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[Article]

Juvenile Chinook Salmon Summer Microhabitat Availability, Use, and Selection in a Central Idaho Wilderness Stream

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Abstract.—We measured summer microhabitat use, availability, and selection by age-0 Chinook salmon *Oncorhynchus tshawytscha* in the Big Creek drainage, Idaho. Age-0 fish selected for low-velocity (0–25 cm/s), moderate-depth (40–80 cm) habitats that were located within 80 cm of cover. Pools (52%) and runs (38.5%) were the most commonly used habitat types, while pebbles (33.7%) and sand (23%) were the most often used substrates. Cover type use was predominated by woody debris (54.8%) and rock outcrops (23.7%). Run (38.5%) and riffle (32.9%) were the most available habitats in Big Creek, while pebble (38.4%) and cobble (28.2%) were the most available substrates. Mean water velocity (47 cm/s) availability and distance to cover (108 cm) availability were greater than those selected by age-0 Chinook salmon, while mean total water depth (30 cm) availability was lower than that selected by the fish. Linear regression was used to show that an increase in juvenile Chinook salmon total length was significantly ($P < 0.05$) related to increased total water depth ($r^2 = 0.68$), focal water depth ($r^2 = 0.73$), and focal water velocity ($r^2 = 0.49$) use. The relationship of habitat use and fish total lengths indicate that even within a short temporal period, juvenile Chinook salmon will select for different habitats as they grow. Upper and lower Big Creek microhabitat availability characteristics differed significantly ($P < 0.05$). Upper Big Creek had more fish per unit of preferred rearing habitat than lower Big Creek, which suggests that either summer microhabitat availability or redd density partially explain the density differences observed in Big Creek. Microhabitat use and availability data were useful for identifying habitat selection of age-0 Chinook salmon in Big Creek. The data from this study can be used for future identification, quantification, and restoration of suitable Chinook salmon rearing habitat in other Pacific Northwest streams.

Knowledge of the habitat availability and habitat use of fishes at critical life cycle stages can provide important information for species conservation, particularly as freshwater habitats change. Habitat requirements and preferences of fish species can be used to predict presence or absence (Simonson et al. 1994), abundance of fishes (Lyons 1991), and habitat capacity (Jowett 1992). Additionally, studies that link habitat preference with habitat capacity can potentially identify limiting factors in a system (Simonson et al. 1994), which can ultimately be used to prioritize or increase the success of habitat restoration or enhancement projects. Finally, quantifying habitat use by individual fish provides the basis for energy use and gain functions in bioenergetics models that can be used to further our understanding of the underlying mechanisms in growth, density, and perhaps survival of fishes (Rosenfeld 2003).

Chinook salmon *Oncorhynchus tshawytscha* belonging to the Snake River spring–summer Chinook salmon Evolutionarily Significant Unit were listed as threatened under the Endangered Species Act (ESA) in 1992 (NMFS 1992). There are many potential contributors to listing under the ESA, but among the most commonly implicated causes are hydroelectric dams, large-scale habitat degradation, and fish harvest (NMFS 1992). Although the causes of declines may be complex and numerous, the long-term declines emphasize the importance of understanding all life history stages of the remaining Chinook salmon populations in Idaho, including the earliest freshwater stages. Freshwater rearing habitat and its interactions with other parts of the life cycle continue to be of increasing importance as (1) developmental pressure on riparian corridors increases with population growth in the Pacific Northwest, (2) effects of climate change influence hydrologic variables (Crozier and Zabel 2006), (3) invasive species continue to expand across salmonid ranges (Fausch et al. 2006), and (4) the reduction in marine-derived nutrients suggests cyclic interdependencies of habitat, fish density, and fish survival.

Size, density, and survival differences have been observed between juvenile Chinook salmon populations throughout central Idaho, particularly in upper and lower Big Creek, a tributary to the Middle Fork Salmon River (Achord et al. 2003, 2007; Zabel and Achord 2004). Age-0 Chinook salmon in lower Big Creek had consistently lower density and larger mean total lengths (TLs) than other central Idaho populations

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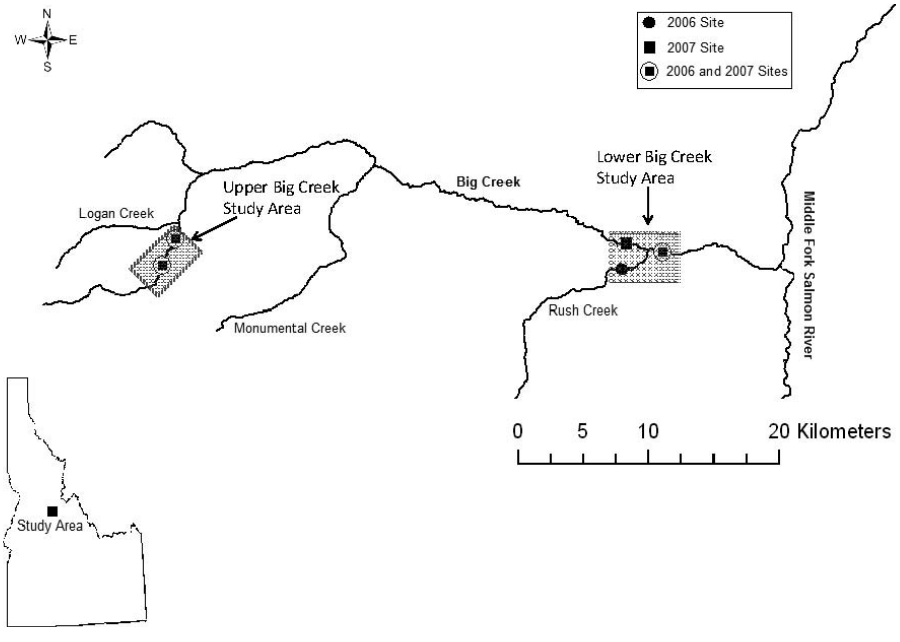

FIGURE 1.—Big Creek drainage, Idaho, map showing study sites for 2006 and 2007. Shaded regions represent upper and lower Big Creek sites. Inset shows location of study area in Idaho.

studied by Achord et al. (2003). This larger size appears to give them a competitive advantage in survival. As determined from passive integrated transponder tagging studies, Chinook salmon in lower Big Creek have the highest average overwinter and migration survival to the federal Columbia River hydrosystem (Achord et al. 2003; Zabel and Achord 2004). Conversely, Chinook salmon in upper Big Creek tend to be smaller, occur at higher densities, and have a lower average survival rate than those from other sites in central Idaho (Achord et al. 2003). Importantly, these two sites in Big Creek encompass the range of size and survival for juvenile Chinook salmon from a suite of long-term study sites throughout the Middle Fork Salmon River drainage. Given the consistent survival differences between populations within this drainage as documented over more than a decade, our overall goal was to determine the extent to which habitat differences existed among sites and whether these differences could help explain historical trends. The specific objectives of this study were to (1) quantify microhabitat availability, use, and selection by age-0 Chinook salmon in the Big Creek drainage, (2) describe the changes in habitat use as Chinook salmon grow throughout the summer, and (3) determine habitat availability differences between upper and lower Big Creek study sites.

Study Area

Big Creek is located almost entirely in the Frank Church River of No Return Wilderness area of Idaho (Figure 1). Big Creek is a third- to fourth-order stream that flows east into the Middle Fork Salmon River. The headwaters of Big Creek begin at an elevation of 2,438 m above mean sea level (asl), and the confluence of Big Creek and the Middle Fork Salmon River is at 1,051 m asl. The forest community in upper Big Creek primarily consists of Douglas-fir *Pseudotsuga menziesii* and lodgepole pine *Pinus contorta*, while lower Big Creek is generally more open and has an increased representation of ponderosa pine *P. ponderosa*. The Big Creek drainage contains some of the most pristine stream rearing habitat in the continental United States; there is no ongoing hatchery program, few anthropogenic disturbances, and only one known introduced exotic species, the brook trout *Salvelinus fontinalis* (Thurow 2000). The salmonid fish community in the Big Creek drainage consists of Chinook salmon, bull trout *S. confluentus*, brook trout, westslope cutthroat trout *O. clarkii lewisi*, steelhead *O. mykiss*, and mountain whitefish *Prosopium williamsoni*.

Methods

Microhabitat use.—To quantify microhabitat use by age-0 Chinook salmon, we snorkeled established reaches in the Big Creek drainage (Figure 1). Reaches

TABLE 1.—Cover complexity rating scale for evaluating stream cover for juvenile Chinook salmon in the Big Creek drainage of Idaho.

Complexity rating	Description of rating	Example of observed cover for fish
1	Lowest complexity. Very simple cover consisting of one homogeneous structure–habitat type.	A large boulder or rock that provides minimal cover.
2	Low complexity. Simple cover that at most consists of two simple structures–habitat types.	A large boulder with sparse vegetation hanging over the boulder.
3	Moderate complexity. Complex cover type composed of at least two types of cover. Provides adequate refuge for fish.	Large–complex wood debris submerged in deep water (>1 m) and perhaps sparse overhanging vegetation.
4	High complexity. Very complex cover composed of at least three types of cover and likely provides multiple uses for fish.	Complex wood debris (e.g., rootwad) submerged in deep water near an undercut bank with overhanging vegetation.
5	Highest complexity. The most intricate and heterogeneous composition of multiple types of cover. Snorkeler has difficulty observing fish due to the complexity of such cover.	Multiple complex wood structures (e.g., rootwads and logs) submerged in deep or turbulent water. Thick vegetation in stream and overhanging an undercut bank near the wood structures.

were selected based on stratification within the drainage (upper and lower reaches), accessibility, and proximity to long-term tagging sites. There were two reaches in upper Big Creek, one reach in lower Big Creek, and one reach in Rush Creek, a tributary to lower Big Creek. We snorkeled each 100-m study reach at least twice from June to August 2006. In 2007, we quantified microhabitat use at the same two sites in upper Big Creek and at two sites in lower Big Creek (the same one from 2006 plus an additional site). Two field crew members snorkeled the reaches; snorkelers worked simultaneously in an upstream direction (one snorkeler on each side of the stream) and followed the methods described by Thurow (1994). Seven microhabitat variables were measured to determine juvenile habitat use in this study: total water depth, focal water depth, focal water velocity, substrate, distance to cover, cover complexity, and habitat type. Each variable was recorded from where each individual age-0 Chinook salmon was observed. Total and focal water depths were recorded to the nearest 0.1 m with a wading rod. We determined relative water depth ([total water depth − focal water depth]/total water depth; Hillman et al. 1987) for each respective total depth and focal depth. Focal water velocity was measured with an electromagnetic flowmeter (Marsh-McBirney Model 2000) at the observed focal point of the fish. Four pieces of substrate were measured directly beneath where each fish was observed and were classified as silt (particle size = 0.0–0.6 mm), sand (0.6–1.0 mm), gravel (2.0–15.0 mm), pebble (16–63 mm), cobble (64–256 mm), or boulder (>256 mm; Cummins 1962). We defined cover as anything that provided concealment for an age-0 Chinook salmon; cover types included woody debris, rock outcrops, undercut banks, and overhanging vegetation. When fish were observed, the snorkeler identified cover that was closest to the fish and assigned a cover complexity rating from 1 to 5 as described in Table 1. In 2007, we quantified cover type use; however, in 2006 we only recorded cover complexity. We classified habitat types as pool, pocket, riffle, or run (Arend 1999). Habitat type was not recorded in 2007. The size of each observed fish was estimated to the nearest centimeter by snorkelers who were trained by observing simulated fish of various lengths under water each day before the snorkel surveys. Additionally, each snorkeler carried a small measuring device to aid in estimating fish length (Thurow and Schill 1996).

Microhabitat availability.—We assessed microhabitat availability in each snorkel reach by measuring water depth, water velocity, substrate size, habitat type, distance to cover, and cover complexity at five equally spaced points along 20 transects oriented perpendicular to streamflow during the 2006 growing season. No habitat availability data were collected in 2007. Each habitat availability measurement was collected in the same way as the habitat use measurements described above, except that water velocity was measured at 0.6 × total depth. A random starting point was chosen for each reach, and transects were spaced evenly from that point to the end of the 100-m reach.

We used analysis of covariance to identify possible habitat use differences between 2006 and 2007; fish TL was treated as a covariate. Wilcoxon rank-sum two-sample tests were used to identify habitat availability differences between upper and lower Big Creek in 2006, and we used a Kruskal–Wallis test to identify differences in habitat use between upper and lower sites for both years. If a significant difference was found, we used Tukey's honestly significant difference procedure to identify which sites and years differed in habitat use. We compared proportions of habitat type and substrate type with chi-square goodness-of-fit tests.

TABLE 2.—Mean (SD) and range of microhabitat use and availability characteristics for age-0 Chinook salmon at four reaches sampled 2–3 times/study season (June–August) for 2006 and 2007 in Big Creek, Idaho. Habitat availability was not measured in 2007. Water velocity was measured at 0.6 × total depth for availability and at the focal point of each observed fish for use. Relative water depth was calculated as (total water depth used – focal water depth used)/total water depth used. Cover complexity is a rating of 1–5, with 1 being the lowest and 5 being the highest complexity. Variables that were statistically different ($P \leq 0.05$) between 2006 and 2007 are denoted by an asterisk in the column heading.

	Total water depth (cm)*			Focal water velocity (cm/s)*			Distance to cover (cm)		
Statistic	Available	Used	Used	Available	Used	Used	Available	Used	Used
Year	2006	2006	2007	2006	2006	2007	2006	2006	2007
Mean (SD)	30 (18)	36 (16)	46 (14)	47 (37)	11 (11)	9 (7)	108 (134)	49 (57)	58 (77)
Range	0.0–1.0	5–89	20–89	−19–160	−9–43	0–39	0.0–1400	0–400	0–300
N	1,790	131	122	1,754	131	122	1,778	131	122

All statistical tests were considered significant at *P*-values of 0.05 or less. An underwater temperature logger (HOBO Pro v2) recorded water temperature hourly in upper and lower Big Creek and in Rush Creek. Water temperature in lower Big Creek was estimated by linear regression for May and June 2006 because our temperature logger was not operational during that period.

Microhabitat selection.—We used the electivity index (D) equation of Jacobs (1974) to show selection behavior of age-0 Chinook salmon for water depth, water velocity, distance to cover, habitat type, and substrate:

$$D = (r - p)/(r + p - 2rp),$$

where r is the proportion of fish using a particular habitat variable and p is the proportion of habitat available. This index ranges from -1 to 1, where -1 indicates complete avoidance, 0 indicates use in proportion to availability, and 1 indicates exclusive use. Selection for habitat type and substrate was identified using chi-square goodness-of-fit tests to determine whether use (observed) differed from availability (expected). Observed counts came from the total number of fish using the particular habitat or substrate type, while expected counts were derived from the proportion of habitat or substrate type available multiplied by total fish count sample size (Muhlfeld et al. 2001). If there was a statistical difference between observed and expected counts, we used Jacobs' electivity index to quantify selection. We only report habitat selection for 2006 because we did not take habitat availability measurements in 2007.

We used principal component analysis (PCA; Shaw 2003) to evaluate microhabitat use and availability of four variables at both upper and lower sites: water depth, water velocity, distance to cover, and cover complexity. Principal components (PCs) were extracted from the matrices of four environmental variables measured at all used and available habitat points in each site. Using the PC coefficients (loadings), a single-value score was calculated for each multivariate habitat observation. These scores were used to determine the reach-specific proportion of age-0 Chinook salmon preferred habitat (PPH). We defined PPH as the proportion of available microhabitats having PC scores within a 95% confidence range of the scores calculated for used microhabitats (adapted from Urabe and Nakano 1999). The PPH is intended to quantify (in terms of the most biologically relevant variables) the proportion of the total available channel habitat that resembles the habitats actually selected by the fish. Pearson's correlation analysis was used to determine the relationship between fish densities and PPH.

We calculated fish density by estimating the population with triple-pass electrofishing depletion of a blocked reach and dividing the population estimate by the area of the reach. Linear regression of mean fish TL against mean habitat use (e.g., mean water velocity use) was used to identify potential differences in habitat use for fish of different TLs. Because we found a nonnormal distribution for the habitat data, the data were log transformed for regression analysis.

Results

Microhabitat Use and Availability

Mean summer microhabitat use (2006 and 2007) and availability characteristics (2006) are reported in Table 2. Runs and riffles were the habitat types with the greatest availability, while pool habitats were the most commonly used (Table 3). Gravel, pebble, and cobble were the most available substrates in the Big Creek drainage in 2006, while pebble, cobble, and sand were the most commonly used substrates in 2006 and 2007 (Table 4). Chinook salmon used all substrate classes from silt to boulder. In 2007, juvenile Chinook salmon used four types of cover: woody debris (54.8%), rock

TABLE 2.—Extended.

Statistic	Cover complexity*			Focal water depth (cm)*		Relative water depth*		Fish total length (mm)*	
	Available	Used	Used	Used	Used	Used	Used		
Year	2006	2006	2007	2006	2007	2006	2007	2006	2007
Mean (SD)	1.3 (0.57)	1.94 (0.86)	2.7 (1.0)	25 (14)	39 (15)	0.32 (0.16)	0.84 (0.14)	63 (12)	66 (13)
Range	1–4	1–4	1–5	2–69	8–86	0.1–0.82	0.32–1.0	40–98	29–125
N	1,778	131	122	131	122	131	122	131	122

outcrops (23.7%), undercut banks (13.3%), and overhanging vegetation (8.2%).

Microhabitat Selection

Age-0 Chinook salmon in 2006 selected for focal water velocities of 0.00–0.25 m/s, total water depths of 0.4–1.0 m, and habitats that were 0.8 m or closer to cover (Figure 2). Chinook salmon used habitat and substrate types in different proportions than expected based on availability ($P < 0.001$). The fish selected for pool and pocket habitats as well as silt, sand, and gravel substrates (Figure 2).

The first and second PCs (PC1 and PC2, respectively) explained the majority of variance in all cases (Table 5). Principal component 1 had a strong positive correlation with depth and velocity variables for both sites. However, the correlation of PC1 with cover complexity was positive for upper Big Creek, whereas it was negative and relatively weak for lower Big Creek. Principal component 2 from both sites had stronger associations with cover variables than with depth and velocity; in contrast to results from PC1, the correlation of PC2 with cover complexity was strongly positive for lower Big Creek and negative for upper Big Creek. Consistent with our univariate analyses, the PCA scores of occupied habitats suggested that fish in both sites use microhabitats of relatively greater depth, low to moderate velocity, low distance to cover, and high cover complexity. Mean age-0 Chinook salmon density in Big Creek was 0.09 fish/m^2, but site-specific densities for upper and lower Big Creek averaged 0.126 and 0.017 fish/m^2, respectively. Based on observed use by Chinook salmon, all reaches had less than 10% PPH; however, PPH correlated significantly with density overall ($r^2 = 0.90$, $P = 0.004$; Figure 3).

TABLE 3.—Habitat type use and availability (%) for juvenile Chinook salmon in combined reaches of Big Creek, Idaho, during the 2006 growing season (June–August).

Variable	*N*	Pool	Pocket	Run	Riffle
Use	131	52.0	4.8	38.5	4.6
Availability	1,790	16.1	2.7	45.2	32.9

Fish Size and Habitat Use

Linear regression showed that TL of age-0 Chinook salmon was related to habitat use. Fish with larger TLs used increased total water depths ($P < 0.001$), increased focal water depths ($P < 0.001$), increased focal water velocities ($P < 0.005$), and decreased relative depths ($P < 0.01$; Figure 4). Larger fish also used greater cover complexity ($P < 0.05$), but we found no relationship between TL of Chinook salmon and distance to cover (Figure 4).

Spatial Habitat Comparisons

Microhabitat availability differed between upper and lower Big Creek during the 2006 growing season. Stream width, water depth, water velocity, cover complexity, and distance to cover were all significantly different between the sites during August ($P < 0.001$; Figure 5, Table 6). All habitat variables except cover complexity were significantly different between the two sites in July ($P < 0.001$). Upper Big Creek had more pool habitat and gravel substrates than did lower Big Creek during the August sampling period ($P < 0.05$; Table 7). Mean microhabitat use also differed between the two sites and years for total and focal water depths but not for focal water velocity or distance to cover (Figure 6). Summer water temperatures were also different between upper and lower Big Creek sites during 2006 (Table 8).

Discussion

We were motivated to study Chinook salmon in Big Creek because we observed consistent differences in population trends as part of an ongoing long-term juvenile Chinook salmon monitoring effort in the Salmon River basin (Zabel and Achord 2004). The

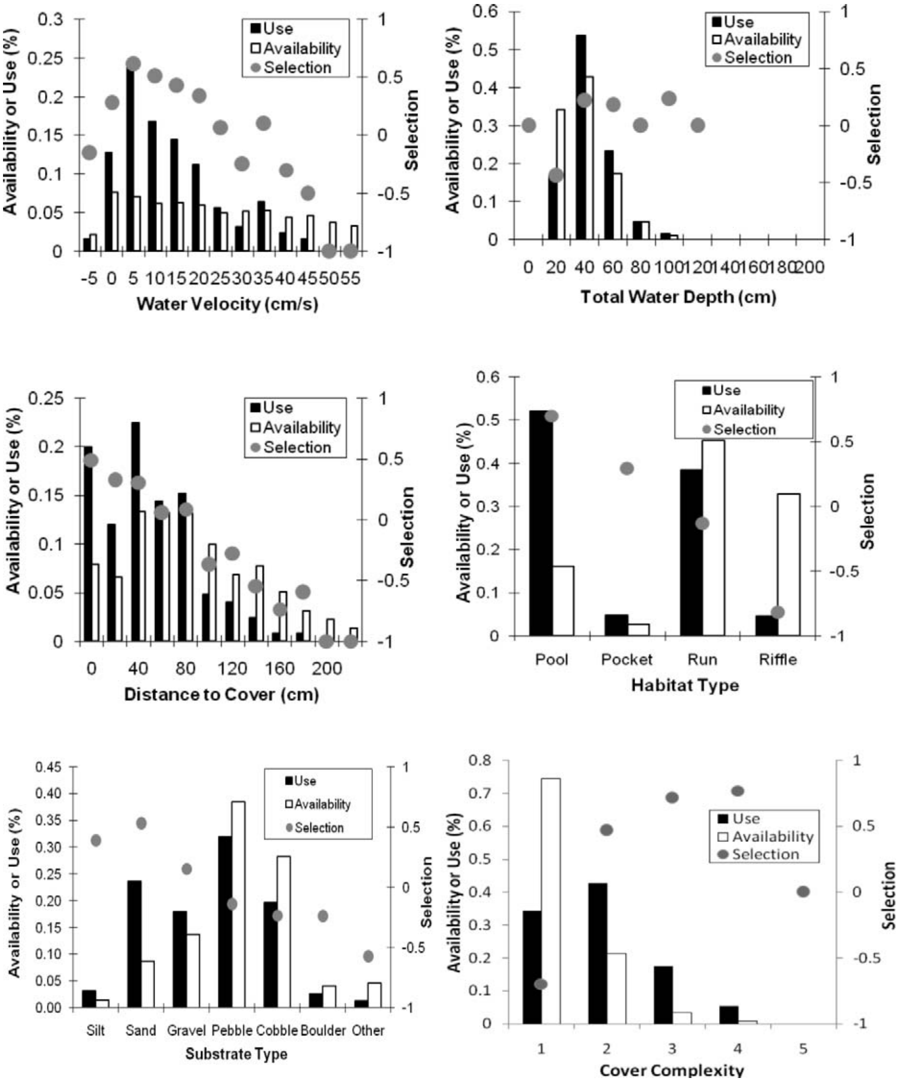

FIGURE 2.—Selection and proportion of use and availability of six habitat variables for age-0 Chinook salmon in the Big Creek drainage, Idaho, during the 2006 growing season.

long-term effort includes data from more than 15 consistent sites that span a large spatial area across the Salmon River drainage. However, trends in size and survival from just two sites within the single watershed of Big Creek encompass the range of juvenile salmon size and survival measured as part of that monitoring effort. Given the consistent survival differences observed between populations within this drainage over more than a decade, our overall goal was to determine the extent to which habitat differences

TABLE 4.—Substrate type use and availability (%) for juvenile Chinook salmon in combined study reaches of Big Creek, Idaho. No habitat availability data exist for 2007.

Year	Variable	*N*	Silt	Sand	Gravel	Pebble	Cobble	Boulder	Other
2006	Use	131	3.2	23.6	17.9	31.9	19.6	2.5	1.2
2006	Availability	1,790	1.4	8.7	13.8	38.4	28.2	4.1	4.6
2007	Use	122	2.5	22.3	8.0	35.4	31	0.8	0.0

TABLE 5.—Principal component analysis of site-specific habitat data for juvenile Chinook salmon in the Big Creek drainage, Idaho, during summer 2006, used to reduce the dimensions of the data matrix to two major axes (PC1 and PC2) that explained the majority of variance within the data set. Loadings for each original habitat variable show the direction and magnitude of correlation between the original variables and the derived principal component axis.

	Upper Big Creek		Lower Big Creek	
Variable	PC1	PC2	PC1	PC2
Water depth	0.737	−1.124	0.636	0.053
Water velocity	0.447	0.546	0.677	−0.020
Cover distance	0.205	0.583	0.326	0.426
Cover complexity	0.463	−0.588	−0.176	0.903
Eigenvalue	1.34	1.27	1.88	1.00
Total variation explained (%)	33.6	33.6	47.1	25.0
Cumulative variation explained (%)	31.6	65.2	47.1	72.1

existed among sites and whether these differences could help explain the historical trends. As the focus of salmon population restoration increasingly widens to include habitat alteration within the Columbia River basin, it is imperative to quantify the relationship between freshwater habitat and fish growth and survival differences across the basin.

Microhabitat Use and Availability

Across the Big Creek watershed, our results support those of previous investigations that have quantified microhabitat use and selection by wild juvenile Chinook salmon. Age-0 Chinook salmon microhabitat use in the Big Creek drainage was similar to that found in a study of the Clearwater River drainage of Idaho (Hillman et al. 1987), where age-0 fish selected for water velocities less than 20 cm/s, total water depths of 20–80 cm, and cobble substrates. Beechie et al. (2005) reported that densities of juvenile Chinook salmon and coho salmon *O. kisutch* were higher in low-velocity areas (<15 cm/s) than in high-velocity areas. Results of these studies and the present study are consistent with those of Bjornn and Reiser (1991), who noted that juvenile salmonids tended to occupy low-velocity, shallow portions of streams. Habitat type use in our study was also consistent with the observations by Bjornn and Reiser (1991); they reported that for age-0 Chinook salmon in 22 Idaho streams, pools were used most frequently, followed by runs, pocket water, and riffles. This is also consistent with the results of Scarnecchia and Roper (2000), who observed higher densities of juvenile Chinook salmon in pools than in riffle habitats.

The PCA indicated that multiple variables describe Chinook salmon habitat use in a pattern consistent with Jacobs' electivity index scores. Chinook salmon preferred moderate depths, lower velocities, shorter distances to cover, and higher complexity cover. These habitat features probably favor profitable foraging and sheltering. Habitat use in this study may be skewed towards highly preferable habitats if because of the low observed densities, the fish were not forced into less-

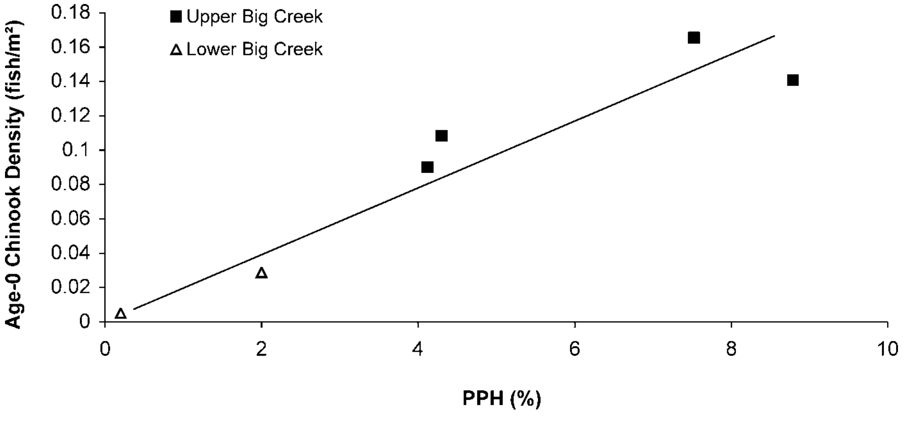

FIGURE 3.—Relationships between reach-scale proportion of preferred habitat (PPH) and age-0 Chinook salmon density in upper and lower Big Creek, Idaho, during the 2006 growing season (June–August).

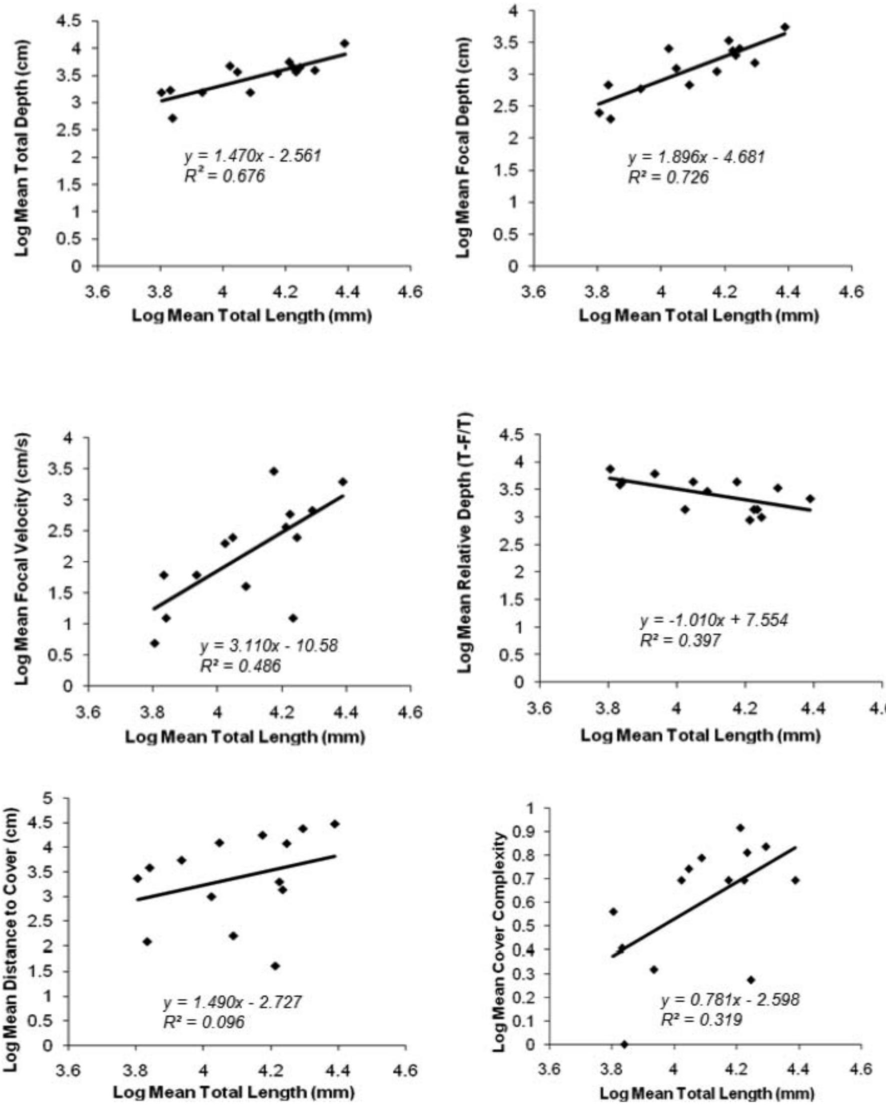

FIGURE 4.—Linear regressions between mean juvenile Chinook salmon total length (log transformed) and mean habitat occupancy variables (log transformed) in the Big Creek drainage, Idaho.

advantageous habitats. This could partially explain the low PPH ($<10\%$) that we observed for all reaches and dates. Nevertheless, PPH successfully predicted fish density throughout the season; thus, premium rearing habitat may be limiting even at relatively low densities.

Mean density of juvenile Chinook salmon in Big Creek during 2006 was lower than previous reports for other systems; Everest and Chapman (1972) reported that the age-0 Chinook salmon density was 1.8 fish/m^2 in one Idaho stream, and Hillman et al. (1987) reported a range of 0.52–0.75 fish/m^2 in their study streams in 1984 and 1985. The relatively low density in Big Creek compared with densities in the other two studies is probably attributable to a combination of low adult returns to the Middle Fork Salmon River basin and a lack of hatchery supplementation. A total of 37 redds were counted in Big Creek in 2005, which is relatively low compared with the high of 768 redds counted in 1957 (Idaho Department of Fish and Game, unpublished data). In 2005, 14 Chinook salmon redds were counted in a transect that corresponded to our upper Big Creek study site, while only one redd was counted in a transect that corresponded to lower Big Creek. There has been no documented hatchery supplementa-

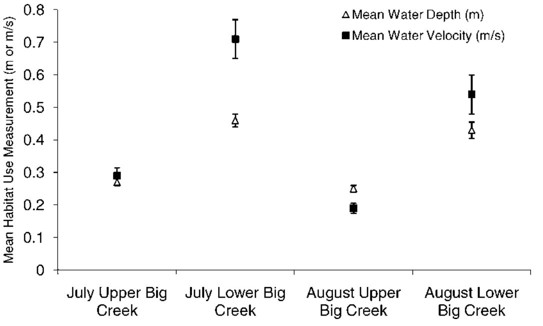

FIGURE 5.—Mean water depth and velocity availability comparison in upper and lower Big Creek, Idaho, during July and August 2006.

TABLE 7.—Percent composition (%) of available habitat types and substrate types for upper and lower Big Creek, Idaho, in August 2006. Habitat and substrate types were statistically different between upper and lower Big Creek ($P < 0.05$).

Characteristic	Upper Big Creek	Lower Big Creek
Habitat type		
Run	62	65
Riffle	15	34
Pool	17	1
Substrate type		
Silt	0	1
Sand	0	5
Gravel	16.5	6
Pebble	53	44.5
Cobble	24.5	37
Boulder	0.5	6.5

tion of Chinook salmon in the Middle Fork Salmon River basin (Thurow 2000).

Habitat Use and Size

Age-0 Chinook salmon with greater TLs occupied increased water depths, focal depths, and velocities. Other studies have observed a similar pattern of larger juvenile Chinook salmon using faster, deeper water than smaller Chinook salmon (Everest and Chapman 1972; Hillman et al. 1987), and these differences may be related to foraging (Chapman and Bjornn 1969). The relationship of habitat use and fish TL indicates that even over short temporal periods (e.g., summer rearing), juvenile Chinook salmon will probably use and select for different habitats as they grow.

Larger fish were observed in or near cover of increased complexity than were smaller fish. The use of increased cover complexity may result from two factors: (1) larger fish require more complex cover to hide in as a result of increased size and (2) selective pressures and survival rates are higher for age-0 Chinook salmon using increased cover complexities. As a result, over the course of the growing season fish are observed near more complex cover.

TABLE 6.—Mean microhabitat variable comparison of upper and lower Big Creek, Idaho, in July and August 2006. Statistically different variables between upper and lower Big Creek are denoted by asterisks(*). See Table 1 for a description of cover complexity.

Habitat variable	Upper Big Creek	Lower Big Creek
July		
Stream width (m)*	12.0	33.18
Cover complexity	1.31	1.23
Distance to cover (m)*	0.98	3.68
August		
Stream width (m)*	10.9	29.4
Cover complexity	1.34	1.07
Distance to cover (m)*	0.85	1.35

Distance to cover and cover complexity may be related such that fish move to higher complexity cover but tend to stray farther from that cover when compared with lower complexity cover habitats. Our study found that 40% of juvenile Chinook salmon were within 0.4 m of cover (Figure 7) compared with 85% for the Chinook salmon fry studied by Hardy et al. (2006) in the lower Klamath River. We did not differentiate between vegetation cover types. However, like Hardy et al. (2006), we found that large woody debris and vegetation accounted for most of the cover type use (63%). Our fish used undercut banks (13.3%), which was not included as a cover type by Hardy et al. (2006), perhaps because few undercut banks existed in their study area. Habitat restoration efforts throughout the range of Chinook salmon will have to account for cover distance, type, and complexity because otherwise restored or improved rearing habitat may be unused by salmon if sufficient cover is not available.

Spatial Habitat Comparisons

The observed microhabitat availability differences between upper and lower Big Creek in 2006 were expected. The amount of preferred juvenile Chinook salmon rearing habitat in upper Big Creek was greater than that in lower Big Creek by approximately fivefold. Mean densities of fish were nearly 12-fold higher in upper Big Creek. Thus, the number of fish per unit area of PPH was higher in upper Big Creek relative to lower Big Creek. Habitat use differences between upper and lower sites were also expected for two reasons: (1) habitat availability differed between the two sites and (2) fish observed in lower Big Creek were consistently larger than those observed in upper Big Creek.

Size differences observed between upper and lower

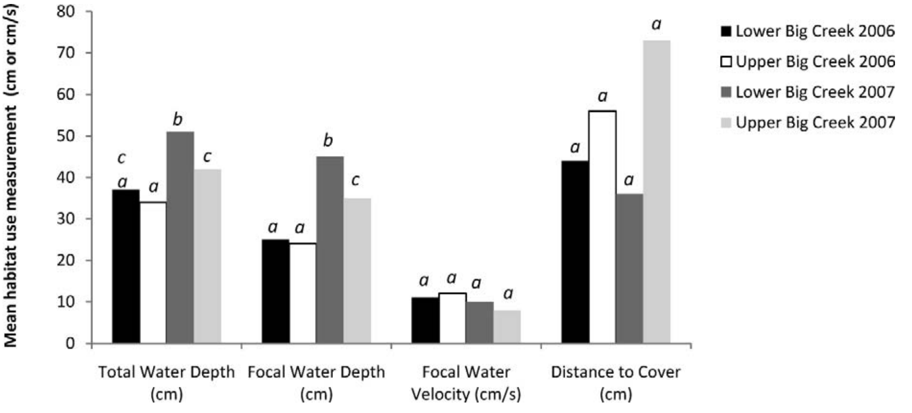

FIGURE 6.—Comparison of mean habitat use characteristics for age-0 Chinook salmon in upper and lower Big Creek, Idaho, during the 2006 and 2007 growing seasons. Bars with letters in common are not significantly different ($P > 0.05$).

Big Creek may be related to water temperature, as estimated temperatures averaged 4.0°C higher in lower Big Creek than in upper Big Creek during the 2006 growing season. Life history differences may also explain differences in size and habitat use. Summer Chinook salmon spawn in the lower portions of main-stem Big Creek (east of Monumental Creek), while spring Chinook salmon spawn in the upper portions of Big Creek (west of Monumental Creek) and Rush Creek (ICTRT 2007). Therefore, Chinook salmon observed in lower Big Creek may be summer-run fish, and those observed in upper Big Creek may be spring-run fish. We could not differentiate between juvenile offspring of the two life history types during snorkel surveys. However, based upon otolith microchemistry, we suspect that there is significant temporal and spatial overlap of juveniles from the respective life history types and that juvenile Chinook salmon may move among study reaches (B.P.K., unpublished data).

2006 and 2007 Habitat Use Comparisons

The mean and range of habitat use variables reported in this study were similar between years. However, all variables except distance to cover were significantly different between years. Fish in 2007 used greater total, focal, and relative depths; this is counterintuitive since 2007 was a lower water year than 2006. One possible explanation is that shallower stream margin or side channel habitats were not available in the lower water year and therefore fish were confined to more main-channel habitats; however, we do not have habitat availability data from 2007 to validate this. Overall, the mean and range of habitat use values for 2007 were consistent with the Jacobs' habitat selection indices from 2006. This suggests our habitat selection data for age-0 Chinook salmon are accurate and could be used as guidelines for habitat restoration efforts where little or no habitat use data exist for juvenile Chinook salmon.

Conclusions

There were substantial differences in microhabitat use and availability between upper and lower Big Creek sites. However, the extent to which these habitat differences contribute to historical survival differences reported by Achord et al. (2007) and Zabel and Achord (2004) remains unclear. Additional studies will be necessary to understand the complex relationship between habitat and survival of juvenile Chinook salmon in the Middle Fork Salmon River drainage.

The microhabitat use and availability data were useful for identifying habitat selection of age-0

TABLE 8.—Water temperature (°C) data for three study sections of Big Creek, Idaho, during the 2006 growing season for juvenile Chinook salmon.

Site (and dates) monitored	Mean temperature	Minimum temperature	Maximum temperature	Mean daily temperature fluctuation
Upper Big Creek (3 Jun–26 Jul)	9.1	3.5	20.1	5.7
Lower Big Creek (4 Jun–2 Aug)	13.1	6.8	21.9	5.5
Rush Creek (4 Jun–5 Aug)	12.9	6.6	21.2	5.7

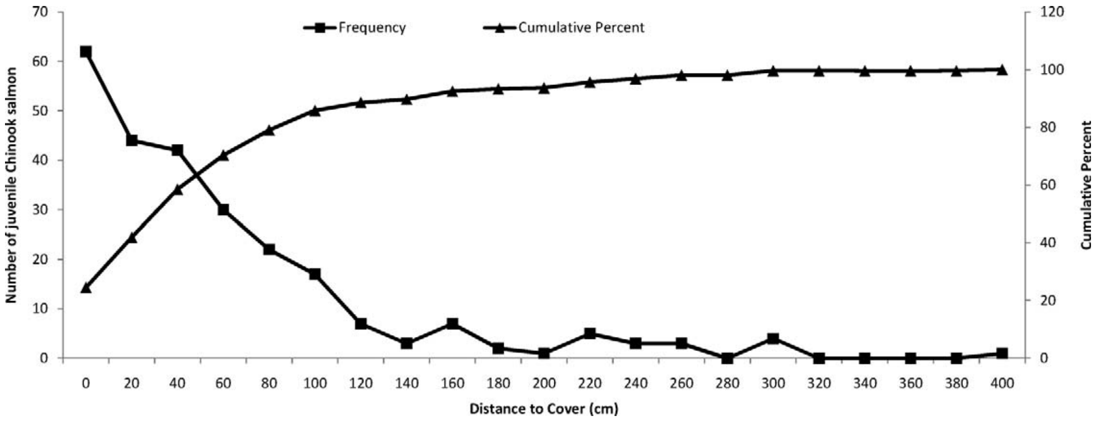

FIGURE 7.—Frequency and cumulative percentage of age-0 Chinook salmon observed at various distances to cover in the Big Creek drainage, Idaho, during the 2006 and 2007 growing seasons.

Chinook salmon in Big Creek. The data can be used for identification, quantification, and restoration of suitable spring–summer Chinook salmon rearing habitat in other streams in the Pacific Northwest. Because freshwater rearing habitat is important for the recovery of Snake River basin Chinook salmon populations (McHugh et al. 2004), these data may be useful for conservation purposes. Additionally, our detailed microhabitat data could allow future studies to monitor habitat changes in the largest wilderness watershed in the contiguous United States. Our spatially extensive data set is based on more than 250 observations of age-0 Chinook salmon, but data are limited to two summers. As episodic events (e.g., climate irregularities or fire) alter wilderness stream habitats, it will be useful to monitor consequent effects on habitat use by juvenile Chinook salmon.

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