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Summer Distribution of and Habitat Use by Chinook Salmon and Steelhead within a Major Basin of the South Umpqua River, Oregon

Brett B. Roper and Dennis L. Scarnecchia
Department of Fish and Wildlife Resources, University of Idaho
Moscow, Idaho 83843, USA

Tim J. La Marr
U.S. Forest Service, Umpqua National Forest
North Umpqua Ranger District, Glide, Oregon 97408, USA

Abstract.—Snorkeling and established stream habitat assessment methods were used to determine basinwide summer habitat use by juvenile chinook salmon *Oncorhynchus tshawytscha* and juvenile steelhead *O. mykiss* in 1989 in eight reaches along 39 km of Jackson Creek, a fifth-order tributary to the South Umpqua River, Oregon. Juvenile steelhead (ages 0–3) were widely distributed throughout the entire stream but age-1 and older fish were found in higher densities in the middle reaches whereas age-0 fish were found in higher densities in the upper reaches. Juvenile chinook salmon were found in the highest densities in the middle reaches. Juvenile steelhead used mostly riffles in the downstream reaches but mostly pools in the upstream reaches. Age-0 chinook salmon were strongly associated with pools in all reaches. Several factors are suggested that may have influenced distribution and abundance of both species; these include high stream temperatures in the lower reaches, habitat preferences of each species, and the interaction and resultant habitat segregation between the two species. Densities of steelhead varied by nearly 5-fold over the reaches studied and densities of chinook salmon varied by more than 10-fold. Thus, habitat studies on streams with variable habitat and patchy fish distributions should be conducted over a larger area of the basin than has typically been the case in previous studies.

Juvenile salmon and trout *Oncorhynchus* spp. commonly segregate in streams along gradients of depth, velocity, substrate, and temperature (Chapman and Bjornn 1969; Everest and Chapman 1972; Reeves et al. 1987). The habitat a species actually uses within a stream is the manifestation of a variety of preferences and constraints, including optimization of foraging location (Chapman and Bjornn 1969; Fausch 1984), restrictions of ontogeny (Everest and Chapman 1972), past interactions with other species (Roughgarden 1972; Schoener 1982; Schlosser 1988), and developmental constraints (Gould and Lewontin 1979; Bisson et al. 1988), as well as current interactions with other species in the local habitat (Reeves et al. 1987). Both the biotic and abiotic characteristics of streams change from upstream to downstream reaches within a basin (Vannote et al. 1981; Power et al. 1988), thus the distribution and relative abundance of salmonid species between reaches will also change (Platts 1979). Because habitat preferences and morphological constraints may be fixed for a species and life stage, the distribution of cohabitating species may be predictable among stream reaches within a river basin. To date, however, few studies have been published that integrate the mechanisms determining spatial distribution of salmonids with basin-wide habitat variability to see if this is the case (Hicks et al. 1991).

If each salmon and trout species maintained a constant density and consistent (but different) habitat use throughout a basin, and if habitat characteristics were also uniform, then an understanding of the ecology of salmonid species and the relation of the species to their habitat and to each other could be inferred by investigating one or two short reaches within a basin. But if species-specific habitat use varied significantly within the basin, and if habitat gradients existed, more comprehensive basin-wide studies would be needed to understand how salmonid species use stream habitats.

In this paper, we describe how consistently the juveniles of two anadromous salmonids, chinook salmon *Oncorhynchus tshawytscha* and steelhead *O. mykiss*, used stream habitat throughout a 39-km section of a southwest Oregon stream. Habitat

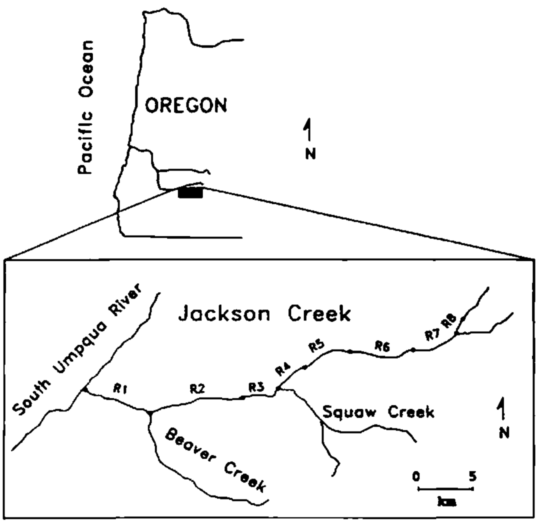

FIGURE 1.—Jackson Creek and the eight stream reaches investigated in this study.

use was compared, both by stream reach and habitat type (riffle, run, glide, and pool), and was related to changing characteristics of the stream.

Study Site

We evaluated stream characteristics and juvenile salmonid populations in eight contiguous reaches of Jackson Creek, a fifth-order tributary of the South Umpqua River in southwestern Oregon during the summer of 1989 (Figure 1). Follow-up studies were conducted from 1990–1993. Upland forest vegetation in this 373 km^2 basin consists primarily of conifers along with some deciduous riparian vegetation consisting of maples *Acer* spp. and red alder *Alnus rubra.* Fish species commonly encountered in Jackson Creek include chinook salmon, steelhead, coho salmon *O. kisutch,* cutthroat trout *O. clarki,* Oregon chub *Oregonichthys crameri,* redside shiner *Richardsonius balteatus,* Umpqua dace *Rhinichthys evermanni,* Umpqua squawfish *Ptychocheilus umpquae,* largescale sucker *Catostomus macrocheilus,* and sculpins *Cottus* spp.

Average stream discharge of Jackson Creek during July and August of 1989 was 0.57 m^3/s (range = 0.43–0.92 m^3/s). Daily mean stream temperature during the summer of 1989 was 18.4°C; however, temperatures ranged from a low of 13.6°C to a high of 23.8°C (determined with a continuously recording Ryan TempMentor installed near Jackson Creek's confluence with the South Umpqua River). Temperatures decreased upstream within the basin and, based on 10 temperature profiles of the basin taken from 1400 to 1600 hours during July and August of 1991–1993, were 5–8°C cooler in the upper reaches of the study area than those recorded in the lower-most reach (Figure 2).

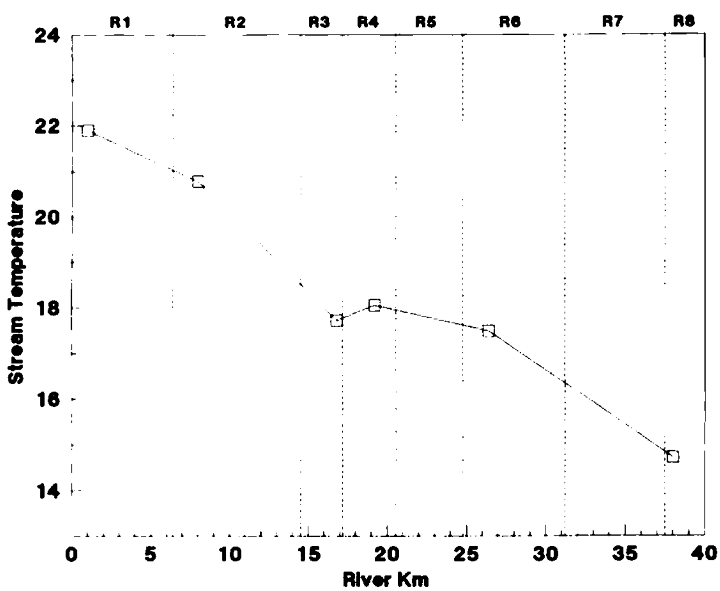

FIGURE 2.—Mean afternoon (1300–1600 hours) stream temperatures (°C) recorded at six locations within Jackson Creek. River km indicates the number of kilometers from the confluence of Jackson Creek and the South Umpqua River. Vertical dashed lines indicate boundaries between the eight reaches surveyed.

Juvenile chinook salmon and juvenile steelhead were the two most common salmonids in Jackson Creek during the summer of 1989. Follow-up studies, conducted from 1990 to 1993 with a smolt trap located near the mouth of Jackson Creek, indicated that more than 95% of the spring outmigration of chinook salmon and steelhead smolts occurs prior to 1 July. There are two general life histories of naturally produced juvenile chinook salmon (Nicholas and Hankin 1988): in one, fish migrate to sea after remaining 16 months in the river (stream type), and in the other, fish migrate to sea in their first spring, a few months after hatching (ocean type). Because stream surveys for this study were conducted from mid-July to August, only the stream-type juvenile chinook salmon were encountered.

Counts of adult spring chinook salmon within the basin (Oregon Department of Fish and Wildlife, unpublished) have determined that the majority of the adult chinook salmon over-summer in the middle reaches (river km 7–18) of Jackson Creek. Spawning surveys conducted by the authors between 1989 and 1992 found no spring chinook salmon spawning above river km 28 or in the tributaries to Jackson Creek. Although no surveys of the adult steelhead spawning distribution have been conducted within the basin, the distribution of steelhead juveniles indicated that they are wide-spread throughout Jackson Creek and its tributaries.

Naturally produced juvenile chinook salmon were augmented by 154,000 hatchery-reared fry (30–45 mm fork length) stocked by the Oregon Department of Fish and Wildlife during the early spring. Released fry were progeny of spring chinook salmon from the adjacent North Umpqua River. Hatchery-reared fish were distributed throughout the upper 23 km of Jackson Creek (river km 15–38). Subsequent recovery of marked hatchery-reared juvenile chinook salmon released in 1990 and 1991 captured in a smolt trap located at the mouth of Jackson Creek indicated that more than 95% of the hatchery-reared fish migrate seaward in their first spring (ocean type).

Juvenile steelhead, ages 0–3, were also encountered in Jackson Creek. No hatchery augmentation of steelhead took place in 1989.

Methods

Evaluation of stream characteristics and salmonid use of habitat in Jackson Creek was completed during the period 7 July–15 August 1989, when stream discharge was low. The survey started where Jackson Creek entered the South Umpqua River and continued upstream for 39 km to the end of anadromous fish presence, where Jackson Creek is a third-order stream. For our analyses, Jackson Creek was divided into eight contiguous stream reaches based on stream characteristics, basin geomorphology, and sampling concerns (Figure 1; Table 1). Basin characteristics used to delineate reaches included valley type, gradient, sinuosity, and the addition of tributaries (U.S. Forest Service 1989).

Habitat within each of the eight reaches was classified into one of four habitat types: riffle, run, glide, and pool. A riffle had surface turbulence, substrate penetrating the surface, and no residual depth (i.e., no pool remaining at zero discharge). A run had surface turbulence, no residual depth, and a nonuniform bottom substrate, which seldom extended above the water surface. Glides also lacked residual depth, but had minimal surface turbulence and a uniform bottom substrate. Pools had residual depth at zero discharge (as modified from U.S. Forest Service 1989).

The amount of stream habitat in each reach and the amount of each of the four habitat types within a reach were quantified by the method described by Hankin and Reeves (1988). This method relied on one observer moving upstream and estimating, by visual inspection, stream area (length and width) of all habitat within a reach. For this survey the same observer estimated stream area in all reaches. To determine observer bias associated with visual estimation, the dimensions (length and average width) of a set of habitat units (stratified by habitat type) within each reach were first visually estimated then accurately measured to the nearest 0.1 m by a second observer. Visual bias was then estimated by comparing visual estimates to accurate measurements of this stratified set of habitat units. Depending on the reach, accurate measurements complimented visual estimates for one in three to one in eight habitat units of each habitat type. Correction for visual bias (Hankin and Reeves 1988: equation 3) is included in all estimates of habitat area. Maximum depths were recorded in all habitat units.

Fish abundances were estimated by the mean counts of two divers snorkeling a set of the habitat units (stratified by habitat type) within each reach. Divers entered each habitat unit that was sampled from the downstream end of the unit, then simultaneously swam upstream and independently estimated fish numbers.

TABLE 1.—Stream reach characteristics and areas and numbers of habitat units available and sampled for juvenile salmonids in eight reaches of Jackson Creek, 1989.

Measurement	Stream reach 1	2	3	4	5	6	7	8
				Reach characteristics				
Length of reach (m)	6,500	8,329	2,417	3,470	4,165	6,331	6,330	1,245
Total reach area (m^2)	92,493	97,204	29,886	34,587	36,244	45,076	26,421	4,895
Mean habitat width (m)	14.2	11.7	12.4	10.0	8.7	7.1	4.2	3.9
% of total stream area	25.3	26.5	8.1	9.4	9.9	12.3	7.2	1.3
% of total stream length	16.8	21.5	6.3	8.9	10.7	16.3	16.3	3.2
Gradient (%)	0.7	1.0	1.2	1.6	1.4	2.5	2.9	6.4
				Habitat available by reach				
Riffles								
Area (m^2)	21,984	25,524	9,191	10,675	16,629	23,870	17,429	2,244
Number	57	84	24	51	67	122	92	60
Run								
Area (m^2)	21,544	18,771	7,144	8,735	7,920	9,119	4,852	1,333
Number	35	59	17	39	56	79	67	41
Gilde								
Area (m^2)	16,304	7,023	1,463	661	2,581	2,152	1,116	278
Number	17	10	4	3	8	10	8	9
Pool								
Area (m^2)	32,661	45,886	12,088	14,516	9,114	9,935	3,024	1,040
Number	46	76	23	49	41	58	30	32
				Habitat sampled by reach				
Riffle								
Area (m^2)	6,089	5,556	920	1,294	1,769	3,364	3,045	208
Number	13	17	5	8	13	22	17	6
Run								
Area (m^2)	5,130	2,524	1,126	1,405	1,247	1,696	1,008	163
Number	8	11	4	6	8	15	13	5
Gilde								
Area (m^2)	2,141	443	0	551	228	456	243	0
Number	2	1	0	2	2	2	2	0
Pool								
Area (m^2)	11,849	14,715	2,313	2,648	1,680	2,202	689	168
Number	13	21	6	8	7	13	7	5

Visual bias associated with snorkeler counts was corrected by comparing snorkeler counts within several habitat units to more accurate estimates within those same units (separately for pool–glide habitat and riffle–run habitat; Hankin and Reeves 1988). To determine visual bias we first snorkeled through a habitat unit then electrofished that same unit. Population estimates from electrofishing relied on multiple-pass removal methods (Zippin 1958) with the objective of reducing the population of fish in a habitat unit by 90% between passes so that precise estimates of fish numbers would result. All electrofished units were blocknetted to prevent fish from avoiding capture or leaving the habitat unit.

Fifteen habitat units, six pool–glide and nine riffle–run units were first snorkeled then electrofished. These 15 habitat units were scattered throughout the upper 31 km of Jackson Creek. Because only older steelhead were consistently and reliably captured in all 15 habitat units sampled, these fish were used to determine correction factors. In the six pool–glide units analyzed, an average of 1.16 older age steelhead were captured by electrofishing for every fish seen by snorkeling ($r^2 = 0.837$, $P < 0.01$). In the nine riffle–run units analyzed, an average of 1.38 older age steelhead were captured for each fish seen by snorkeling ($r^2 = 0.93$, $P < 0.001$).

A systematic stratified sample of discrete habitat units was snorkeled within a reach, resulting in counts of fish in approximately 17% of the total stream area (Table 1). All habitat types were sampled in each reach with the exception of glide habitat in reaches 3 and 8. Because of the low abundance of glides in these two reaches, none were encountered at the predetermined systematic interval before the survey of the reach was completed. In these two reaches pool densities were used as an estimate of fish densities in glides (pools were used because they appeared more similar to glides due to the lack of turbulence).

All counts of fish were conducted from 0930 to 1630 hours on days with less than 50% cloud cover and when underwater visibility was greater than 6 m. Counts were made of both age-0 chinook salmon and juvenile steelhead. Steelhead from age 0 to age 3 were seen, but because it was difficult to age fish precisely underwater only two groups were distinguished, age-0 steelhead and older steelhead. Use by habitat type was estimated for three groups: age-0 chinook salmon, age-0 steelhead, and older steelhead.

Mean fish densities within each reach were determined with equations for stratified sampling (Cochran 1953). In addition to determining fish densities (number/m^2), we also calculated the number of fish found per kilometer of stream by expanding reach-specific densities to estimate the number of fish that were encountered in a kilometer of stream in each reach.

To evaluate if fish consistently used all stream reaches, we determined if the proportion of the estimated total number of fish, by species and age-group, in each reach was different than the proportion of total stream surface area in each reach. Because fish numbers were estimated rather than censused precisely, we deemed it inappropriate to use a chi-square goodness-of-fit test on estimated fish numbers within a reach as this would have artificially inflated the power of the chi-square statistic. Instead we standardized fish counts (100 × estimated number in reach/estimated total number in stream) so that they reflected reach-specific counts and then summed to 100 (Gorman 1988).

The null hypothesis that use of stream reaches was in proportion to availability was accepted if the standardized number of fish did not deviate significantly ($P < 0.05$) from the expected number of fish in the reach determined by multiplying the reach's percentage of the total stream area by 100. For example, since reach 1 accounted for 25% of the total stream area, we would expect 25 of the 100 standardized fish to be in this reach. The chi-square statistic was used to determine if there was significant departure from the null hypothesis. In addition, the chi-square statistic was used as a relative measure (Rubin et al. 1991) to compare which species or age-group was most selective in its use of the eight reaches.

To evaluate if use of the four habitat types (riffles, runs, glides, and pools) within a reach was proportional to their availability, we used the same method as described for the reach comparisons. In this case, however, the null hypothesis that use of the four habitat types was in proportion to availability was accepted if the number of fish in a habitat type constituted a percentage of the total number of fish counted equal to the percentage of the total habitat surveyed in that habitat type. For example, 48% of the area sampled for fish in reach 1 was pool habitat, thus, under the null hypothesis, we expected 48% of the fish counted in this reach to be found in pool habitat. A chi-square goodness-of-fit test was used to determine if utilization of a given habitat type, by species or age-group, was in proportion to the abundance of that habitat type surveyed.

Habitat use by the three groups was visually displayed with Jacobs' (1974) utilization index. Possible values for this index range from 1 to −1, where 1 indicated exclusive use of a habitat type, 0 indicated use of a habitat type in proportion to the surface area of that habitat sampled within a reach, and −1 indicated no fish of that group were found in that habitat type within that reach.

Results

Age-0 and older steelhead were relatively abundant and unevenly distributed throughout the basin. The density of age-0 steelhead generally decreased downstream (Table 2), and varied from a high of 0.232 fish/m^2 in reach 8, to a low of 0.095 fish/m^2 in reach 1. Older steelhead, in contrast, attained highest densities in the middle reaches, and were less dense at the upper and lower ends of Jackson Creek. Reach 6, with a density of 0.181 older steelhead/m^2, had nearly five times the density of these fish as reach 1 (0.047 fish/m^2).

Juvenile chinook salmon were also unevenly distributed throughout the basin (Table 2). Densities of chinook salmon were highest in reach 6 (0.032 fish/m^2), more than 10 times the density found in reach 2 (0.0024 fish/m^2). Age-0 chinook salmon, like older steelhead, were found at highest densities in the middle reaches and lowest densities at the extremes.

The highest numbers of juvenile chinook salmon and older steelhead per kilometer were also found in the middle reaches of Jackson Creek (Table 2). However, the greatest number of age-0 steelhead per length of stream (1,915/km) was found downstream in reach 2, not in reach 8 (903/km) where the highest density was observed. This occurred because the average width of the river increased substantially downstream (from 3.9 m wide in reach 8 to 11.7 m in reach 2), whereas the

TABLE 2.—Estimated fish densities (number/m²) and numbers of age-0 steelhead, older steelhead, and age-0 chinook salmon in the eight reaches of Jackson Creek. Numbers in parentheses are standard errors.

Reach	Age-0 steelhead		Older steelhead		Age-0 chinook salmon (SE)	
	Density	Number/km	Density	Number/km	Density	Number/km
1	0.0947 (0.0256)	1,345 (364)	0.0474 (0.0082)	672 (118)	0.0034 (0.0014)	49 (20)
2	0.1637 (0.0227)	1,915 (265)	0.0617 (0.0119)	722 (140)	0.0024 (0.0007)	28 (8)
3	0.1369 (0.0211)	1,698 (262)	0.0713 (0.0200)	884 (248)	0.0111 (0.0073)	137 (90)
4	0.1593 (0.0196)	1,593 (196)	0.0915 (0.0135)	915 (135)	0.0185 (0.0073)	185 (73)
5	0.1411 (0.0157)	1,227 (137)	0.1254 (0.0210)	1,091 (182)	0.0226 (0.0051)	197 (45)
6	0.1540 (0.0116)	1,094 (82)	0.1808 (0.0156)	1,284 (111)	0.0319 (0.0028)	227 (97)
7	0.1625 (0.0202)	683 (85)	0.1431 (0.0147)	601 (62)	0.0243 (0.0043)	101 (18)
8	0.2317 (0.0533)	903 (208)	0.0552 (0.0103)	215 (40)	0.0111 (0.0101)	42 (39)

density of fish dropped less rapidly (from 0.232 m² in reach 8 to 0.164 m² in reach 2).

Both species used the middle reaches (4–7) more than would have been expected based solely on surface area of these reaches (Figure 3). Reach 6, which had the highest use by juvenile chinook salmon and older steelhead, constituted only 12% of the total stream area but contained 32% of the age-0 chinook salmon and 25% of the older age steelhead. Use of reach 1, the lowermost and warmest reach, was low by all groups. This reach constituted 25% of the total surface area in the basin but contained only 7% of the age-0 chinook salmon, 13% of the older steelhead, and 17% of the age-0 steelhead.

Deviations from the null hypothesis, that fish numbers reflected stream surface area, were lowest for age-0 steelhead (χ^2 = 4.5, not significant), intermediate in older steelhead (χ^2 = 26.3, P < 0.05), and largest in age-0 chinook salmon (χ^2 = 79.7, P < 0.05). These results indicate that age-0 steelhead were not specific in the use of stream reaches but that both older steelhead and chinook salmon did use some stream reaches more than others. Comparisons among the three groups provide evidence that chinook salmon were the most

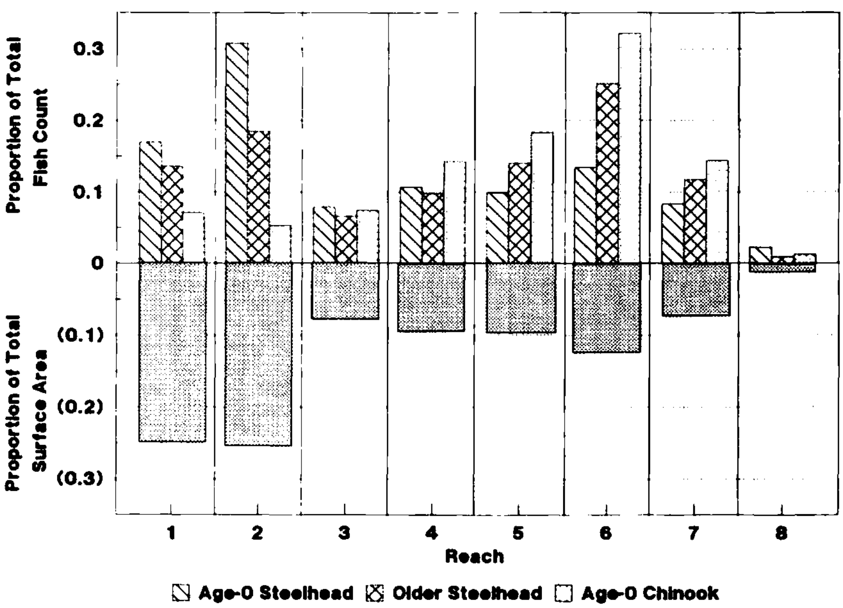

FIGURE 3.—Proportional distributions age-0 steelhead, older steelhead, and age-0 chinook salmon among reaches compared with the proportional distribution of total surface area among reaches in Jackson Creek. Uses of stream reaches by older steelhead and age-0 chinook salmon differed significantly ($P \leq 0.05$) from the habitat availability in the eight reaches of Jackson Creek.

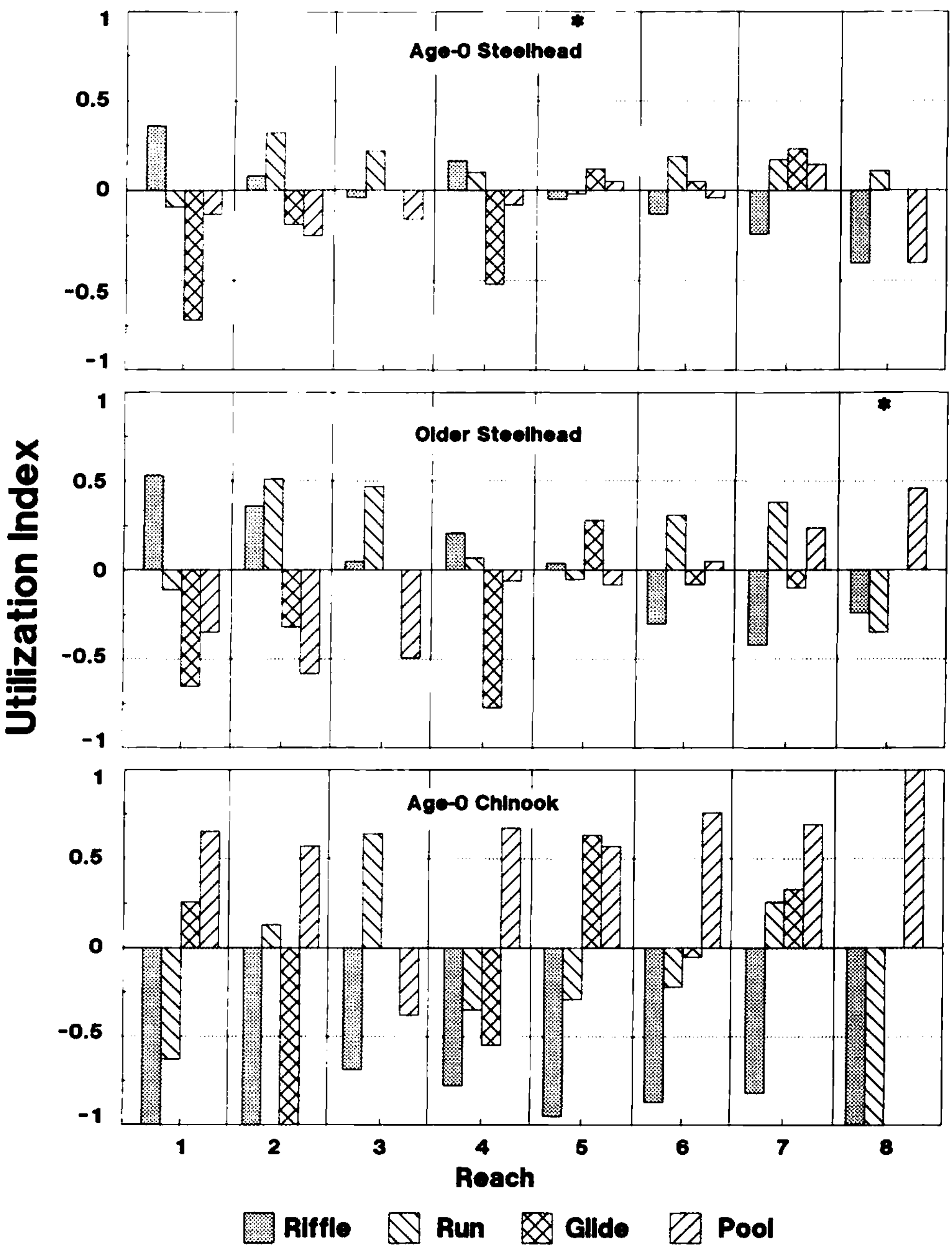

FIGURE 4.—Uses of riffles, runs, glides, and pools by age-0 steelhead, older steelhead, and age-0 chinook salmon in the eight reaches of Jackson Creek. Positive values indicate use of a habitat type in a higher proportion than the availability of the habitat, while negative values indicate use below that expected from habitat availability. The distribution of fish differed significantly from habitat availability ($P \leq 0.05$) in all but the two cases marked by an asterisk (*).

specific in their use of stream reaches within Jackson Creek.

Age-0 steelhead and older steelhead were found more often than expected in riffles in the lower reaches, but less often than expected in riffles in the upper reaches (Figure 4). For example, in the lowermost reach (1), half of older-age steelhead counted were in riffles even though riffles accounted for only a fourth of the area sampled, whereas in the uppermost reach (8) only 39% of the older-age steelhead were counted in riffles although riffles constituted 61% of the area sampled. Chinook salmon, in contrast, selectively utilized pools in all but one reach.

Discussion

Temperature and Habitat Use

The uneven distribution of juvenile chinook salmon and steelhead within the Jackson Creek basin at summer base flows probably reflected variation of both biotic and abiotic characteristics within the stream (Vannote et al. 1981). One important abiotic characteristic of Jackson Creek was water temperature. In Jackson Creek, temperatures went from the range preferred by salmonids (10–14°C; Bjornn and Reiser 1991) in the upstream reaches to near lethal temperatures (23–25°C; Bjornn and Reiser 1991) in the lowest reach.

Although the actual effects high water temperatures in the lower reaches of Jackson Creek had on salmonids are not known, it is known from other studies that high water temperature influences the distribution and abundance of salmonids (Bisson and Davis 1976; Reeves et al. 1987). The high water temperatures in the lower reaches of Jackson Creek likely caused greater proportions of the juvenile chinook salmon and older-age steelhead to emigrate from these reaches in the spring (Holtby 1988) and decreased survival rates for these species in these reaches (Bisson and Davis 1976). Both factors would have led to the observed higher summer densities of salmonids in the cooler upstream reaches of Jackson Creek.

Density versus Number per Kilometer

Along with fish density, the number of fish per linear kilometer of stream may also be a meaningful indicator of the number of juvenile salmonids within a stream. Under some circumstances, as found for age-0 steelhead in this study, lower stream reaches that have lower densities of fish may, nevertheless, have more fish per kilometer than upper basin stream reaches that have higher fish densities. This observation underscores the importance of considering total numbers of fish and total habitat, not just densities, in quantitatively assessing the importance of habitat (Platts 1979).

Species-Specific Habitat Use

Chinook salmon and steelhead differed markedly in their use of the four habitat types. Juvenile steelhead, especially age-0 fish, commonly used all habitat types surveyed in all stream reaches, whereas juvenile chinook salmon were heavily concentrated in pool habitat. These findings appear to contradict those of Everest and Chapman (1972), who reported broad overlap in habitat use between these two species and concluded that apparent differences in habitat use were primarily a result of the different spawning seasons of these two fishes. In their opinion, if steelhead and chinook salmon had been the same size at the same time (which they were not), juveniles of these two species would have occupied the same habitat.

The differences between our results and conclusions and those of Everest and Chapman (1972) may be explained by one or more of several factors. First, Everest and Chapman evidently collected chinook salmon to be used to regress fish lengths against habitat characteristics over a 3-month period (mid-May to mid-August), whereas they collected steelhead only during August. Chinook salmon were thus collected throughout a range of changing water temperatures, stream discharges, and other conditions, whereas steelhead were sampled under one set of physical conditions at one time. In our study we also collected data throughout a range of conditions but data for both species were collected concurrently. Secondly, Everest and Chapman's (1972) results could, in our opinion, be interpreted as demonstrating not just broad habitat overlap between juvenile steelhead and chinook salmon, but also species-specific habitat use. In their study, juveniles of the two species were found together in only about half of the 4.5-m^2 habitat sets sampled. Age-0 chinook salmon also preferred deeper water than all age-classes of steelhead (Everest and Chapman 1972: Figures 3, 4). These results are consistent with our interpretation from Jackson Creek, that steelhead and chinook salmon used different habitats during summer and that juvenile chinook salmon prefer the deeper pool habitat.

Steelhead.—Both age-0 and older steelhead shifted from greater use of riffles in the downstream reaches to greater use of pools in the upstream reaches, perhaps in response to the progressively changing physical attributes of the habitat types. For example, the mean maximum depth of riffles in reach 1 (52 cm) was similar to that of pools of reach 8 (68 cm), so although pools and riffles were labeled different habitat types, they may well have shared some of the same microhabitat characteristics (Dambacher 1991). If, for example, depth, velocity, or substrate size within a specific range is an important habitat requirement (rather than simply the "pool" or "riffle" per se), the actual choice of pool or riffle habitat may vary with changes in depth, substrate, or velocity (Everest and Chapman 1972). It may thus be a physical characteristic not unique to a pool or riffle that dictates habitat suitability, and shifts between pool use and riffle use might be explained by the different physical characteristics of the habitat types in different reaches.

Use of habitat by age-0 steelhead was only slightly different from habitat availability throughout the basin, so habitat availability within a reach had only minimal consequences on reach densities. Older steelhead, which used riffle habitat in reach 1, might have been found in greater numbers in this reach if a greater proportion of the reach had been riffle habitat. As stated previously, however, temperature in the lower reaches of Jackson Creek probably constrained salmonid densities, not habitat availability.

Chinook salmon.—The strong preference by age-0 chinook salmon for deep-water habitat throughout the Jackson Creek basin is consistent with results of several studies of their ecology. Chinook salmon are typically gregarious (Hillman et al. 1987; McCain 1992), have a slab-sided body morphology perhaps better suited to pools than riffles (Stein et al. 1972; Bisson et al. 1988), and are found higher in the water column than age-0 steelhead (Rubin et al. 1991) and in deeper water than both age-0 and older steelhead (Everest and Chapman 1972: Figures 3, 4).

Because juvenile chinook salmon were found primarily within pool habitat, the mean density of these fish within a reach was strongly affected by the amount of pool habitat available in a reach. For example, juvenile chinook salmon had equally high use of pool habitats in reaches 6 and 7 but their mean density in reach 7 was only 75% their mean density in reach 6, a consequence of reach 7 having only half of the available pool habitat of reach 6 (11% versus 22% of the surface area). In reaches of Jackson Creek with sufficiently cool stream temperatures (reaches 5–8), the amount of available pool habitat, to a large extent, determined mean densities of age-0 chinook salmon within the reach.

Value of Basinwide Habitat-Use Studies

Reach-specific densities of both steelhead and chinook salmon varied widely among reaches. If sampling had been conducted on only a single reach, estimates of densities for the basin may have differed by as much as a factor of 5 for older-age steelhead and by a factor of more than 10 for age-0 chinook salmon, depending on the reach surveyed. Densities of fish were affected by abiotic (e.g., temperature and habitat composition) and biotic (e.g., habitat use) elements, which differed from reach to reach. In studies based on surveys of individual short reaches, basinwide patterns would be difficult to discern. The published literature, however, reveals that most of what we currently know about juvenile salmonid distribution within streams comes from studies that have been conducted on short reaches (<500 m long) of small streams (<5 m wide) (e.g., Chapman and Knudsen 1980; Bisson et al. 1982; Bjornn et al. 1991). Because each stream reach is subject to different in-stream characteristics (such as gradient) and external activities (such as forestry) within a basin (Kershner et al. 1992), a study design that focuses on a single "representative" reach may not lead, by itself, to a understanding of the ecological factors that determine the distribution of salmonids within a basin.

The concept that stream basins can be thought of as hierarchically organized systems (Frissell et al. 1986) suggests that a variety of spatial scales within a basin can be used as units of observation. Each level within this hierarchy, from stream microhabitat to watershed, operates within a different time frame and spatial scale (Frissell et al. 1986), with lower levels of the hierarchy exhibiting the most variability (Urban et al. 1987). Although there is no correct level at which to describe a system (Levin 1992), this study and others (Hankin and Reeves 1988; Newman and Waters 1989; O'Neill et al. 1989) suggest larger-scale studies will be needed to answer some questions related to the abundance and distribution of juvenile salmonids within a basin.

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