the factors, including water temperature, fish density and fish size, that influenced that shift.

STUDY AREA

The Grande Ronde River Basin is located in northeastern Oregon and southwestern Washington (Figure 1). The Basin encompasses 10,537 km^2, and is formed by the Wallowa and Blue Mountain ranges (Jaindl et al. 1996). The Grande Ronde River flows from its headwaters northeast 341 km to its confluence with the Snake River (Nowak and Kuchenbecker 2004). The confluence of the Grande Ronde and Snake rivers is 705 m above sea level and rises to peak elevations in the Wallowa and Blue Mountains of 2,440 and 2,134 m above sea level, respectively (Nowak and Kuchenbecker 2004).

The basin has been partitioned into three primary management areas (Nowak and Kuchenbecker 2004), referred to as Watersheds, using United States Geologic Survey fourth field hydrologic units (HUC4 – http://www.streamnet.org/onlinehelp/user-guide-01.htm 6/1/02). The Lower Grande Ronde Watershed includes the downward sloping topographic area from the confluence of the Grande Ronde and Snake rivers upstream to the confluence of the Wallowa River. The Wallowa River Watershed includes the downward sloping topographic area from the confluence of the Wallowa and Grande Ronde Rivers upstream to the headwaters of the North and South forks of the Wallowa River. The upper Grande Ronde Watershed includes the downward sloping topographic area upstream of the confluence of the Wallowa and Grande Ronde rivers.

Annual increases in river flow occur during April-June, and October-November (Nowak and Kuchenbecker 2004). Daily mean water temperatures fluctuate from 0 to 24° C annually, with frost-free conditions persisting in the basin for 130 to 160 days annually. Winter conditions bring cold temperatures and precipitation, mostly in the form of snow, averages > 152 cm per year in high elevations. Rivers are generally characterized by icing conditions from November to April.

Vegetation in the basin varies by location and altitude. Valley landscapes in the basin are primarily grassland prairie (Johnson and Simon 1987). Mid-elevations are predominantly

transitional step with low shrub-scrub vegetation mixed with pine forest. Ponderosa pine, fir and hemlock forest occupy much of the mid to upper elevations. Wetland habitats are present throughout the basin. These areas are characterized by sedge meadows and riverine riparian vegetation dominated by cottonwood, willow and other deciduous plant species (Johnson and Clausnitzer 1992).

Land use activities have impacted aquatic health in the basin since European settlers arrived in the 1800's. Activities associated with timber harvest, mineral extraction, livestock grazing, agricultural production, and urbanization have lead to less natural areas and reduced ecosystem health (Nowak and Kuchenbecker 2004). Many subbasins throughout the Grande Ronde River Basin were impounded in the 1920's for irrigational purposes, altering the hydrograph, stream channel morphology, wetlands, riparian and aquatic habitat.

Following the recommendation to list Snake River populations of spring Chinook salmon as threatened under the Endangered Species Act (ESA) June 1992, Oregon Department of Fish and Wildlife began investigations of the early life history characteristics of juvenile spring Chinook salmon in the Grande Ronde River Basin. Rotary screw traps were located at the downstream end of adult spring Chinook salmon spawning areas in Catherine Creek (since Fall 1994; rkm 32), upper Grande Ronde River (since Fall 1993; rkm 299) and Lostine River (since Fall 1997; rkm 3) (Figure 1). The present investigation into winter concealment behavior was carried out upstream of those trap sites in juvenile spring Chinook salmon hatching areas of Catherine Creek (rkm 42-50), upper Grande Ronde River (rkm 321-324) and Lostine River (rkm 19-22) (Figure 1).

SPRING CHINOOK SALMON WINTER CONCEALMENT BEHAVIOR INVESTIGATIONS

Methods

Approach

The general approach was to identify where over half of the spring Chinook salmon redds occur (primary hatching areas) in Catherine Creek, Lostine and upper Grande Ronde rivers. An initial pool inventory was conducted to determine the number and general condition of pools present in each hatching area. From these counts, a subset was randomly selected and a baseline characterization of winter concealment habitat features in each pool was measured prior to Fall dispersal (June-September). Additional measurements of winter concealment habitat features would be repeated following major hydrological events that noticeably altered winter concealment habitat features. Fish densities were determined for each pool using multi-census mark-and-recapture each month, and changes in fish size were assessed each month using the fork length and weight of these fish. Differences in the size of fish that remained in hatching area pools were compared to those that migrated to overwinter in lower river habitats (rotary screw trap detections) each month.

Winter concealment behavior was assessed monthly using nocturnal index, which was based on counts of fish during the day, night and subsequent day snorkeling activities. In

addition, a monthly count of concealed PIT-tagged fish was collected during the day by thoroughly scanning interstitial space with a water tight detection device.

Initial hatching area inventory

Initial habitat inventories were conducted to determine the number of pool habitats in the area where over half of the previous year redds were counted (primary hatching area) in Catherine Creek, Lostine River and the upper Grande Ronde River, Oregon (ODFW Fish Research La Grande, unpublished data). Methods described by Bain and Stevenson (1999) were used to distinguish the number and characteristics of habitat features of pool units in primary hatching areas. Macro-habitat was indexed using Hawkins habitat classification system which delineates the location and size of fast (riffle) and slow (pool) units based on channel geomorphology. Substrate composition, based on its diameter, was estimated using modified Wentworth classification (Appendix 1). Substrate embeddedness was rated using methods developed by Platts et al. (1983) that quantified the degree to which large substrates were impacted by sand, silt and clay (Appendix 2). Instream cover composition and amount of habitat attributes (large wood debris, vegetation, large substrate, undercut banks, and small debris piles) were visually estimated using single factor technique described by Bain and Stevenson (1999). Stream bank cover was rated based on the extent of vegetation and rock material along the stream bank (Appendix 3).

Unit selection and baseline characterization

In 2003, six pool habitat units in each subbasin were used to compare relationships between quality and quantity of winter concealment habitat to fish density and size. Markers were put at the upstream and downstream end of each pool to locate each pool from month to month. During the day in September, habitat was indexed measuring wetted surface diameter, unit slope, stream depth, water velocity, and dominant substrate type. Potential winter concealment habitat densities were measured using a modified version of the cover density technique described by Bain and Stevenson (1999). Cover density was quantified using a 2x2 meter grid made of lead-core line that encompassed the entire pool. Substrate pieces with diameter between 10-24.9 cm were counted and overall embeddedness of those pieces rated (Platts et al. 1983) within each 2x2 meter cell. Pieces of wood debris > 1 cm in diameter were counted and the wetted area within the 2x2 cell it occupied recorded. Other concealment habitat features such as vegetation, undercut banks, root wads and sedges were recorded in the same manner.

Randomly selected pools identified during the initial pool inventory in each subbasin were more rigorously studied to provide an index of habitat characteristics within each pool. Wetted pool surface area was measured each time a pool was sampled. We did not repeat habitat inventory measurements after the initial measurement because no major hydrologic events occurred over the period September 2003-January 2004, and physical habitat features that provided interstitial spaces for concealment (e.g. wood, substrate composition) did not change noticeably during that period.

Habitat attributes were used to rank pool quality in terms of winter concealment value. Ranking was based on a scale from 1 to 5 where a higher score indicated better winter concealment quality. Nine attributes were included in the total ranking system (Appendix 4). Individual scores were summed and the largest overall score indicated the best pools for winter concealment.

Water temperature loggers were placed in each unit by 15 September 2003 to track changes throughout the study period in Catherine Creek, Lostine and upper Grande Ronde rivers. Mean temperatures (C°) were summarized by week.

Fish densities and growth

Juvenile spring Chinook salmon were collected from pool habitats using either a passive seining technique in which snorkelers locate and herd the fish into a stationary seine, or by dip netting individual fish.

Changes in the number of PIT-tagged fish overtime were used to estimate changes in total densities of spring Chinook salmon parr within each pool. Prior to tagging, fish were anesthetized in an aerated bath containing 40 to 50 mg/L of tricaine methanesulfonate (MS-222). PIT tags were injected manually using a modified hypodermic syringes as described by Prentice et al. (1986, 1990). Syringes were disinfected for 10 minutes in 70% isopropyl alcohol and allowed to dry for an additional 10 minutes before using. All fish $\geq$ 65 mm fork length were tagged. A mobile tagging station that consisted of a computer, PIT-tag reader, measuring board, and electronic balance was used to record the tag code, fork length (1 mm), and weight (0.1 g) of each tagged fish. All fish were released in the pool of their capture on the same day they were tagged.

Initial fish densities were determined using a mark-recapture method of population estimation. Recapture was conducted at night in each pool approximately 24 hours after release. A subsample of fish was collected using the snorkel seine method and interrogated for the presence-absence of a PIT tag. After interrogation, fish were released back into the pool of capture. Initial abundance was estimated using Peterson index (Van Den Avyle and Hayward 1999):

$$\hat{N} = \frac{MC}{R}$$

where $\hat{N}$ is the estimated population size, M is the number of fish initially tagged and released, C is the number of fish collected and examined for tags in the second period, and R is the number of recaptures found in C. Variance was estimated using the equation:

$$\hat{V(N)} = \frac{M^2(C+1)(C-R)}{(R+1)^2(R+2)}$$

Bailey's modification of the Peterson index was used when the number of recoveries was less than seven (Van Den Avyle and Hayward 1999).

Changes in fish density were evaluated monthly from September through January. Juvenile spring Chinook salmon were collected from each pool at night using either passive seining or dip nets. Each fish was interrogated for a PIT tag using a Destron-Ferring 2001F PIT tag detector and length and weight data collected. The total number of tagged and untagged fish was recorded. Population estimates were determined using the Schnabel population expression:

$$\hat{N} = \frac{\sum_{t=1}^{n} C_t M_t}{\sum_{t=1}^{n} R_t}$$

where $\hat{N}$ is the estimated population size, M is the number of fish initially tagged and released, C is the number of fish collected and examined for tags in the second period, and R is the number of recaptures found in C. The variance was estimated using the equation:

$$V(1/\hat{N}) = \frac{\sum_{t=1}^{n} R_t}{\sum_{t=1}^{n} (C_t M_t)^2}$$

Differences in fish density estimates among ranked pools were analyzed using single factor analysis of variance (ANOVA; $P < 0.05$).

Descriptive statistics were used to describe size and growth rate of juvenile spring Chinook salmon captured in pools in the hatching areas of Catherine Creek, Lostine and upper Grande Ronde rivers. Differences among monthly mean fork length of tagged and untagged fish captured in hatching area pools were analyzed using single factor ANOVA ($P < 0.05$). Tukey's Studentized Range test was used to confirm significant difference when the null hypothesis of no difference was rejected. The null hypothesis that main effects of each factor level equal zero was tested using factorial analysis. Mean fork length y within a given subbasin was modeled using the expression:

$$y_{ijk} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \varepsilon_{ijk}$$

where μ was the mean fork length among pools, α_i was the main effect of tag group at the ith factor level, β_j was the main effect of month in the hatching area at the jth factor level, $\alpha\beta_{ij}$ was the interaction term tag group*month in the hatching area, and ε_{ijk} was error. When data was unbalanced Type III sum of squares were used to confirm significance ($P < 0.05$) (Oehlert 2000).

Specific growth rate (G) in hatching areas was determined for PIT-tagged fish only, and was calculated as:

$$G = \frac{ln\ W_t - ln\ W_O}{t}$$

where W_t is the last observed weight, W_O is the initial weight and t is the growth period measured in days (Fausch and White 1983). Differences among growth periods for paired data were analyzed using single factor ANOVA as described above. In order to increase sample size, growth analysis included data with different number of d between detection in pools when t-tests indicated no significant difference ($P < 0.05$) between mean growth rates.

The number of PIT-tagged fish that migrated out of hatching areas was monitored from catch of tagged fish captured in rotary screw traps operated by the Oregon Department of Fish and Wildlife. Traps were located downstream of the hatching area in each subbasin. Mean fork length and mean specific growth rate of tagged fish that migrated in October-January were compared to tagged fish that remained in the hatching areas using all the analysis methods described above for fish captured in pools in the hatching area, replacing "migrant type" for "tag group" and "monthly growth period" for "month in hatching area", and were used to identify possible ecological mechanisms related to size and growth of migrants.

Shift to concealment

The number of juvenile spring Chinook salmon reported during day and night snorkeling surveys was used to identify when fish shifted to concealment behavior. We used the nocturnal index (NI; Meyer and Gregory 2000) to determine when fish shifted to nighttime preference (i.e. concealing their position during the day). The NI is expressed as:

$$NI = \frac{F_n}{F_n + F_d} \; x \; 100$$

where F_n is the number of fish counted during nighttime snorkel observations, and F_d is the number of fish counted during daytime snorkel observations.

A watertight Destron-Fearing 2001F PIT-tag reader was used to identify tagged fish that were either swimming or concealed during the day. Following daytime snorkel counts, a surveyor scanned swimming juvenile spring Chinook salmon by gently passing the antenna near a fish's position. Concealed fish were located by scanning over all substrate types and physical structures. The location of concealed fish was verified and marked, and the type of structure that provided the interstitial spaces was noted.

Individual pool water temperature profiles were compared to timing of the shift to concealment behavior and migration out of hatching areas. Since temperature refugia is a possible aspect of habitat preference and selection, attempts were made to identify the presence of temperature refugia using a sophisticated thermal coupler sensitive to 0.1 °C within selected habitat units.

<center>**Results and Discussion**</center>

Pool Habitat Characterization

Initial pool inventories

In the inventories of pool habitats within hatching areas of Catherine Creek (8 and 14 July 2003) there were 34 pools between river kilometers (rkm) 42 and 50 with maximum depth > 90 cm. The median pool surface area was 158.5 m^2 with a minimum 51.0 m^2 and a maximum of 351.3 m^2. The median percentage of the visible hyporheic area with substrates larger than cobble was 38% (range 0-80%). The median percentage of instream cover was 10% (range 0-55%), and consisted primarily of vegetation and undercut banks. On average, pool substrates larger than cobble were estimated to have a low level of embeddedness (5-25% surface area covered by fine sediment). Cover rankings indicated that 68% of stream banks around pools contained vegetation and rock materials that at best provided poor resistance to erosion while the remaining 24% contained material that would limit erosion at high flows, and 9% provided excellent protection from bank erosion.

In the inventories of pool habitats within hatching areas of Lostine River (29 July 2003) there were 30 pools with maximum depth > 90 cm between river rkm 20 and 22. The median pool surface area was 170.9 m^2 (range 37.5-980.6 m^2). The median percentage of the visible hyporheic area with substrates larger than cobble was 21% (range 1-45%). The median percentage of instream cover was 14% (range 0-45%), and consisted primarily of vegetation, undercut banks and single logs. Pool substrates larger than cobble were moderately embedded. Cover rankings indicated that 100% of stream banks around pools contained vegetation and rock materials that at best provided poor resistance to erosion.

In the inventories of pool habitats within hatching areas of the upper Grande Ronde River identified 73 pools with maximum depth > 90 cm between river kilometer 318 and 324. The median pool surface area was 119.3 m^2 (range 41.7-389.6 m^2). The median percentage of the visible hyporheic area with substrates larger than cobble was 10% (range 2-45%). The median percentage of instream cover was 10% (range 1-40%), and consisted primarily of undercut banks and boulders. On average, pool substrates larger than cobble were estimated to be moderately embedded. Cover rankings indicated that 92% of stream banks around pools contained vegetation and rock materials that at best provided poor resistance to erosion while the remaining 8% contained material that would limit erosion at high flows.

Selected pool characterization and ranking

Individual habitat features were indexed in six pools of Catherine Creek on 2, 3 and 15 September 2003 and are summarized in Table 1. Mean pool depth did not exceed 50 cm in any of the pools sampled. Mean water velocity was > 0.25 m/s in four of six pools. The number of substrate pieces 10 to 24.9 cm diameter/m^2 was > six in all but two pools. Mean embeddedness ratings of substrate pieces > 10 cm diameter was between 3.0 and 3.9. Only two pools scored embeddedness of 4 or better in > 50% of the grid cells. Instream cover encompassed no more than 5% of the pool surface area in four of the six pools sampled, and did not exceeded 12% of

<center>14</center>

the total pool surface area. Total pool surface area with water velocities < 0.25 m/s ranged from 36 to 69%. The percentage of the pool surface area that contained both water velocities < 0.50 m/s and depth < 51 cm was between 46 and 72% (Table 1).

Individual habitat features were indexed in six pools of the Lostine River on 8-10 September 2003 (Table 1). Mean pool depth exceeded 50 cm in four of six pools sampled. Mean water velocity was < 0.25 m/s in every pool sampled. The number of substrate pieces 10 to 24.9 cm diameter/m^2 was > six in all but two pools. Mean embeddedness ratings of substrate pieces > 10 cm diameter were between 2.8 and 4.0. All but one pool scored embeddedness of 4 or higher in > 50% of the grid cells. Instream cover encompassed no more than 5% of the pool surface area in two of the six pools, and did not exceeded 16% of the total pool surface area. Total pool surface area with water velocities < 0.25 m/s ranged from 73 to 100%. The percentage of the pool surface area that contained both water velocities < 0.50 m/s and depth < 51 cm was between 16 and 67% (Table 1).

Individual habitat features were indexed in six pools of the upper Grande Ronde River on 5, 10 and 11 September 2003 (Table 1). Mean pool depth exceeded 50 cm in one of the six pools sampled. Mean water velocity was < 0.25 m/s in all six pools. The number of substrate pieces 10 to 24.9 cm diameter/m^2 was > six in all but two pools. Mean embeddedness ratings of substrate pieces > 10 cm diameter was between 2.2 and 3.3. Only one of the six pools scored embeddedness of 4 or better in > 50% of the grid cells. Instream cover encompassed no more than 5% of the pool surface area in two of the six pools sampled, and did not exceed 11% of the total pool surface area. Total pool surface area with water velocities < 0.25 m/s ranged from 75 to 100%. The percentage of the pool surface area that contained both water velocities < 0.50 m/s and depth < 51 cm was between 44 and 95% (Table 1).

As in 2002, Catherine Creek pools were generally characterized by moderate to high scores (≥ 3) for all attributes except mean depth and the number of substrate pieces 10 to 24.9 cm/m2, which varied widely (scores 1 to 5), and percent instream cover that were low (scores ≤ 2) (Table 2). Total scores for individual pools in 2003 were similar to those observed in 2002, and each pool ranked in the same order both years. In the Lostine River, low scores (≤ 2) predominated for percent of substrate < 6.3 cm and instream cover. As in 2002, depth and velocity scores were moderate to high (scores ≥ 3). In the upper Grande Ronde River, velocity measures generally scored high (5) whereas physical habitat and embeddedness measures scored low (≤ 2).

Hatching areas in the Grande Ronde Basin encountered a reduction in physical habitat and an increased level of embeddedness between 1935 and 1992 (McIntosh et al. 1994). Although our ranking can not be compared directly with historic records, it appears that low quality and quantity of physical habitat features, small substrate sizes and embeddedness continue to define habitat condition in the Basin. Loss of these habitat features has been shown to negatively impact survival (Quinn and Peterson 1996) and use by fish (Hillman et al. 1987). Therefore, reestablishing historic levels of large wood and substrates in the wetted channel could help realize natural fish production goals while helping to create and maintain better quality fish habitats in the Basin.

Fish density

Capture histories

PIT-tagged juvenile spring Chinook salmon that were redetected in pools in the hatching area of Catherine Creek were usually observed in their pool of original capture. In all, 265 of the 698 fish tagged between September and December 2003 were recaptured in their original pool of capture. In addition, six tagged fish were found in different pools in the hatching area, and eight bare tags were recovered from pool substrates. The majority of the tagged fish observed outside of their original pool of capture migrated out of the hatching area. Based on recoveries at the trap, we estimated that 271 ± 38 of the 698 fish tagged between September and December 2003 migrated out of the hatching area by 31 January 2004.

Tagged fish that were redetected in pools in the hatching area of the Lostine River were also most often observed in their pool of original capture. In all, 272 of the 675 fish tagged between September and December 2003 were recaptured in their original pool of capture. In addition, we observed four tagged fish in a different pool in the hatching area, four bare tags were recovered from pool substrates, and one tagged fish that was presumably eaten by a bull trout. Since the rotary screw trap was not operated on the Lostine River September 2003 through January 2004, we were unable to ascertain the number of fish that migrated out of the hatching area.

Tagged fish that were redetected in pools in the hatching area of the upper Grande Ronde River were also most often observed in their pool of original capture. In all, 274 of the 412 fish tagged between September and November 2003 were recaptured in their original pool of capture. In addition, we observed 12 tagged fish in a different pool in the hatching area, and two bare tags were recovered from pool substrates. Unlike Catherine Creek, migration out of the hatching area was minimal. We estimated that only 2 ± 3 of the 435 fish tagged between September and December 2003 migrated out of the hatching area by 31 January 2003.

Although there is evidence that juvenile spring Chinook salmon exhibited both localized movement within and directed movement out of the hatching area, we often observed individuals using the same pool during summer, fall and winter. Juvenile spring Chinook salmon, coho salmon and steelhead have been shown to have a fidelity to stations (Mason and Chapman 1965; Edmundson et al. 1968). Atlantic salmon were observed moving from unsheltered summer feeding stations to sheltered winter concealment in the same unit (Rimmer et al. 1983, McCormick et al. 1998). However, Atlantic salmon and brown trout showed greater preference for foraging habitat than daytime shelters and thus were more willing to leave habitats to find adequate daytime concealment (Harwood et al. 2002). Maintaining pools that contain diverse habitat features is thus important in sustaining fish during multiple rearing phases and seasons.

Initial fish densities in pools

Pools in Catherine Creek contained between 0.60 and 1.48 juvenile spring Chinook salmon per m^2 16 September 2003 (Table 3). Half of the pools contained < 1 fish/m^2. Although pools with the best winter concealment habitat ranking (Table 2) generally had higher fish

densities during September than the worst ranked pools (ANOVA; P = 0.4100) differences were not significant.

Pools in Lostine River contained between 0.16 and 1.41 fish/m^2 24 September 2003 (Table 3). Half of the pools contained < 1 fish/m^2. Although pools with the best winter concealment habitat ranking (Table 2) generally had higher fish density during September than the worst ranked pools differences were not significant (ANOVA; P = 0.9511).

Pools in upper Grande Ronde River contained between 0.05 and 0.49 juvenile spring Chinook salmon per m^2 21 September 2003 (Table 3). Half of the pools contained < 0.4 fish/m^2. Although pools with the best winter concealment habitat ranking (Table 2) generally had higher fish density during September than the worst ranked pools differences among ranking types were not significant (ANOVA; P = 0.3494).

Monthly fish densities

Fish densities began to decrease as early as October in two of the six pools in Catherine Creek, and were decreasing in all pools by December (Table 4). Fish density was less in January than September in four of the six pools. This pattern was similar to what was seen in 2002 when all ten pools had a lower fish density in January than September. Monthly mean fish density of best and worst ranked pools followed the pattern described in September, where pools with the best winter concealment habitat ranking contained more fish/m^2 than the worst ranked pools (Figure 2). Among pool comparisons indicated that fish densities in pools with the best winter concealment ranking were significantly higher than the worst ranked pools (ANOVA; P = 0.0049).

Fish densities increased through January in three of six pools in the Lostine River while three pools decreased as early as October-November (Table 4). Fish density was greater in January than in September in every pool but one. Monthly mean fish density of best and worst ranked pools followed the pattern described in September, where pools with the best winter concealment habitat ranking contained more fish/m^2 than the worst ranked pools (Figure 3). Comparisons among ranked pools indicated that fish densities in pools with the best winter concealment ranking were significantly different than the worst ranked pools (ANOVA; P = 0.0378).

Fish densities increased through December in all six pools in the upper Grande Ronde River (Table 4). Monthly mean fish density of best and worst ranked pools followed the pattern described in September, where pools with the best winter concealment habitat ranking contained more fish/m^2 than the worst ranked pools (Figure 4). Comparisons among ranked pools indicated that fish densities in pools with the best winter concealment ranking were not significantly greater than the worst ranked pools (ANOVA; P = 0.0623). Low escapement may have limited the overall distribution of juvenile fish throughout the hatching area favoring one area over another. Redds counted in the hatching area of the upper Grande Ronde River (10 redds; Oregon Department of Fish and Wildlife unpublished 2003) were exponentially less than what occurred in the other two subbasins (156 and 107 redds; Oregon Department of Fish and Wildlife unpublished 2003). Lower hatching area pools had significantly greater fish densities

than upper hatching area pools in upper Grande Ronde River (ANOVA; P = 0.0003). This difference was not significant in either Catherine Creek or the Lostine River (ANOVA; P = 0.0715 and 0.8416).

Trends in density did not follow a common pattern among subbasins. As described in 2002, interpreting differences using fish density alone may be distorted by other ecological factors (e.g. foraging availability, habitat quality, predation risks). Theory on relationships of scale maintain that the magnitude of some organisms change at a predictable rate with size (Kleiber 1947). As fish increase in size, natural decreases in fish density would be expected at a point where growth and mortality are no longer independent, thus producing a slope referred to as a self-thinning line (Fréchette and Lefaivre 1995). As long as total energy flow is constant within sites or populations differences among sites or populations may be comparable (Bohlin et al. 1994). Therefore, meaningful relationships of fish abundance and habitat quality may require using allometric scaling equations combining biomass and density.

Fish size and growth

Size and growth in hatching areas

Mean fork lengths of PIT-tagged fish subsequently recaptured in pools in the hatching area of Catherine Creek were shorter than captured fish without a PIT tag in all months that we sampled (Figure 5). Monthly mean fork length increased through January for both tagged and untagged groups. Mean fork lengths of tagged and untagged fish among months were not significantly different overall (ANOVA; P = 0.0641), and mean fork length did not differ significantly for the overall model (ANOVA; P = 0.2546).

Tagged fish that reared in hatching areas of Catherine Creek had positive growth rates during all individual growth periods (Figure 6). Specific growth rate declined from September through December with the largest decrease occurring between the ends of October and November. Specific growth rate differed significantly among months (ANOVA; P = 0.0256), however differences were only confirmed when comparing earlier (October-November) to later growth periods (Tukey's Studentized Range test; P < 0.05).

Mean fork lengths of tagged fish subsequently recaptured in hatching areas of Lostine River were shorter than untagged fish in all months but November (Figure 7). With the exception of untagged fish in November, monthly mean fork length increased through January for both tagged and untagged groups. Monthly mean fork lengths of tagged and untagged fish were not significantly different overall (ANOVA; P = 0.1016), and fork length did not differ significantly for the overall model (ANOVA; P = 0.1447).

Tagged fish that reared in hatching areas of Lostine River had positive growth rates during all individual growth periods (Figure 8). Specific growth rates decreased abruptly from October to November and increased slightly through January. Specific growth rates differed significantly among growth periods (ANOVA; P = 0.0012), but the only individual differences detected were between October and all other months (Tukey's Studentized Range Test; P < 0.05).

Mean fork lengths of PIT-tagged fish subsequently recaptured in pools in the hatching area of upper Grande Ronde River were similar in size with captured fish without a PIT tag in all months that we sampled (Figure 9). Monthly mean fork length did not change much through December for both tagged and untagged groups. Mean fork lengths of tagged and untagged fish among months were not significantly different overall (ANOVA; $P = 0.9857$), and mean fork length did not differ significantly for the overall model (ANOVA; $P = 0.9983$).

Tagged fish that reared in hatching areas of upper Grande Ronde River had positive growth rates during all individual growth periods (Figure 10). Specific growth rate declined from September through December with the largest decrease occurring between the ends of October and November. Specific growth rate differed significantly among months (ANOVA; $P = 0.0063$), however differences were only confirmed when comparing October to later growth periods (Tukey's Studentized Range test; $P < 0.05$).

Larger fish have been shown to retain territories better than smaller fish (Mason and Chapman 1965). As in 2002, the larger fish in Catherine Creek tended to remain in the hatching area, as indicated by the trend in mean fork length. Lostine River also showed some evidence of larger fish remaining in the hatching areas, but there were no clear differences in size of fish that stayed in the upper Grande Ronde River. Monthly mean differences in the hatching areas may indicate differences in ecological mechanisms, habitat availability or both (Conover 1990; Bohlin et al. 1994; Keeley 2001; Harwood et al. 2002). Again, understanding these patterns may also require analyzing biomass and population density jointly.

Growth differences between resident and migrant fish

Mean fork lengths of PIT-tagged fish present in the hatching areas of Catherine Creek were greater than PIT-tagged fish that migrated out of the hatching areas during the same month (Figure 11). Mean fork length generally increased from October to January for both groups. Tagged fish that remained in the hatching areas were significantly longer than those that migrated out (ANOVA; $P = 0.0188$, Tukey's Studentized Range test; $P < 0.05$). Mean fork length differed significantly for the overall model (ANOVA; $P = 0.0017$). The main effects of migrant group and month were both confirmed to have a significant influence on fork length of migrants (Type III sum of squares; $P = 0.0075$ and $P = 0.0016$), but there was no evidence that the combination of tag group and month acted jointly to influence the response (Type III sum of squares; $P = 0.4540$).

Tagged fish captured in the hatching areas of Catherine Creek had a higher mean specific growth rate than tagged fish that migrated out of the hatching areas during the same month (Figure 12). Mean specific growth rate declined October to January for fish that reared in the hatching area, and did not follow a consistent pattern for fish that migrated. Unlike 2002, Growth did not differ significantly among fish that remained in the hatching areas and those that migrated out (ANOVA; $P = 0.2589$), and mean specific growth rate did not differ significantly for the overall model (ANOVA; $P = 0.2172$).

The rotary screw trap was not operated on the Lostine River September 2003 through March 2004, so we were not able to complete a comparative analysis between fish that migrated and those that remained to overwinter in the hatching area. Similarly, only one fish was captured leaving the hatching area of the upper Grande Ronde River. The individual that left the hatching area had a smaller fork length and specific growth rate (70.0 mm; g = -0.0017) than the respective means of tagged fish (74.6 mm; g = 0.0012) that remained in its pool of origin during the same month it migrated, but we were not able to determine if the difference was significant.

Divergent trends in size and growth may indicate that ecological qualities impact rearing behavior in each subbasin differently. As in 2002, fish that left the hatching area of Catherine Creek in 2003 were smaller than those that remained, which could imply that competition dependent factors influenced migration behavior (Bjornn 1971 and 1978), whereby smaller fish were displaced by larger fish (Mason and Chapman 1972). However, migrating fish were smaller in length but had a similar growth rate as fish that remained in November. This could imply that foraging opportunity was not limiting in November (Riehle and Griffith 1993, Keeley and McPhail 1998), and thus involved space regulating factors (Bohlin 1994, Harwood et al. 2002). Mean weight and density data from the hatching areas in Catherine Creek suggest that self-thinning developed in November (Figure 13). Self-thinning did not appear to develop in the Lostine or upper Grande Ronde (Figure 13) rivers in 2003, which may indicate that space regulating factors may not be influencing fish behavior the same way as in Catherine Creek. More comprehensive analysis is needed to identify factors involved in determining early migration out of the hatching areas.

Water temperature

Monthly temperature profiles

All the pools sampled in Catherine Creek had weekly mean water temperatures that were > 10° C in weeks ending 16 September, 23 September and 30 September (Table 5), and both the Lostine and upper Grande Ronde rivers never exceeded 10° C during any week (Tables 6 and 7). Weekly mean water temperatures in Catherine Creek were < 4° C between week ending 4 November 2003-28 January 2004, and were < 1° C seven of 20 weeks. Weekly mean water temperatures in the Lostine River were consistently < 4° C by weeks ending 4 November 2003-28 January 2004 in all but pool 27, and were not < 1° C in all but pools 43 and 45 during any of the 20 weeks we sampled. Weekly mean water temperatures in upper Grande Ronde River were < 4° C between week ending 4 November 2003-28 January 2004, and were < 1° C twelve of 20 weeks.

Temperature refugia

We did not detect any measurable difference in micro habitat water temperatures within individual pools in Catherine Creek, Lostine or upper Grande Ronde rivers 15 September 2003-28 January 2004. Water temperatures in Catherine Creek were similar among pools throughout the period we sampled (Table 5). As in 2002, pool 27 appeared to provide an area of thermal refugia which occurred both in the summer and winter, and only pool 43 and 45 had recorded temperatures of < 0.8° C during the period sampled (Table 6). As in Catherine Creek, water

temperatures in the upper Grande Ronde River were similar among pools throughout the period sampled (Table 7).

Shift to concealment behavior

Day vs. Night abundance

Fish activity in Catherine Creek differed among pools in October, whereby fish in four pools were more active by day while fish in two pools were more active by night (Table 8). By November, fish were more active by night in every pool (Table 8). However, fish were observed by day in all months sampled. The lack of pool use by day was most evident in January when four of the six pools had no fish active during the day. During the day, fish schooled in deeper (> 40 cm) areas of pools in or near the thalweg. At night, fish dispersed throughout the pool, and typically disassociated from each other. Fish were most often found in shallow areas (20-60 cm) of low velocity (< 0.25 m/s).

In the Lostine River, fish were more active by night in all but one pool in October, and by November were more active by night in every pool (Table 8). However, fish were observed by day in every month sampled. In pool 27, fish were active by day in all months, and were always closely associated with woody structure. By November, three of the six pools had no active fish by day, and in December all but one pool (27) had no fish active by day. At night, fish disassociated and typically utilized the shallow, low velocity areas near pool margins.

In the upper Grande Ronde River, fish were more active by night in all but one pool in October, and by November were more active by night in every pool (Table 8). However, fish were observed by day in all months sampled. The lack of pool use by day was most evident in December when three of the six pools had no fish active during the day. By day, fish schooled in deeper (> 40 cm) areas of pools in or near the thalweg, where as by night, fish dispersed throughout the pool and typically disassociated from each other. By night, fish were most often found in shallow areas (20-60 cm) of low velocity (< 0.25 m/s).

Tagged fish were detected using the same pool day and night when mean water temperatures were less than 4° C. In Catherine Creek during December (mean 1.1-1.6° C) 22 of the 58 tagged fish collected at night were also active earlier that day. Meyer and Gregory (2000) observed this same condition with adult rainbow and suggested that it may have been related to competition for interstitial space. They hypothesized further that adult rainbow may have been more flexible in diel activities than juvenile fish and that food availability, water temperature, competitive interactions and other conditions may have influenced their behavior. Our data identify juveniles also employing some flexibility in pool use during the day and night. Poor physical habitat availability in pools and negative growth rate in January may have influenced this flexibility in diel activity patterns in our investigation, but other aspects that we did not measure (such as forage densities, predation risks) may have influenced the outcome.

Pool use

In general juvenile spring Chinook salmon schooled by day and disassociated by night. During the day fish were observed feeding in positions in or near the thalweg. Day use typically occurred at depths > 40 cm, but fish generally did not occupy the deepest areas of the pool. At night, fish moved into shallow (20-60 cm) lower velocity (< 0.25 m/s) areas in pools (20-60 cm depth). As mean daily water temperatures decreased to about 4° C, fish were more closely associated with areas in the pool that contained physical structure. In the Lostine River, fish were always closely associated with physical structure during the day. At night, fish were distributed throughout the pool, usually over shallow areas and in back eddy habitats.

Movement by fish from feeding stations to shallower low velocity area in the same unit between day and night was also observed in an Idaho stream (Edmundson et al. 1968). An affinity for physical structure as water temperatures decreased and with successive sampling periods has been observed by others (Bustard and Narver 1975; Taylor 1988). However, mean water temperature alone was not a consistent indicator of day time concealment in the Grande Ronde Basin, because we observed fish using pools during the day even though temperatures were < 1° C. Juvenile spring Chinook salmon did not have as strong a tendency to seek cover as coho, and have been described elsewhere as being active when temperatures were as low as 0° C (Taylor 1988). Therefore, a threshold temperature for concealment may be influenced by species and geomorphic characteristics (Meyer and Gregory 2000). Water temperature is not necessarily dependable in determining when fish are concealing; if so other factors may be linked to the initiation of concealment behavior.

Scanned detections of concealed fish

We detected 20, 69 and 41 PIT-tagged juvenile spring Chinook salmon concealed in Catherine Creek, Lostine and upper Grande Ronde rivers, respectively (Table 9). Fish were using root wads, other woody structures, cobbles (>10 cm diameter) and macrophytes to conceal themselves during the day. Combined pool detections of concealed tagged fish increased from October to December in all three subbasins. Detections were greatest in Lostine and upper Grande Ronde rivers because several pools contain woody habitats that we were able to insert the antenna and leave stationary for a long period of time. Many of the detections in those pools occurred only after fish moved in-and-out of the detection field. Although we did not detect any concealed fish in pool 27 in the Lostine River, all the fish observed during the day were associated with the large rootwad/wood pile in the pool. Our ability to detect fish under substrate layers was less successful. In no pool were more than five fish ever located using substrate for concealment, and thus we were not able to identify if substrate found in one pool was used more than the substrate in another pool from month-to-month.

FUTURE DIRECTIONS

A final report and master's thesis for Erick Van Dyke will be completed in 2005 incorporating all the data collected in 2002 and 2003 from hatching areas of Catherine Creek, Lostine River and upper Grande Ronde River.

REFERENCES

Bain, M.B. and N.J. Stevenson. 1999. Aquatic Habitat Assessment: Common Methods. American Fisheries Society, Bethesda, Maryland.

Bell, R. 1958. Time, size, and estimated numbers of seaward migrants of Chinook salmon and steelhead trout in the Brownlee-Oxbow section of the middle Snake River. Idaho Department of Fish and Game. Boise, Idaho.

Bjornn, T.C. 1971. Trout and salmon movements in two Idaho streams as related to temperature, food, stream flow, cover, and population density. Transactions of the American Fisheries Society 100:423-438.

Bjornn, T.C. 1978. Survival, production, and yield of trout and Chinook salmon in the Lemhi River, Idaho. Bulletin 27. Idaho Cooperative Fishery Research Unit, College of Forestry, Wildlife and Range Sciences. Moscow, Idaho.

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

Bohlin, T., C. Dellefors, U. Faremo and A. Johlander. 1994. The energetic equivalence hypothesis and the relation between population density and body size in stream-living salmonids. The American Naturalist 143: 478-493.

Bustard, D.R. and D.W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 32:667-680.

Campbell, R.F. and J.H. Neurner. 1995. Seasonal and diurnal shifts in habitat utilized by resident rainbow trout in western Washington Cascade Mountain streams. Pages 39-48 *in* F.W. Olson, R.G. White, and R.H. Hamre editors. Proceedings of the Symposium on Small Hydropower and Fisheries. American Fisheries Society, Bethesda, Maryland.

Chapman, D.W. 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. Journal of the Fisheries Research Board of Canada 19:1047-1080.

Chapman, D.W. and T.C. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. Pages 153-176 *in* T.G. Northcote, editor. Symposium on salmon and trout in streams. H.R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver, Canada.

Chisholm, I.M., W.A. Hubert and T.A. Wesche. 1987. Winter stream conditions and use of habitat by brook trout in high-elevation Wyoming streams. Transactions of the American Fisheries Society 116:176-184.

Conover, D.O. 1990. The relation between capacity for growth and length of growing season: evidence for and implications of countergradient variation. Transactions of the American Fisheries Society 119:416-430.

Contor, C.R. 1989. Diurnal and nocturnal winter habitat utilization by juvenile rainbow trout in the Henry's Fork of the Snake River, Idaho. Master's Thesis. Idaho State University, Pocatello, Idaho.

Cunjak, R.A. 1988. Behaviour and microhabitat of young Atlantic salmon (*Salmo salar*) during winter. Canadian Journal of Fisheries and Aquatic Sciences 45:2156-2160.

Cunjak, R.A. and G. Power. 1986. Winter habitat utilization by stream resident brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*). Canadian Journal of Fisheries and Aquatic Sciences 43:1970-1981.

Edmundson, E., F.E. Everest and D.W. Chapman. 1968. Permanence of station in juvenile Chinook salmon and steelhead trout. Journal of the Fisheries Research Board of Canada 25:1453-1464.

Erkinaro, J. and R.J. Gibson. 1997. Interhabitat migration of juvenile Atlantic salmon in a Newfoundland river system, Canada. Journal of Fish Biology 51:373-388.

Everest, F.H. and D.W. Chapman. 1972. Habitat selection and spatial interaction by juvenile Chinook salmon and steelhead trout in two Idaho streams. Journal of the Fisheries Research Board of Canada 29:91-100.

Fausch, K.D. and R.J. White. 1986. Competition among juvenile coho salmon, and brown trout in a laboratory stream, and implications for Great Lakes tributaries. Transactions of the American Fisheries Society 115:363-381.

Fréchette, M. and D. Lefaivre. 1995. On self-thinning in animals. Oikos 73:425-428.

Gregory, J.S. and J.S. Griffith. 1996a. Winter concealment by subyearling rainbow trout: space size selection and reduced concealment under surface ice and in turbid water conditions. Canadian Journal of Zoology 74:451-455.

Gregory, J.S. and J.S. Griffith. 1996b. Aggressive behaviour of underyearling rainbow trout in simulated winter concealment habitat. Journal of Fish Biology 49:237-245.

Griffith, J.S. and R.W. Smith. 1993. Use of winter concealment cover by juvenile cutthroat and brown trout in the South Fork of the Snake River, Idaho. North American Journal of Fisheries Management 13:823-830.

Hartman, G.F. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 22:1035-1079.

Harwood, A.J., N.B. Metcalfe, S.W. Griffiths and J.C. Armstrong. 2002. Intra- and inter-specific competition for winter concealment habitat in juvenile salmonids. Canadian Journal of Fisheries and Aquatic Sciences 59:1515-1523.

Healey, M.C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*). Pages 311-393 *in* C. Groot and L. Margolis, editors. Pacific Salmon Life Histories. University of British Columbia Press, Vancouver, Canada.

Heggenes, J., O.M.W. Krog, O.R. Lindås, J.G. Dokk and T. Bremnes. 1993. Homeostatic behavioural responses in a changing environment: brown trout (*Salmo trutta*) become nocturnal during winter. Journal of Animal Ecology 62:295-308.

Hillman, T.W., J.S. Griffith and W.S. Platts. 1987. Summer and winter habitat selection by juvenile Chinook salmon in a highly sedimented Idaho stream. Transactions of the American Fisheries Society 116:185-195.

Jaindl, R.G., T.M. Quigley and R. Harrod. 1996. Forest Health Issues and Resources of the Blue Mountains. Pages 1-10 *in* R.G. Jaindl and T.M. Quigley, editors. Search for a Solution Sustaining the Land, People, and Economy of the Blue Mountains. American Forests, Washington D.C.

Jakober, M.J., T.E. McMahon, R.F. Thurow and C.G. Clancy. 1998. Role of stream ice on fall and winter movements and habitat use by bull trout and cutthroat trout in Montana headwater streams. Transactions of the American Fisheries Society 127:223-235.

Johnson, C.G. Jr. and S.A. Simon. 1987. Plant Associations of the Wallowa-Snake Province. R6-ECOL-TP-225A-86. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Portland, Oregon.

Johnson, C.G. Jr. and R.R. Clausnitzer. 1992. Plant Associations of the Blue and Ochoco Mountains. R6-ERW-TP-036-92. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Portland, Oregon.

Jonasson, B. C., J. V. Tranquilli, P.M. Sankovich, E.S. Van Dyke, M. Keefe and R. W. Carmichael. 1999. Investigations into the early life history of naturally produced spring Chinook salmon in the Grande Ronde River Basin. Oregon Department of Fish and Wildlife, Annual Progress Report to Bonneville Power Administration, Portland, Oregon.

Keeley, E.R. 1998. Food abundance, intruder pressure, and body size as determinants of territory size in juvenile steelhead trout (*Oncorhynchus mykiss*). Behaviour 135:65-82.

Keeley, E.R. 2001. Demographic responses to food and space competition by juvenile steelhead trout. Ecology. 82:1247-1259.

Kleiber, M. 1947. Body size and metabolic rate. Physiological Reviews 27:511-541

Lister, D.B. and H.S. Genoe. 1970. Stream habitat utilization by cohabiting underyearlings of Chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) in the Big Qualicum River, British Columbia, Canada. Journal of the Fisheries Research Board of Canada 27:1215-1224.

Mains, E.M. and J.M. Smith. 1964. The distribution, size, time, and current preferences of seaward migrant Chinook salmon in the Columbia and Snake rivers. Washington Department of Fisheries, Fish Research Paper 2(3):5-43.

Major, R.L. and J.L. Mighell. 1969. Egg-to-migrant survival of spring Chinook salmon (*Oncorhynchus tshawytscha*) in the Yakima River, Washington. Fisheries Bulletin 67:347-359.

Mason, J.C. and D.W. Chapman. 1965. Significance of early emergence, environmental rearing capacity, and behavioral ecology of juvenile coho salmon in stream channels. Journal of the Fisheries Research Board of Canada 22:173-190.

McCormick, S.D., L.P. Hansen, T.P. Quinn and R.L. Saunders. 1998. Movement, migration, and smolting of Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences 55:77-92.

McIntosh, B.A., J.R. Sedell, J.E. Smith, R.C. Wissmar, S.E. Clarke, G.H. Reeves and L.A. Brown. 1994. Management History of Eastside Ecosystems: Changes in Fish Habitat Over 50 Years, 1935 to 1992. U.S. Department of Agriculture, Forest Service, General Technical Report PNW-GRT-321, Portland, Oregon.

Meyer, K.A. and J.S. Griffith. 1997a. First-winter survival of rainbow trout and brook trout in the Henry's Fork of the Snake River, Idaho. Canadian Journal of Zoology 75:59-63.

Meyer, K.A. and J.S. Griffith. 1997b. Effects of cobble-boulder substrate configuration on winter residency of juvenile rainbow trout. North American Journal of Fisheries Management 17:77-84.

Meyer, K.A. and J.S. Gregory. 2000. Evidence of concealment behavior by adult rainbow trout and brook trout in winter. Ecology of Freshwater Fish 9:138-144.

Nowak, M. C. and L. Kuchenbeckerand. 2004. Grande Ronde Subbasin Plan. Prepared for the Northwest Power and Conservation Council, Portland, Oregon.

Oehlert, G. W. 2000. A First Course in Design and Analysis of Experiments. W. H. Freeman and Company, New York, New York.

Platts, W.S., W.F. Megahan and G. W. Minshall. 1983. Methods for evaluating stream, riparian and biotic conditions. U.S. Forest Service, Inter-mountain Forest and Range Experiment Station, General Technical Report INT-138, Ogden, Utah.

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, Oregon.

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.

Quinn, T.P. and N.P. Peterson. 1996. The influence of habitat complexity and fish size on over-winter survival and growth of individually marked juvenile coho salmon (*Oncorhynchus kisutch*) in Big Beef Creek, Washington. Canadian Journal of Fisheries and Aquatic Sciences 53:1555-1564.

Reimers, P. E. 1970. Behavior troughs with simulated redds to study recently emerged salmon fry. Fish Commission of Oregon Research Report 2(1):96-99

Reimers, P.E. and R.E. Loeffel. 1967. The length of residence of juvenile fall Chinook salmon in selected Columbia River tributaries. Fish Commission of Oregon Research Briefs 13(1):5-19.

Riehle, M.D. and J.S. Griffith. 1993. Changes in habitat use and feeding chronology of juvenile rainbow trout (*Oncorhynchus mykiss*) in fall and the onset of winter in Silver Creek, Idaho. Canadian Journal of Fisheries and Aquatic Sciences 50:2119-2128.

Rimmer, D.M., U. Paim and R.L. Saunders. 1983. Autumnal habitat shift of juvenile Atlantic salmon (*Salmo salar*) in a small river. Canadian Journal of Fisheries and Aquatic Sciences 40:671-680.

Simpkins, D.G., W.A. Hubert and T.A. Wesche. 2000. Effects of fall-to-winter changes in habitat and frazil ice on the movements and habitat use of juvenile rainbow trout in a Wyoming tailwater. Transactions of the American Fisheries Society 129:101-118.

Smith, R.W. and J.S. Griffith. 1994. Survival of rainbow trout during their first winter in the Henry's Fork of the Snake River, Idaho. Transactions of the American Fisheries Society 123:747-756.

Taylor, E.B. 1988. Water temperature and velocity as determinants of microhabitats of juvenile Chinook and coho salmon in a laboratory stream channel. Transactions of the American Fisheries Society 117:22-28.

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

Van Den Avyle, M.J. and R. S. Hayward. 1999. Dynamics of exploited fish populations. Pages 127-166 *in* C.C. Kohler and W.A. Hubert, editors. Inland Fisheries Management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Table 1. Pool habitat index data collected in the hatching areas of Catherine Creek, Lostine and upper Grande Ronde rivers 2003.

Location/ Date	Pool	Mean depth (cm)	Mean velocity (m/s)	Substrate 10-24.9 cm/m2	Percent of pool with substrate < 6.3 cm	Mean embeddedness rating	Percent of grid cells with embeddedness rating > 4	Percent instream cover in pool	Percent of pool with velocity <0.25 m/s	Percent of pool with velocity <0.5 m/s & depth <51cm
Catherine Creek										
2 Sep	2	27.2	0.21	22.63	39	3.7	53	0	68	57
15 Sep	7	28.1	0.33	5.00	47	3.2	44	9	36	72
15 Sep	8	44.2	0.26	8.00	42	3.9	69	4	65	46
3 Sep	9	31.8	0.26	6.87	33	3.0	35	1	53	59
15 Sep	24	19.8	0.43	3.24	66	3.0	35	12	40	65
3 Sep	27	39.9	0.21	11.63	41	3.1	37	0	69	54
Lostine River										
10 Sep	27	46.0	0.02	1.81	80	2.8	27	7	100	58
9 Sep	29	31.3	0.11	2.70	82	3.5	60	16	75	67
9 Sep	31	66.2	0.17	20.65	65	3.6	64	13	73	16
9 Sep	35	85.3	0.07	9.30	62	3.4	57	1	92	39
8 Sep	43	69.0	0.08	19.70	54	4.0	77	0	91	32
8 Sep	45	55.0	0.11	12.40	51	3.5	57	9	92	31
Upper Grande Ronde River										
5 Sep	7	36.9	0.07	8.74	58	2.4	11	11	100	68
5 Sep	8	27.4	0.16	12.54	57	2.2	7	8	86	95
10 Sep	9	40.5	0.11	7.31	72	2.7	27	7	95	68
11 Sep	32	29.8	0.18	5.13	59	2.7	11	5	82	77
11 Sep	55	53.1	0.12	6.61	75	3.3	62	4	94	44
11 Sep	73	26.5	0.16	1.73	85	2.4	4	7	75	83

Table 2. Habitat ranking for indexed pools in the hatching areas of Catherine Creek, Lostine and upper Grande Ronde rivers 2003.

Location/ Pool	Mean depth (cm)	Mean velocity (m/s)	Substrate 10-24.9 cm/m2	Percent of pool with substrate < 6.3 cm	Mean embeddedness rating	Percent of grid cells with embeddedness rating > 4	Percent instream cover in pool	Percent of pool with velocity <0.25 m/s	Percent of pool with velocity <0.5 m/s & depth <51cm	Total score (Rank)
Catherine Creek										
2	2	5	5	4	4	5	1	5	5	36 (1)
7	2	4	1	3	3	4	2	3	5	27 (5)
8	4	4	2	3	4	5	1	5	4	32 (2)
9	3	4	2	4	3	3	1	5	5	30 (4)
24	1	3	1	1	3	3	2	4	5	23 (6)
27	4	5	3	3	3	3	1	5	5	32 (3)
Lostine River										
27	4	5	1	1	2	2	2	5	5	27 (6)
29	3	5	1	1	4	5	3	5	5	32 (4)
31	5	5	5	1	4	5	2	5	2	34 (3)
35	5	5	3	1	3	5	1	5	3	31 (5)
43	5	5	5	2	4	5	1	5	3	35 (1)
45	5	5	4	2	4	5	2	5	3	35 (2)
Upper Grande Ronde River										
7	3	5	2	2	1	1	2	5	5	26 (4)
8	2	5	4	2	1	1	2	5	5	27 (3)
9	4	5	2	1	2	2	2	5	5	28 (2)
32	2	5	1	2	2	1	2	5	5	25 (5)
55	5	5	2	1	3	5	1	5	4	31 (1)
73	2	5	1	1	1	1	2	5	5	23 (6)

Table 3. Initial mark-recapture population estimates, with lower and upper 95% confidence intervals in parentheses, in pools in the hatching areas of Catherine Creek on 16-17 September 2003, Lostine River 24-25 September 2003 and the upper Grande Ronde River 21-22 September, 2003.

Location/ Pool number	River kilometer	Pool surface area (m²)	Estimated spring Chinook salmon/m²	
Catherine Creek				
2	42	164.0	0.60 [a]	(0.37-1.72)
7	43	226.8	0.73	(0.43-2.27)
8	43	126.4	1.34	(1.07-1.80)
9	44	164.1	0.72	(0.57-1.00)
24	45	147.3	1.13	(0.87-1.61)
27	45	182.8	1.48	(1.10-2.26)
Lostine River				
27	20	170.6	1.27	(0.95-1.89)
29	20	44.8	1.24	(1.13-1.38)
31	20	247.2	1.41	(1.00-2.38)
35	20	330.2	0.16 [a]	(0.09-0.61)
43	21	148.4	0.44	(0.32-0.68)
45	21	181.1	0.91	(0.64-1.54)
Upper Grande Ronde River				
7	321	169.3	0.46	(0.39-0.56)
8	321	183.0	0.49	(0.44-0.56)
9	321	312.0	0.44	(0.36-0.56)
32	322	212.6	0.05 [a]	--[b]
55	323	90.2	0.24	--[b]
73	324	130.9	0.21	(0.35-0.50)

a/ Estimate required Bailey's modification because the number of fish recaptured was < seven.
b/ No confidence limit because all the fish that were captured were tagged.

Table 4. Monthly density estimate, with lower and upper 95% CI in parentheses, of juvenile spring Chinook salmon/m^2 in pools within the hatching areas of Catherine Creek, Lostine and upper Grande Ronde rivers September 2003-January 2004. Estimates were generated using a modified Schnabel census that adjusted recapture histories to reflect known loss of individual PIT-tagged fish.

Location/	Juvenile Spring Chinook Salmon density (fish/m^2)				
Pool (rkm)	September	October	November	December	January
Catherine Creek					
2 (42)	0.60[a] (0.37-1.72)	0.65 (0.40-1.70)	0.90[a] (0.60-1.76)	0.85 (0.61-1.40)	0.80[a] (0.58-1.29)
7 (43)	0.73 (0.43-2.27)	0.82[a] (0.53-1.79)	0.64 (0.46-1.08)	0.51 (0.37-0.78)	0.52[a] (0.39-0.79)
8 (43)	1.34 (1.07-1.80)	1.19 (0.93-1.66)	1.29 (1.03-1.74)	1.29 (1.06-1.67)	1.05 (0.86-1.32)
9 (44)	0.72 (0.57-1.00)	0.70 (0.52-1.07)	0.70 (0.54-1.01)	0.71 (0.55-0.98)	0.64[a] (0.50-0.88)
24 (45)	1.13 (0.87-1.61)	1.24 (0.93-1.87)	1.27 (0.98-1.79)	1.24 (0.98-1.71)	1.00[a] (0.79-1.37)
27 (45)	1.48 (1.10-2.26)	2.08 (1.52-3.31)	2.35 (1.78-3.47)	2.17[a] (1.67-3.10)	2.24 (1.76-3.09)
Lostine River					
27 (20)	1.27 (0.95-1.89)	2.45[a] (1.76-4.03)	1.43 (1.07-2.16)	1.42 (1.09-2.02)	1.33 (1.05-1.78)
29 (20)	1.24 (1.13-1.38)	1.50 (1.17-2.12)	1.40 (1.12-1.88)	1.25 (1.02-1.63)	1.43 (1.18-1.81)
31 (20)	1.41 (1.00-2.38)	1.33 (0.96-2.17)	1.12 (0.89-1.51)	1.19 (0.97-1.53)	1.03 (0.86-1.28)
35 (20)	0.16[a] (0.09-0.61)	0.45[a] (0.26-1.72)	0.41 (0.27-0.83)	0.39 (0.28-0.62)	0.49[a] (0.37-0.74)
43 (21)	0.44 (0.32-0.68)	1.73[a] (1.17-3.30)	1.86 (1.35-2.98)	1.96 (1.50-2.82)	2.16 (1.73-2.87)
45 (21)	0.91 (0.64-1.54)	1.72[a] (1.15-3.37)	2.39 (3.93-1.72)	1.86 (1.41-2.77)	3.10 (2.43-4.29)
Upper Grande Ronde River					
7 (321)	0.46 (0.39-0.56)	0.59 (0.46-0.84)	0.61 (0.49-0.79)	0.65 (0.54-0.82)	-- [c]
8 (321)	0.49 (0.44-0.56)	0.72 (0.56-0.99)	0.71 (0.58-0.94)	0.72 (0.60-0.91)	-- [c]
9 (321)	0.44 (0.36-0.56)	0.49 (0.38-0.69)	0.51 (0.42-0.67)	0.53 (0.44-0.67)	-- [c]
32 (322)	0.05[a,b]	0.08[a] (0.05-0.22)	0.12[a] (0.08-0.27)	0.12 (0.09-0.22)	-- [c]
55 (323)	0.24[b]	0.49 (0.35-0.83)	0.39 (0.30-0.59)	0.45 (0.35-0.64)	-- [c]
73 (324)	0.21 (0.35-0.50)	0.46 (0.35-0.68)	0.50 (0.39-0.69)	0.50 (0.48-0.60)	-- [c]

a/ Estimate required Bailey's modification because the number of fish recaptured was < seven.
b/ No confidence limit because all the fish that were captured were tagged.
c/ No estimate because access to the hatching area was blocked by snow.

Table 5. Weekly mean water temperatures (°C) with minimum and maximum temperatures in parenthesis in pools of Catherine Creek September 2003-January 2004 (NA = not available).

Week ending	Pool number											
	2		7		8		9		24		27	
16 Sep	11.3	(6.6-15.6)	11.1	(6.5-15.7)	11.1	(6.6-15.8)	11.0	(6.5-15.6)	10.8	(6.4-14.5)	10.7	(6.3-14.7)
23 Sep	9.8	(6.1-13.7)	9.7	(6.0-14.0)	9.8	(6.1-14.1)	9.6	(6.2-13.5)	9.4	(5.9-12.8)	9.3	(5.8-13.0)
30 Sep	11.0	(6.6-15.2)	11.0	(6.5-15.6)	11.1	(6.6-15.7)	10.9	(6.7-15.1)	10.8	(6.5-14.5)	10.7	(6.4-14.6)
07 Oct	11.2	(7.7-15.0)	11.2	(7.6-15.2)	11.3	(7.7-15.3)	11.1	(7.9-14.7)	11.0	(7.7-14.4)	10.9	(7.6-14.5)
14 Oct	7.9	(4.5-13.7)	7.8	(4.5-14.2)	7.9	(4.6-14.4)	7.9	(4.8-13.8)	7.6	(4.5-13.4)	7.5	(4.4-13.4)
21 Oct	8.0	(3.9-12.5)	7.9	(3.9-12.8)	8.0	(3.9-13.0)	7.9	(4.1-12.4)	7.7	(3.8-11.9)	7.6	(3.7-12.0)
28 Oct	6.6	(1.8-12.0)	6.6	(1.8-12.1)	6.7	(1.9-12.2)	6.6	(2.2-11.7)	6.4	(1.9-11.2)	6.3	(1.7-11.3)
04 Nov	1.9	(0.0-9.3)	2.0	(-0.1-9.1)	2.1	(0.0-9.3)	2.1	(0.1-9.2)	1.8	(0.0-9.0)	1.7	(-0.1-8.9)
11 Nov	1.0	(0.0-4.3)	1.1	(-0.1-4.4)	1.1	(0.0-4.4)	1.0	(0.0-4.0)	0.9	(0.0-3.9)	0.8	(-0.1-3.8)
18 Nov	2.3	(-0.1-4.6)	2.3	(0.0-4.6)	2.3	(0.0-4.6)	2.2	(-0.1-4.4)	2.0	(0.1-4.0)	2.0	(-0.1-4.2)
25 Nov	0.9	(0.0-4.9)	0.9	(-0.1-4.9)	0.9	(0.0-4.9)	0.8	(-0.1-4.7)	0.9	(0.1-4.3)	0.8	(0.0-4.5)
02 Dec	2.0	(0.0-4.8)	2.0	(0.0-4.9)	2.0	(0.0-4.6)	1.8	(-0.1-4.4)	1.6	(-0.1-3.9)	1.7	(-0.1-4.1)
09 Dec	2.2	(0.1-4.5)	2.1	(0.0-4.5)	2.1	(0.0-4.6)	2.0	(-0.1-4.4)	2.2	(0.5-3.9)	1.9	(0.0-4.2)
16 Dec	1.3	(0.0-3.1)	1.3	(-0.1-3.1)	1.3	(0.1-3.2)	1.1	(-0.1-3.0)	1.0	(-0.1-2.8)	1.0	(-0.1-3.0)
23 Dec	0.9	(-0.1-2.9)	0.9	(0.0-2.9)	0.9	(0.0-2.9)	0.8	(-0.1-2.8)	0.6	(-0.1-2.6)	0.7	(-0.1-2.8)
31 Dec	0.4	(0.0-2.6)	0.4	(-0.1-2.6)	0.5	(0.0-2.6)	0.3	(-0.1-2.5)	0.3	(-0.1-2.2)	0.3	(-0.1-2.4)
07 Jan	0.0	(0.0-0.0)	0.0	(-0.1-0.2)	0.1	(0.1-0.1)	-0.1	(-0.1-0.0)	0.0	(-0.1-0.2)	0.0	(-0.1-0.1)
14 Jan	0.0	(0.0-0.0)	0.0	(0.0-0.2)	0.4	(0.1-0.8)	0.0	(-0.1-0.3)	0.0	(-0.1-0.1)	0.0	(0.0-0.1)
21 Jan	0.3	(0.0-1.5)	0.6	(-0.1-1.7)	0.8	(0.2-1.9)	0.4	(-0.1-1.5)	0.5	(0.1-1.3)	NA	
28 Jan	0.2	(-0.1-1.6)	0.3	(-0.1-1.6)	0.6	(0.2-1.9)	0.2	(-0.1-1.5)	0.3	(0.1-1.2)	NA	

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Table 6. Weekly mean water temperatures (°C) with minimum and maximum temperatures in parenthesis in pools of Lostine River September 2003-January 2004 (NA = not available).

Week ending	27		29		31		35		43		45	
16 Sep	9.9	(7.5-13.4)	8.5	(6.1-12.0)	8.4	(6.0-12.0)	8.4	(6.1-11.9)	9.9	(6.8-12.9)	9.8	(6.8-12.9)
23 Sep	8.9	(6.9-12.4)	7.4	(5.3-11.2)	7.3	(5.2-11.0)	7.3	(5.3-10.9)	8.3	(5.8-11.5)	8.3	(5.8-11.4)
30 Sep	9.5	(7.4-12.8)	8.0	(6.1-11.6)	7.9	(5.9-11.4)	7.9	(6.0-11.4)	10.1	(7.4-13.8)	10.0	(7.3-13.7)
07 Oct	9.2	(7.9-11.9)	7.8	(6.6-10.4)	7.7	(6.4-10.3)	7.7	(6.5-10.3)	10.4	(8.4-13.3)	10.1	(8.3-12.8)
14 Oct	7.9	(5.9-11.6)	6.4	(4.4-10.1)	6.3	(4.3-10.0)	6.3	(4.4-10.0)	7.2	(4.5-12.7)	6.9	(4.3-12.0)
21 Oct	7.6	(5.8-11.0)	6.1	(4.2-9.8)	6.0	(4.1-9.6)	6.0	(4.2-9.6)	7.4	(4.5-11.1)	7.1	(4.3-10.9)
28 Oct	7.1	(4.5-10.3)	5.6	(3.4-9.1)	5.5	(3.2-9.0)	5.5	(3.2-8.9)	6.4	(2.5-10.8)	6.0	(2.1-9.8)
04 Nov	4.7	(3.1-8.1)	3.2	(1.6-6.3)	3.1	(1.5-6.2)	3.1	(1.7-6.3)	1.6	(0.1-8.4)	1.4	(0.0-8.3)
11 Nov	4.1	(3.3-5.0)	2.8	(1.8-5.7)	2.7	(1.7-5.5)	2.8	(1.9-5.3)	0.4	(0.1-2.2)	0.3	(0.0-2.1)
18 Nov	4.2	(3.5-5.7)	3.2	(1.9-5.1)	3.1	(1.8-4.8)	3.1	(1.9-4.5)	1.5	(0.1-3.4)	1.4	(-0.1-3.2)
25 Nov	4.1	(2.4-5.7)	2.7	(1.7-5.1)	2.6	(1.6-5.0)	2.6	(1.7-4.8)	0.7	(0.1-4.1)	0.6	(0.0-3.9)
02 Dec	3.6	(2.2-4.9)	2.5	(1.6-4.2)	2.3	(1.4-4.1)	2.3	(1.4-3.9)	0.8	(0.1-3.0)	0.7	(0.0-2.8)
09 Dec	3.6	(2.3-5.1)	2.8	(1.5-4.4)	2.7	(1.4-4.3)	2.7	(1.5-4.2)	1.4	(0.1-3.8)	1.3	(-0.1-3.7)
16 Dec	3.5	(2.3-4.9)	2.2	(1.5-3.1)	2.1	(1.3-3.0)	2.1	(1.4-2.9)	0.6	(0.1-2.0)	0.5	(-0.1-1.9)
23 Dec	3.3	(2.4-5.7)	2.0	(1.4-3.4)	1.8	(1.2-3.2)	1.8	(1.3-3.0)	0.3	(0.1-1.5)	0.2	(-0.2-1.4)
31 Dec	3.5	(2.2-5.5)	2.0	(1.1-3.7)	1.8	(1.0-3.6)	1.9	(1.3-3.6)	0.2	(0.1-1.5)	0.1	(-0.1-1.4)
07 Jan	3.5	(2.3-5.4)	1.8	(1.0-2.7)	1.7	(0.9-2.7)	1.9	(1.4-2.8)	0.1	(0.1-0.1)	0.0	(-0.1-0.2)
14 Jan	3.4	(2.2-5.0)	2.0	(1.2-3.1)	1.8	(1.1-2.9)	1.9	(1.2-2.7)	0.1	(0.1-0.1)	0.0	(-0.3-0.1)
21 Jan	3.0	(2.1-4.4)	2.0	(1.2-4.1)	1.6	(1.0-2.6)	1.9	(1.2-3.7)	0.5	(0.1-1.1)	0.5	(0.0-1.1)
28 Jan	2.4	(1.2-4.0)	1.7	(0.8-2.8)	NA		1.6	(0.8-2.5)	0.5	(0.1-1.2)	0.4	(0.0-1.1)

Table 7. Weekly mean water temperatures (°C) with minimum and maximum temperatures in parenthesis in pools of upper Grande Ronde River September 2003-January 2004.

Week ending	7		8		9		32		55		73	
16 Sep	9.5	(6.7-14.4)	9.6	(6.8-14.5)	9.5	(7.1-14.7)	9.5	(6.7-14.6)	9.4	(6.6-14.6)	9.2	(6.3-15.0)
23 Sep	8.1	(3.2-12.9)	8.3	(3.3-13.0)	8.2	(2.6-12.8)	8.3	(3.3-12.7)	8.2	(3.2-12.3)	8.0	(2.2-12.6)
30 Sep	9.3	(4.3-14.3)	9.4	(4.4-14.4)	9.4	(3.9-14.7)	9.4	(4.2-13.9)	9.4	(5.0-13.5)	9.3	(4.1-13.7)
07 Oct	9.5	(5.2-13.7)	9.6	(5.3-13.8)	9.6	(5.5-14.1)	9.6	(5.3-13.5)	9.5	(5.4-12.9)	9.3	(5.6-13.0)
14 Oct	6.0	(2.6-12.5)	6.1	(2.7-12.6)	6.0	(3.2-12.4)	6.1	(2.6-12.6)	5.9	(2.4-11.7)	5.7	(2.7-11.4)
21 Oct	6.4	(2.4-10.4)	6.5	(2.5-10.5)	6.5	(2.9-10.7)	6.6	(2.9-11.0)	6.5	(3.1-10.8)	6.3	(3.5-10.5)
28 Oct	4.9	(0.4-9.3)	5.0	(0.5-9.4)	4.9	(0.8-9.0)	5.0	(0.9-9.9)	5.0	(1.0-9.6)	4.8	(1.5-8.3)
04 Nov	0.9	(-0.1-7.4)	1.0	(0.0-7.5)	1.1	(0.0-7.6)	1.2	(0.1-7.3)	1.1	(0.0-6.9)	1.2	(0.0-6.7)
11 Nov	0.0	(-0.1-0.8)	0.1	(0.0-1.0)	0.1	(0.0-0.8)	0.4	(0.1-2.6)	0.4	(0.0-2.8)	0.5	(0.0-2.0)
18 Nov	0.6	(-0.1-2.4)	0.7	(0.0-2.5)	0.7	(0.1-2.4)	0.9	(0.1-2.9)	0.9	(-0.1-2.6)	0.9	(0.0-2.2)
25 Nov	0.1	(-0.1-2.6)	0.2	(0.0-2.7)	0.2	(0.0-2.6)	0.4	(0.1-3.2)	0.2	(0.0-2.9)	0.3	(0.0-2.6)
02 Dec	0.2	(-0.1-2.1)	0.3	(0.0-2.2)	0.2	(0.0-2.0)	0.6	(0.2-2.6)	0.5	(0.0-2.5)	0.6	(0.0-2.2)
09 Dec	0.4	(-0.1-2.2)	0.6	(0.0-2.3)	0.5	(0.0-2.1)	0.8	(0.2-2.6)	0.6	(0.0-2.6)	0.7	(0.0-2.2)
16 Dec	0.0	(-0.1-1.1)	0.1	(0.0-1.2)	0.0	(0.0-1.0)	0.4	(0.2-1.9)	0.2	(0.0-2.1)	0.3	(0.0-1.7)
23 Dec	-0.1	(-0.1-0.0)	0.1	(0.0-0.3)	0.0	(-0.1-0.3)	0.3	(0.2-0.3)	0.0	(0.0-0.4)	0.2	(0.0-1.2)
31 Dec	-0.1	(-0.1-0.0)	0.1	(0.0-0.2)	0.0	(0.0-0.1)	0.2	(0.2-0.4)	0.0	(0.0-0.2)	0.1	(0.0-0.7)
07 Jan	-0.1	(-0.1--1.0)	0.1	(0.0-0.2)	0.0	(0.0-0.0)	0.2	(0.2-0.3)	0.0	(0.0-0.0)	0.1	(0.0-0.1)
14 Jan	-0.1	(-0.1-0.0)	0.1	(0.0-0.2)	0.0	(0.0-0.0)	0.2	(0.2-0.3)	0.0	(0.0-0.0)	0.1	(0.1-0.6)
21 Jan	-0.1	(-0.1-0.0)	0.1	(0.0-0.2)	0.0	(0.0-0.0)	0.2	(0.2-0.2)	0.0	(0.0-0.1)	0.4	(0.0-1.2)
28 Jan	-0.1	(-0.1-0.0)	0.0	(0.0-0.1)	0.0	(0.0-0.0)	0.2	(0.2-0.3)	0.0	(0.0-0.0)	0.1	(0.1-0.9)

Table 8. Nocturnal index of pool use by juvenile spring Chinook salmon in Catherine Creek, Lostine and upper Grande Ronde rivers October 2003-January 2004. Nighttime preference is represented by values ≥ 51 (Bold text).

Location/Date	Pool number/Nocturnal index					
Catherine Creek	2	7	8	9	24	27
13-14 Oct	50	**60**	40	44	**53**	43
13-14 Nov	**60**	**84**	**68**	**100**	**100**	**58**
10-11 Dec	**63**	**92**	**66**	**77**	**100**	**90**
8-9 Jan	**100**	**100**	**80**	**100**	**75**	**100**

	Pool number/Nocturnal index					
Lostine River	27	29	31	35	43	45
4-5 Nov	42	**100**	**75**	**96**	**97**	**100**
24-25 Nov	**72**	**98**	**100**	**100**	**96**	**100**
22-23 Dec	**71**	**100**	**100**	**100**	**100**	**100**
21-22 Jan	**69**	**94**	**100**	**100**	**100**	**100**

Upper Grande	Pool number/Nocturnal index					
Ronde River	7	8	9	32	55	73
20-21 Oct	**58**	**52**	**51**	**80**	44	**60**
17-18 Nov	**53**	**58**	**91**	**100**	**71**	**100**
15-16 Dec	**84**	**69**	**99**	**100**	**100**	**100**

Table 9. PIT-tagged juvenile spring Chinook salmon detected using concealment habitat during the day in Catherine Creek, Lostine and upper Grande Ronde rivers October 2003-January 2004.

Location/Date	Pool number						Pools
Catherine Creek	2	7	8	9	24	27	combined
13-14 Oct	0	1	0	0	1	0	2
13-14 Nov	2	2	1	0	0	1	6
10-11 Dec	1	0	0	3	2	1	7
9-10 Jan	0	0	0	0	4	1	5
Combined	3	3	1	3	7	3	20

	Pool number						Pools
Lostine River	27	29	31	35	43	45	combined
4-5 Nov	0	4	0	0	0	0	4
24-25 Nov	0	3	6	5	2	1	17
22-23 Dec	0	6	9	5	2	1	23
20-21 Jan	0	3	7	2	1	12	25
Combined	0	16	22	12	5	14	69

Upper Grande	Pool number						Pools
Ronde River	7	8	9	32	55	73	combined
20-21 Oct	0	0	0	0	0	0	0
17-18 Nov	1	2	5	0	0	6	14
15-17 Dec	6	1	14	3	1	2	27
Combined	7	3	19	3	1	8	41
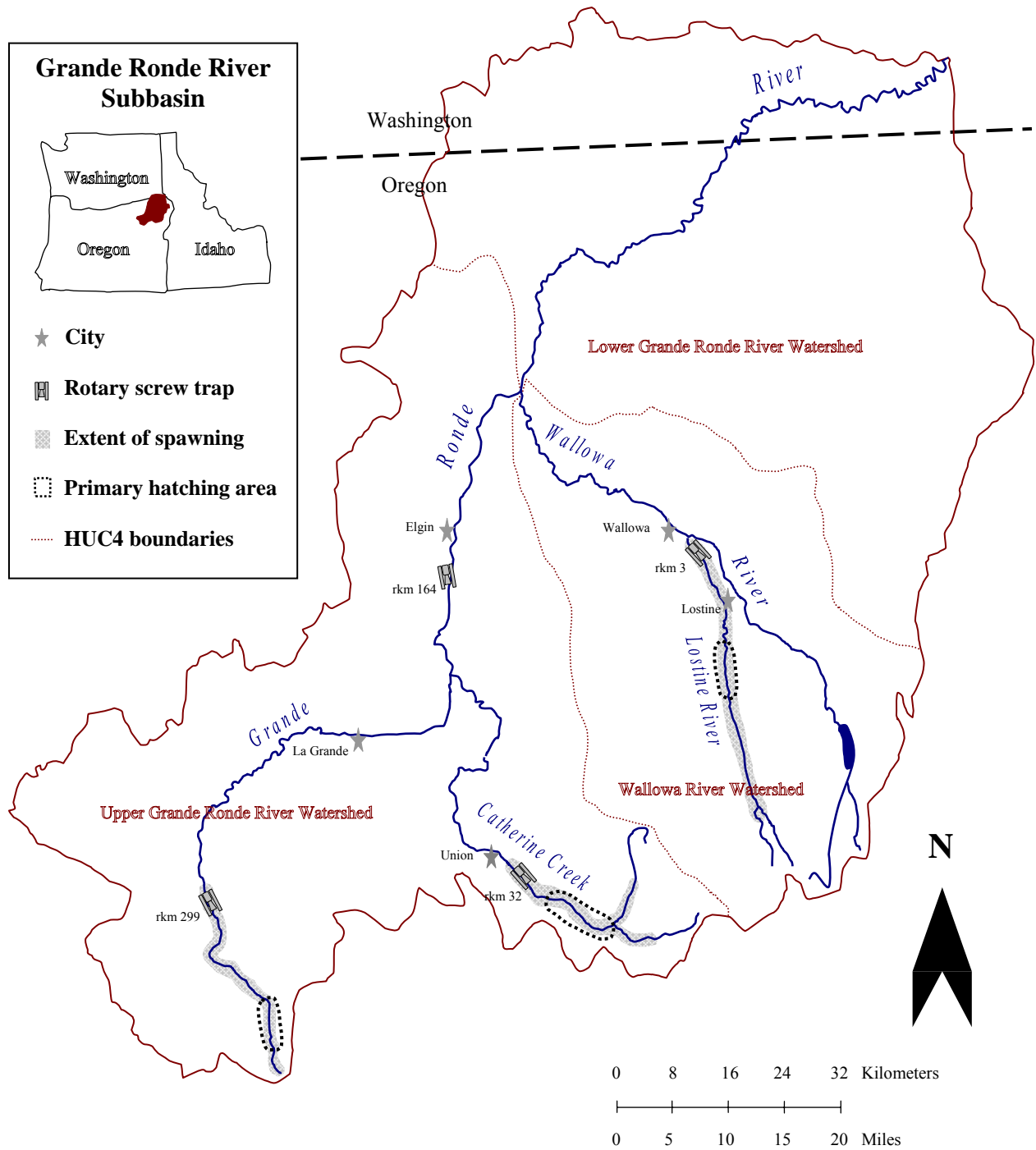
Figure 1. Map of the Grande Ronde River Basin that includes Hydrologic Unit Boundaries of Lower Grande Ronde, Wallowa and Upper Grande Ronde River Watersheds. Each subbasin contains river kilometer (rkm) of rotary screw trap, the extent of area utilized by adult spring Chinook salmon for spawning and the primary hatching areas.
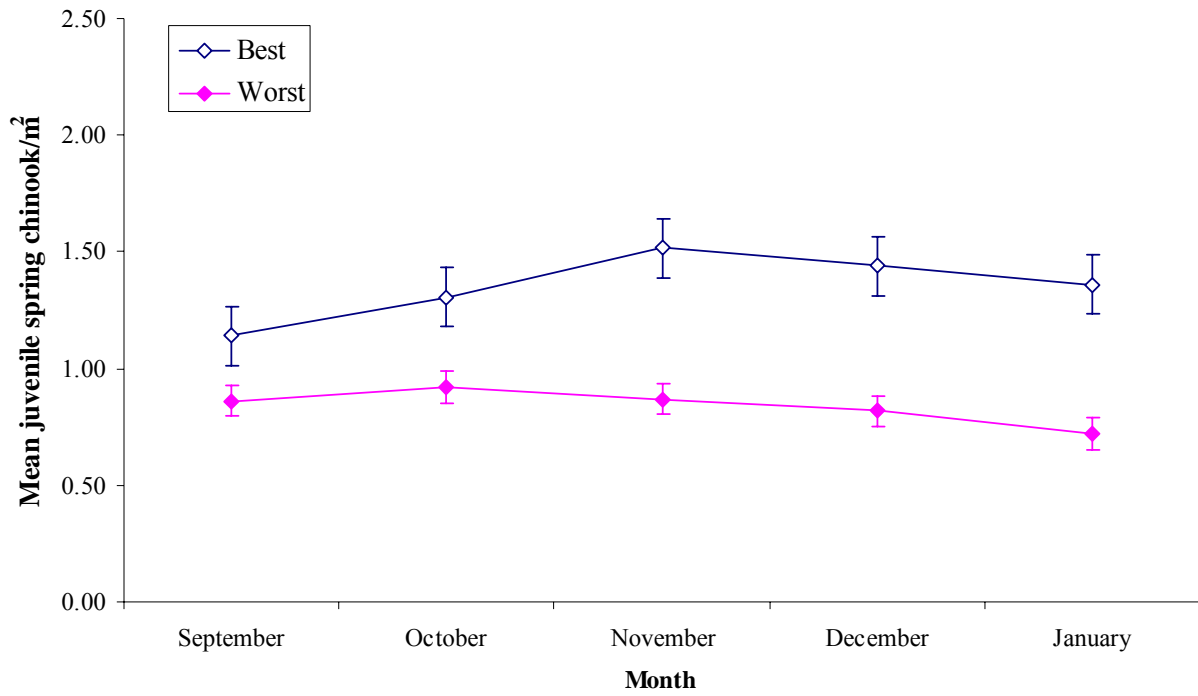
Figure 2. Mean fish density and standard error for pools with the best and worst winter concealment habitat rankings in Catherine Creek September 2003-January 2004.
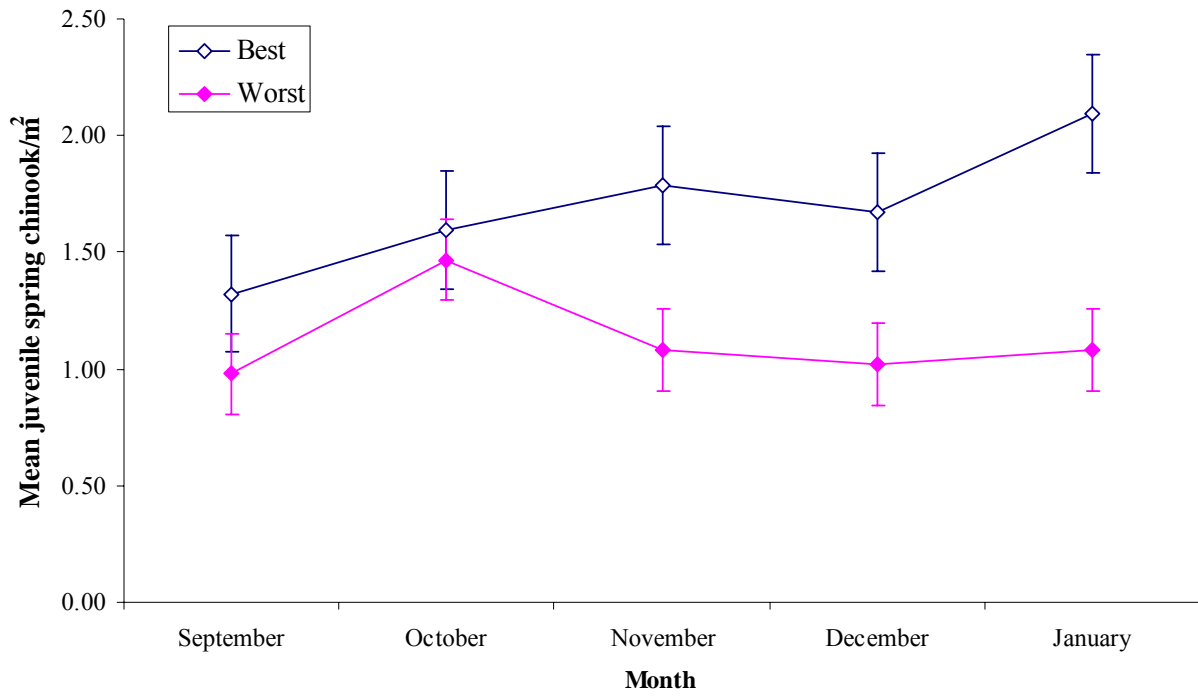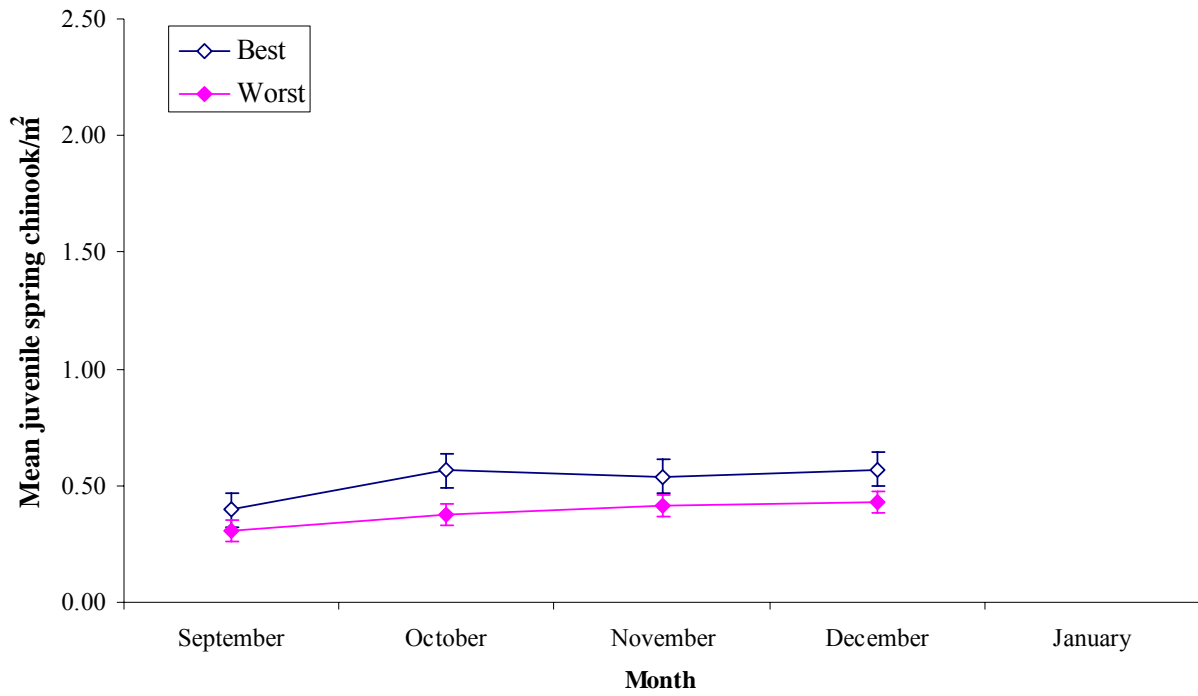
Figure 3. Mean fish density and standard error for pools with the best and worst winter concealment habitat rankings in Lostine River September 2003-January 2004.

Figure 4. Mean fish density and standard error for pools with the best and worst winter concealment habitat rankings in the upper Grande Ronde River September-December 2003.
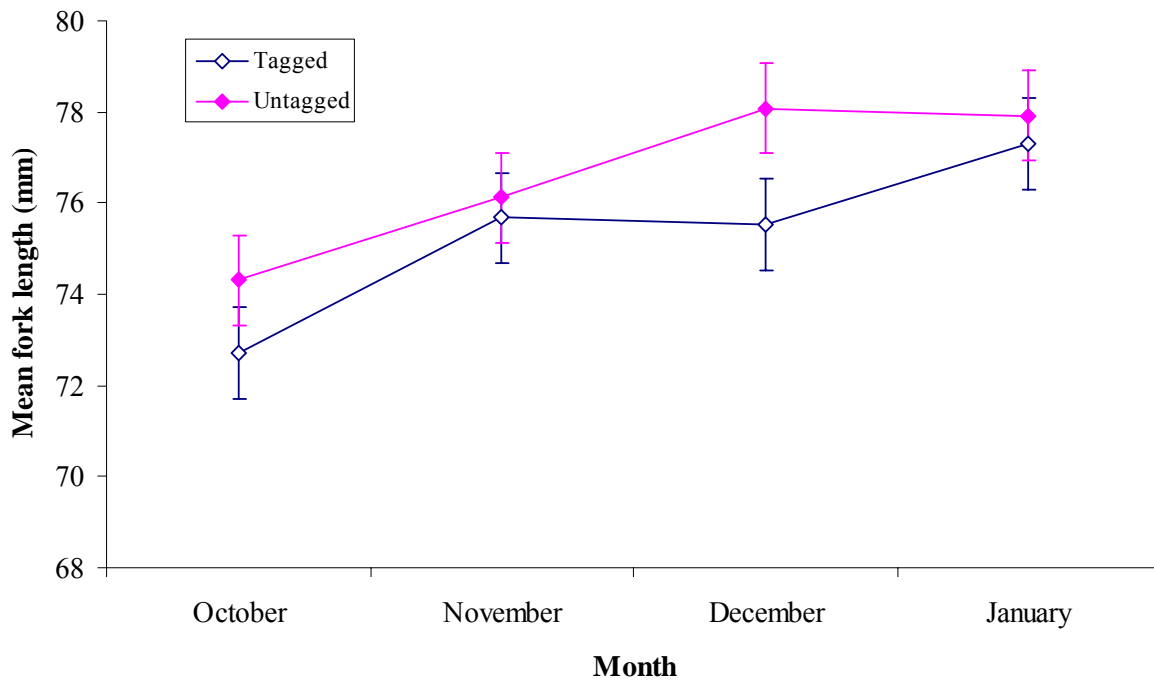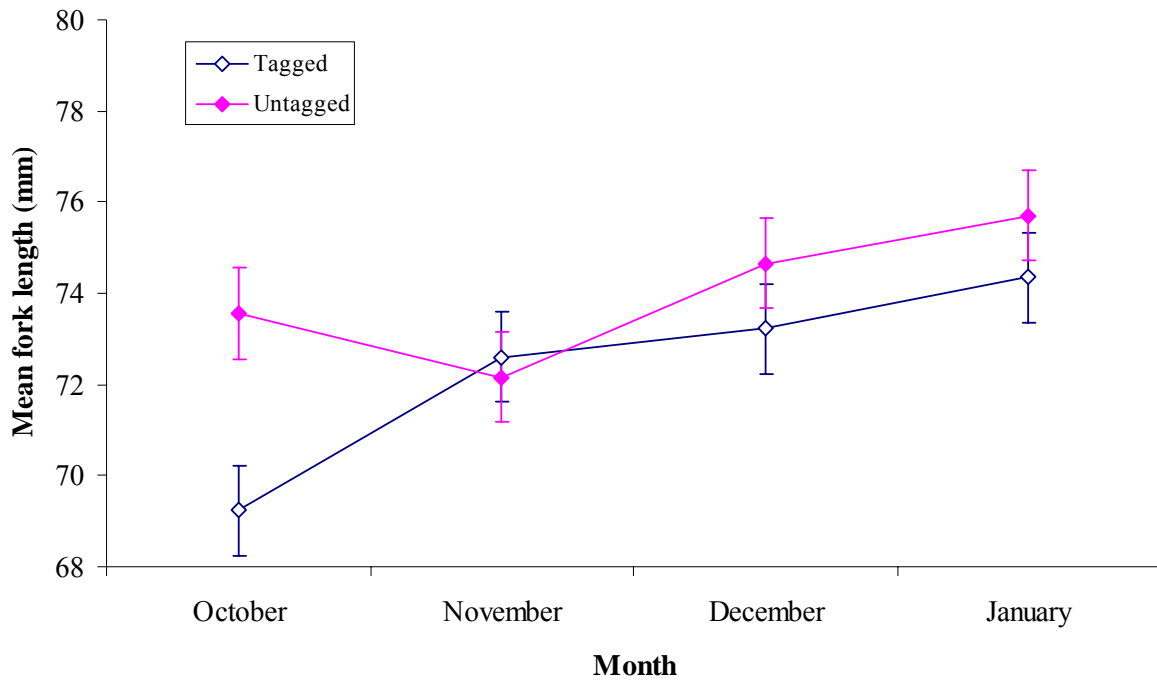
Figure 5. Comparison of monthly mean fork length and standard error of tagged and untagged juvenile spring Chinook salmon collected in pools in the hatching area of Catherine Creek October 2003-January 2004.
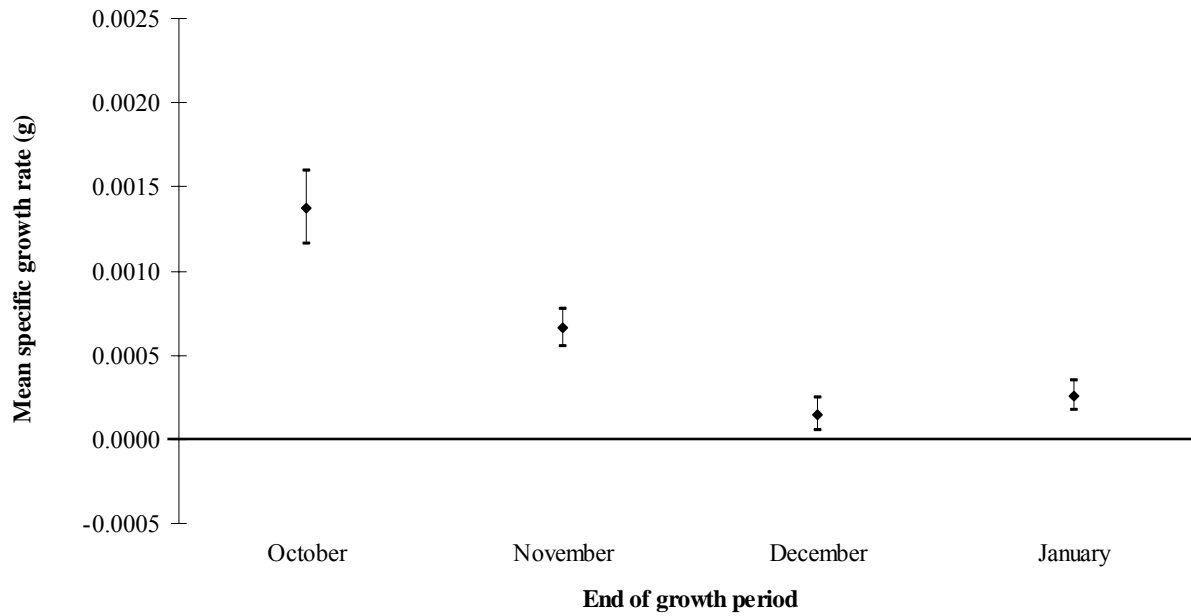
Figure 6. Mean specific growth rate and standard error of PIT-tagged juvenile spring Chinook salmon rearing in the hatching area of Catherine Creek during individual growth periods October 2003-January 2004.

Figure 7. Comparison of monthly mean fork length and standard error of tagged and untagged juvenile spring Chinook salmon collected in pools in the hatching area of Lostine River October 2003-January 2004.
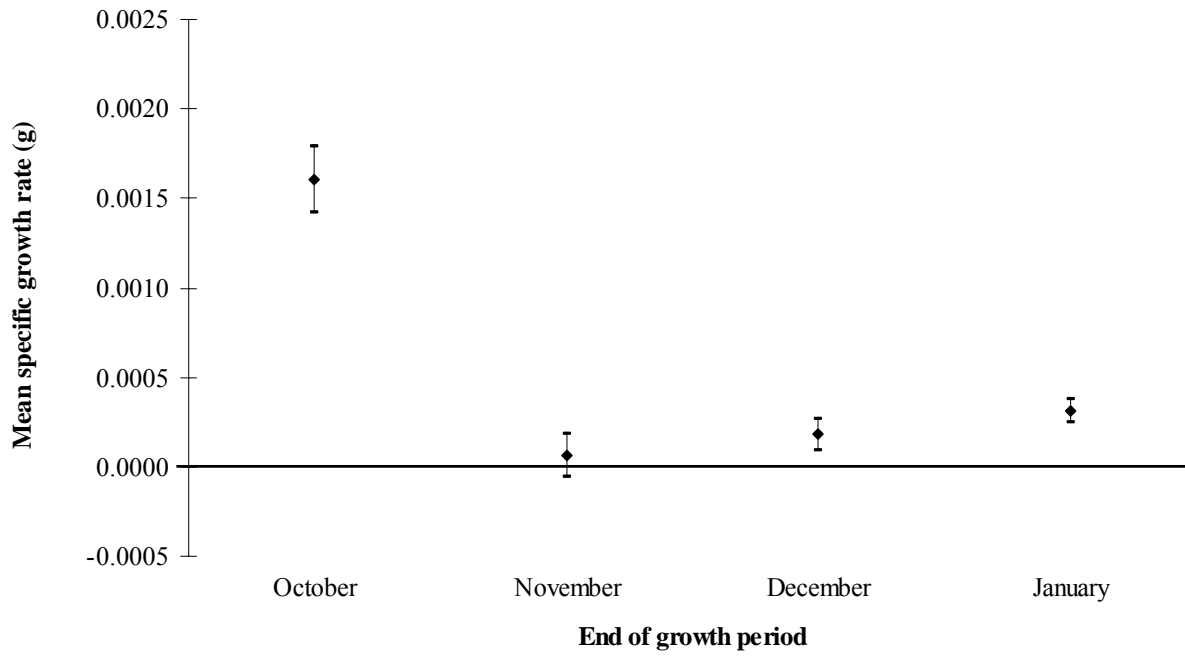
Figure 8. Mean specific growth rate and standard error of PIT-tagged juvenile spring Chinook salmon rearing in the hatching area of Lostine River during individual growth periods October 2003-January 2004.
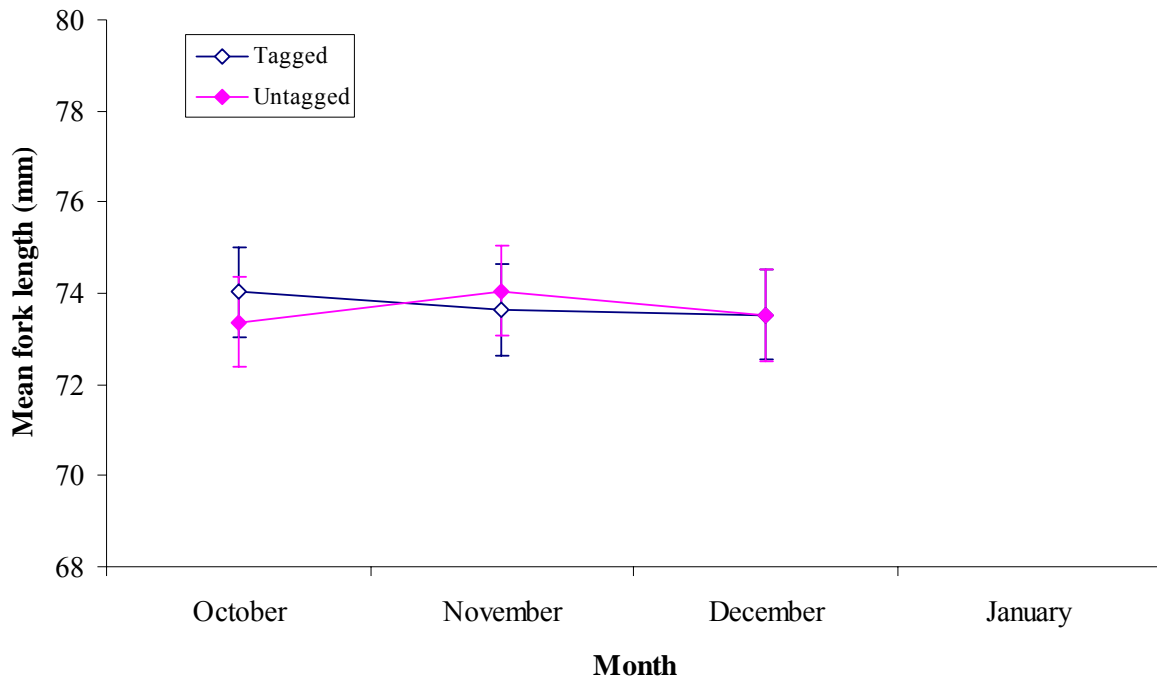
Figure 9. Comparison of monthly mean fork length and standard error of tagged and untagged juvenile spring Chinook salmon collected in pools in the hatching area of upper Grande Ronde River October 2003-December 2004.
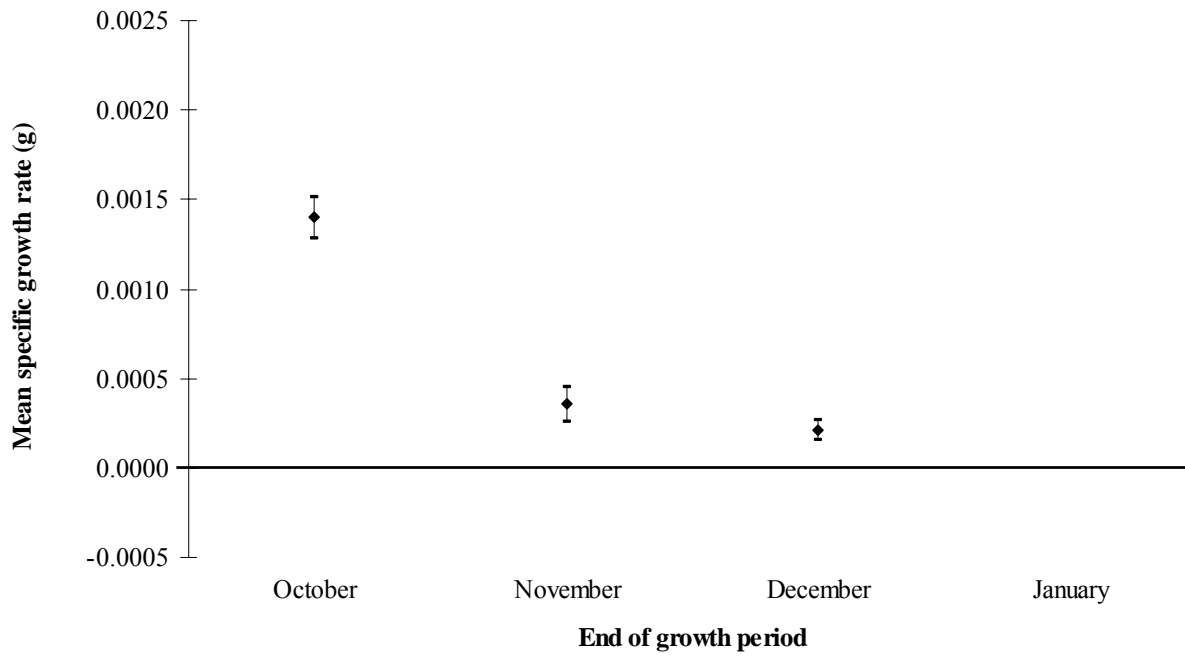
Figure 10. Mean specific growth rate and standard error of PIT-tagged juvenile spring Chinook salmon rearing in the hatching area of upper Grande Ronde River during individual growth periods October-December 2003.
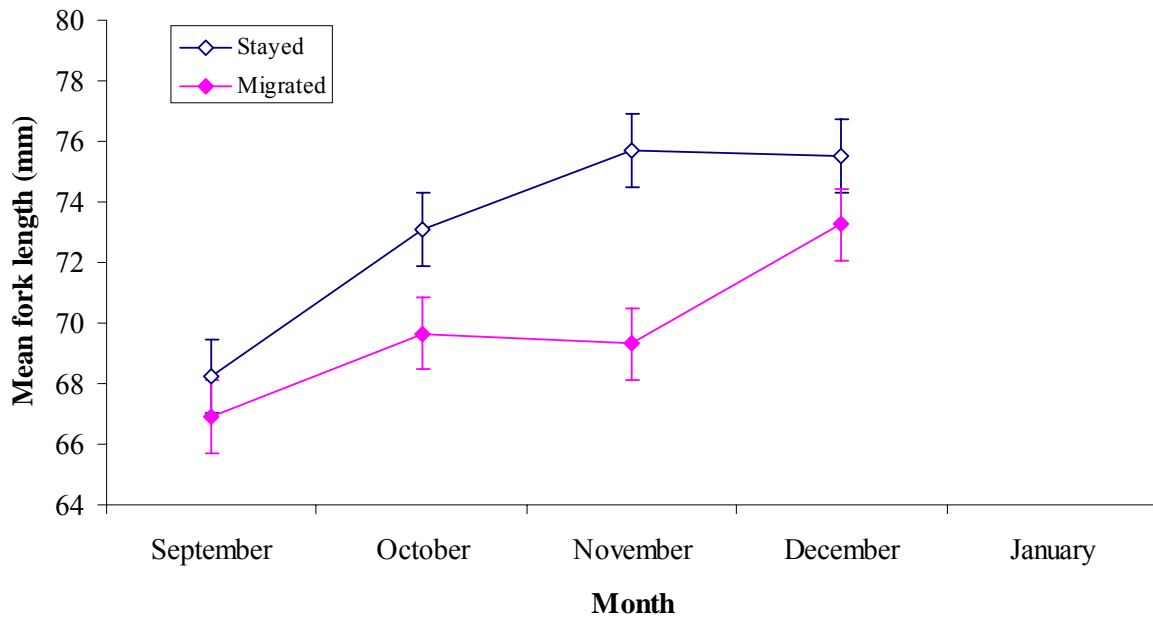
Figure 11. Comparison of monthly mean fork length and standard error of PIT-tagged spring Chinook salmon that stayed in pools within the hatching area and those that migrated in Catherine Creek September 2003-January 2004.
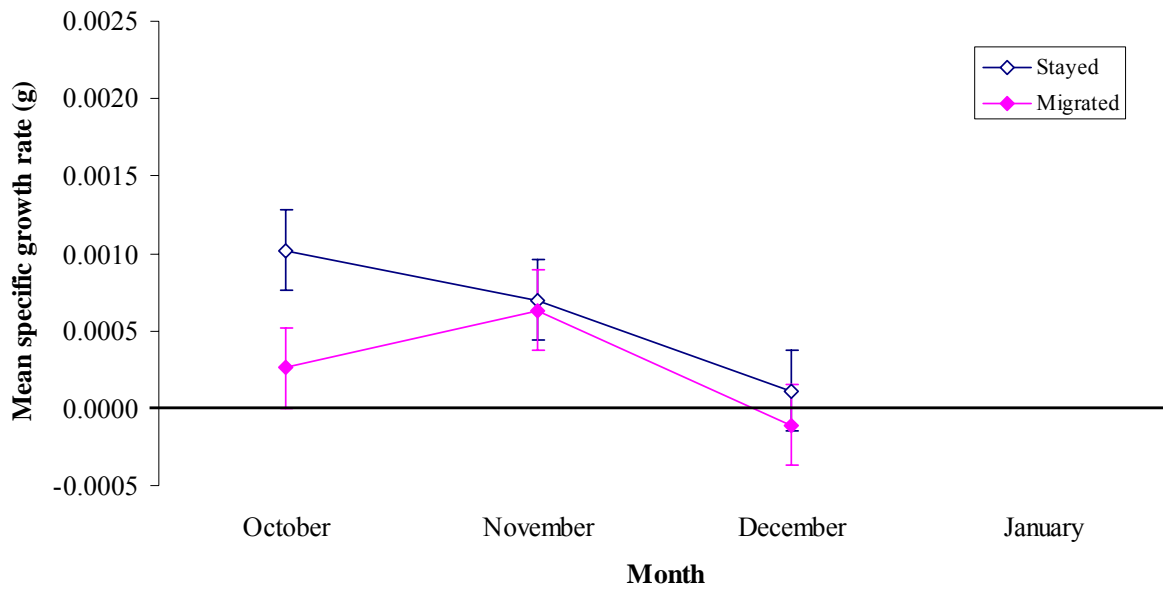
Figure 12. Comparison of monthly mean specific growth rate (g) and standard error of PIT-tagged spring Chinook salmon that stayed in pools within the hatching area and those that migrated in Catherine Creek October 2003-January 2004.
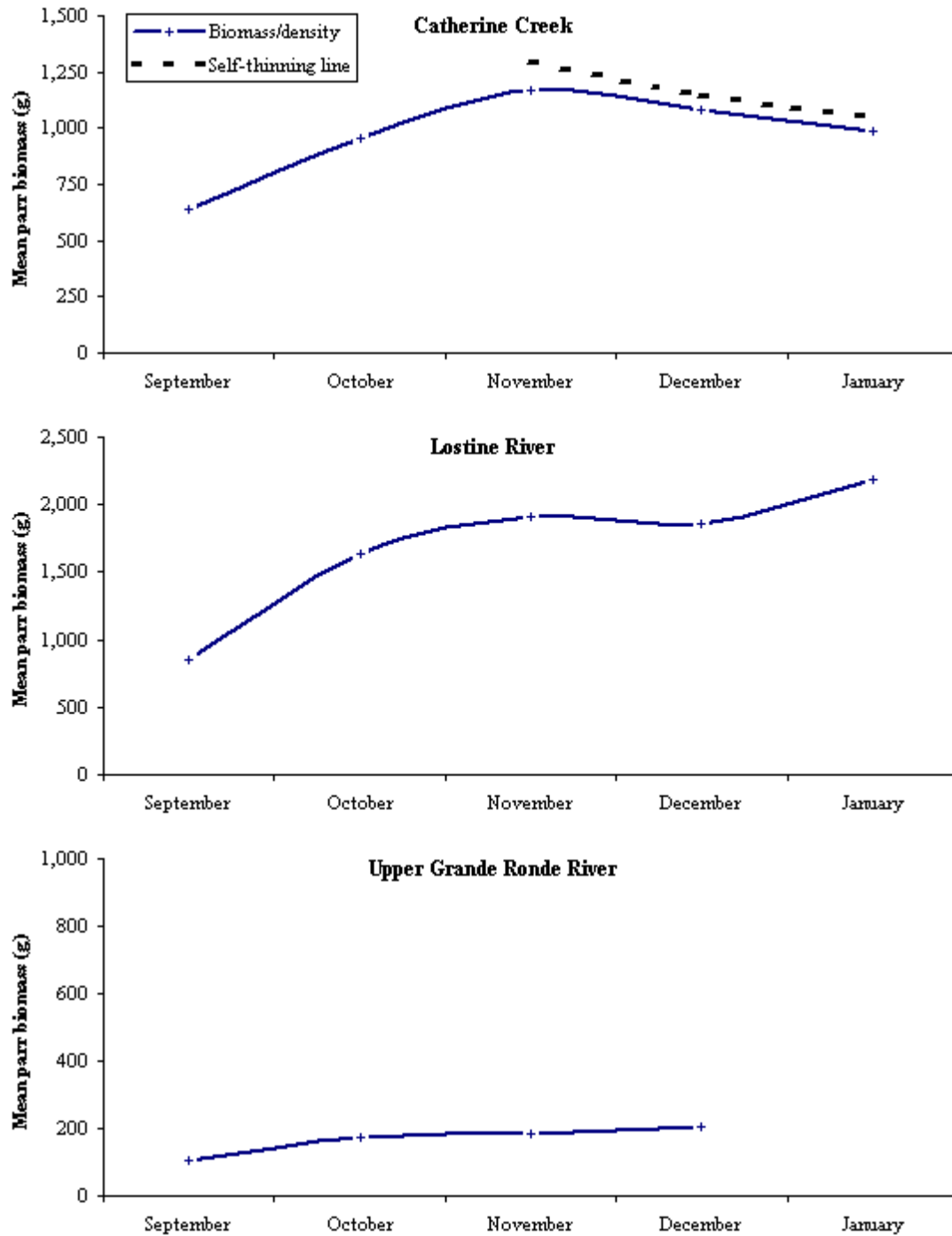
Figure 13. Evidence that space regulating factors in Catherine Creek reached a point where biomass and density were no longer independent and thus self-thinning of juvenile spring Chinook salmon occurred in the hatching area following November 2003. There was no evidence of self-thinning in Lostine River or upper Grande Ronde River.

Appendix 1. Modified Wentworth classification and substrate types by size (from Bain and Stevenson 1999).

Substrate type	Particle size range (mm)	Sample codes
Boulder	> 256	5
Cobble	64-256	4
Pebble	16-63	3
Gravel	2-15	2
Sand	0.06-1	1
Silt and clay	<0.059	0

Appendix 2. Embeddedness rating for stream channel materials (Platts et al. 1983). Fines are defined using the Wentworth classification and are substrate types that are < 2mm in diameter.

Level of embeddedness	Description
Negligible	Gravel, pebble, cobble and boulder particles have <5% of their surface covered by fine sediment.
Low	Gravel, pebble, cobble and boulder particles have 5-25% of their surface covered by fine sediment.
Moderate	Gravel, pebble, cobble and boulder particles have 25-50% of their surface covered by fine sediment.
High	Gravel, pebble, cobble and boulder particles have 50-75% of their surface covered by fine sediment.
Very high	Gravel, pebble, cobble and boulder particles have >75% of their surface covered by fine sediment.

Appendix 3. Total cover rating for vegetation and rock cover for segments along streambanks within units (from Bain and Stevenson 1999).

Ranking	Quality	Description
>4	Excellent	Nearly all the streambank is covered by vegetation in vigorous condition or by boulders and cobble.
4	Good	Most of the streambank surfaces are covered by vegetation or rocky material the size of pebbles and larger. Areas not covered by vegetation are protected by materials that will limit erosion at high stream flows.
3	Fair	A substantial portion of the streambank surface is not covered by vegetation or rocky material. These areas are poor resistance to erosion.
2	Poor	Little of the streambank surface is covered by vegetation or rocky material, and there is little or no resistance to erosion. Banks are clearly eroded each year by high stream flow.

Appendix 4. Parameters used to rank winter concealment habitat in Catherine Creek, Lostine River and upper Grande Ronde River.

Score	Mean depth (cm)	Mean velocity (m/s)	Substrate 10-24.9 cm/m2	% substrate <6.3 cm	Mean embeddedness	% embed > 4	% instream cover	% velocity <0.25 m/s	% velocity <0.5 m/s & depth <51cm
5	> 50	< 0.25	> 15	< 30	> 4	> 50	> .25	> 50	> 50
4	50-41	0.26-0.35	14.9-12	30-40	3.9-3.5	49-40	0.25-0.20	49-40	49-40
3	40-31	0.36-0.45	11.9-9	41-50	3.4-3	39-30	0.19-0.15	39-30	39-30
2	30-21	0.46-0.55	8.9-6	51-60	2.9-2.5	29-20	0.14-0.05	29-10	29-10
1	< 20	> 0.55	< 6	> 60	< 2.5	< 20	<.05	< 10	< 10