Transactions of the American Fisheries Society 116:185–195, 1987

Summer and Winter Habitat Selection by Juvenile Chinook Salmon in a Highly Sedimented Idaho Stream

T. W. HILLMAN AND J. S. GRIFFITH

Department of Biological Sciences, Idaho State University
Pocatello, Idaho 83209, USA

W. S. PLATTS

U.S. Forest Service, Intermountain Forest and Range Experiment Station
Boise, Idaho 83702, USA

Abstract.—Summer and winter habitat utilized by age-0 spring chinook salmon *Oncorhynchus tshawytscha* was assessed in the Red River, an Idaho stream heavily embedded with fine sediment. During summer 1985, chinook salmon used habitats with water velocities less than 20 cm/s, depths of 20–80 cm, and close associations with cover (undercut banks). Densities were greater than 60 fish/100 m^2. As the fish became larger they selected faster, deeper water. Eighty percent of the chinook salmon emigrated from the study sites in October when stream temperatures were 4–8°C, apparently because suitable winter habitat was not available. Those fish that remained in the study sites selected areas where submerged sedges and grasses overhanging undercut banks provided cover and where water velocities were less than 12 cm/s. After cobble substrate was added to the streambed (September 1985) beneath undercut banks and in midchannel in a glide and a riffle habitat, eight times more chinook salmon used the cobble substrate in November 1985 as compared with November 1984. Significantly more chinook salmon utilized cobble placed under banks than any other area. By March 1986, cobble piles were embedded with silt and sand, and chinook salmon densities were not significantly different from those found in March 1985.

Land management activities often increase erosion by disturbing soils and altering stream morphology. Increased sediment production within a watershed increases sediment loads being transported to stream channels. Fish production can be reduced if this additional fine sediment is deposited in salmonid spawning and rearing areas (Hall and Lantz 1969; Phillips et al. 1975; Hausle and Coble 1976; Bjornn et al. 1977).

Fine sediment may affect the rearing potential of streams by altering substrate particle-size composition, riffle–pool ratios, macroinvertebrate production, and pool area (Bjornn et al. 1977). Bjornn et al. (1977) found that addition of fine sediment, less than 6.4 mm in diameter, to natural stream channels during summer decreased abundance of juvenile chinook salmon *Oncorhynchus tshawytscha* in almost direct proportion to the amount of pool volume lost to fine sediment.

Winter survival of anadromous salmonids in cold streams may be reduced by fine sediments. Juveniles can survive harsh icing conditions by entering substrate crevices (Chapman 1966; Edmundson et al. 1968; Chapman and Bjornn 1969; Bjornn 1971; Bjornn et al. 1977; Rimmer et al. 1983). Such refuges are lost if filled by sediment.

With the character of many streams being altered to improve anadromous spawning and rearing habitat, better understanding of salmonid use of a variety of stream environments is needed. Development of satisfactory techniques designed to rehabilitate fish habitat depends on a thorough understanding of natural systems and of factors limiting production.

We examined habitat used by juvenile spring chinook salmon during summer (July through September) and winter (October through March when stream temperatures were below 2°C) in Red River, Idaho, and its tributaries, which have heavily embedded channels. Microhabitat analysis was used to describe focal points, or the locations where fish spend the most time (Wickham 1967). Juvenile chinook salmon were marked to assess their movement from summer into winter rearing habitats. To relate stream sediment to winter habitat use, we altered the streambed beneath undercut banks and in midchannel of a riffle and a glide by adding cobble.

Specific objectives were to (1) assess densities and biomasses of juvenile chinook salmon that inhabited study sections of the Red River during summer and winter; (2) identify habitats used by chinook salmon in summer and winter; (3) assess movement of fish from summer to winter habitat; (4) evaluate the effect of fine sediment on availability of winter habitat; and (5) evaluate re-

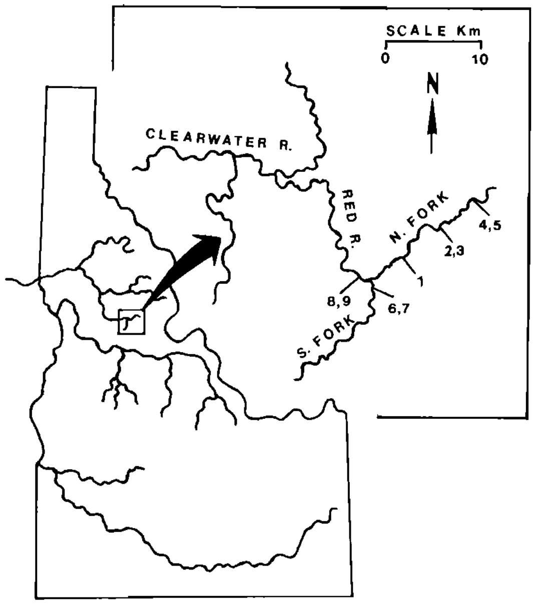

FIGURE 1.—Location of Red River and tributaries, Nez Perce National Forest, Idaho, showing numbered locations of study sites.

sponses of juveniles, during winter conditions, to the addition of cobble substrate.

Study Area

Red River is a tributary of the South Fork Clearwater River that drains an area of approximately 36,761 hectares in Idaho County in north-central Idaho (Figure 1). The drainage lies within the Idaho batholith border zone and is dominated by moderately sloping basin lands and terraces. Extensive floodplains, occurring along tributary streams, are mostly privately owned pasture and natural meadows.

Red River is characterized by alternating sections of straight, high-gradient (>4%) riffles and rapids and meandering, low-gradient (<4%) riffles, pools, and glides. Riparian areas are dominated by alder *Alnus* sp., sedges *Carex* spp., and grasses. Upland areas are primarily spruce–fir *Abies* sp. and *Picea* sp. mixed with lodgepole pine *Pinus contorta*. Annual precipitation ranges from 64 cm below the 1,500-m elevation to 114 cm above 1,800 m. Snowfall represents 83% of the precipitation and total runoff, and the highest runoff occurs during the May snowmelt. Flows between July and November 1985 at Red River kilometer 49.1 (km 49.1) ranged between 0.2 m^3/s in mid-August and 0.8 m^3/s in late September. Water temperatures ranged from 19 to 0.5°C from July through November.

Fish species in the study area in 1985 included (in order of decreasing abundance in July) juvenile chinook salmon, juvenile steelhead *Salmo gairdneri*, mountain whitefish *Prosopium williamsoni*, rainbow trout *Salmo gairdneri*, bull trout *Salvelinus confluentus*, brook trout *Salvelinus fontinalis*, and cutthroat trout *Salmo clarki lewisi*. Bridgelip sucker *Catostomus columbianus*, longnose dace *Rhinichthys cataractae*, speckled dace *R. osculus*, and sculpin *Cottus* sp. were also found, but their abundance was not assessed.

Nine sampling stations, each 100 m long, were selected in low-gradient reaches (1–2%) based on accessibility and presence of chinook salmon (Figure 1). Five sites (1–5) were on the upper Red River (North Fork) upstream from the confluence of the South Fork. The first site began at river km 32.8, immediately below a newly constructed sediment trap. The second and third sites began at river km 49.1 and 49.3, respectively, and the fourth and fifth began at river km 51.2 and 51.4, respectively. Two sites (6,7) were established on the South Fork at river km 0.3 and 0.5. The final two sites (8,9) were on the lower Red River along the U.S. Forest Service stock pasture at river km 24.3 and 24.4, respectively.

Methods

Chinook salmon density and biomass.—Densities (fish/100 m^2 surface area) of juvenile chinook salmon were calculated within study sites 2, 3, and 4 in 1984 and 1985; biomasses (g/m^2) were assessed within these sites in 1985. In August, and again in October, we placed 5-mm-mesh seines at the upper and lower ends of each study site. The sites were electrofished by working upstream with backpack shockers. In November, blocking seines at the upper ends of the study sites were not used because cold water temperatures precluded fish movement out of the sites. Using the same equipment and personnel on each pass, we made four complete passes, retaining fish from each pass in separate holding tanks.

After we measured and weighed, on site, all chinook salmon taken during each pass, population numbers at each site were calculated with the maximum-likelihood formula (Platts et al. 1983), and densities were estimated for 100 m^2 of stream surface. Weights of all chinook salmon collected in 1985 were used to calculate biomass at each site in terms of grams of fish per square meter of stream surface. Unit biomass was calculated as the product of the population estimate and mean weight divided by stream surface area.

Juvenile habitat.—All study sites were mapped by habitat class (Helm 1985) by the plane table–alidade method. Juvenile chinook salmon were located and recorded on the habitat maps from July through November 1985 by a diver equipped with a dry suit and snorkel. Habitat use was noted during the third week of each month.

Concurrent with these habitat observations, microhabitats were analyzed. The diver entered the water at least 15 m downstream of the site and slowly crawled upstream along the bottom while looking for chinook salmon. When a fish was sighted, it was observed from downstream until its focal point could be estimated accurately. Alarmed or displaced fish were excluded from microhabitat measurements.

For each juvenile chinook salmon observed, the following microhabitat measurements were recorded: (1) total depth of the water column, (2) focal point elevation (the distance between the snout of the fish and the substrate), (3) water velocity at the focal point, (4) distance to escape cover, (5) type of escape cover selected, (6) distance from other fish, and (7) substrate composition. A third depth variable, relative depth, was calculated by subtracting focal point elevation from total depth and then dividing by total depth.

Water velocity measurements were made with a Marsh–McBirney model 201 electromagnetic current meter (accuracy, ±2%), and all values were converted into centimeters per second. Depths and distances were measured with a measuring rod calibrated in centimeters. Substrate composition was estimated visually in an area of 0.25 m^2 directly beneath the fish. Percent substrate composition was based on a modified particle-size scale (Platts et al. 1983) in which codes ranged from 1 for plant detritus to 8 for bedrock (Bovee and Cochnauer 1977). A single numeric score for adjacent substrate codes was generated by weighting the percentages of the two dominant substrates (Moyle and Baltz 1985). Thus, a section containing 10% sand (code 4), 60% gravel (code 5), and 30% cobble (code 6) would be coded 5.3, indicating a dominance of gravel and a lesser proportion (0.3) of the adjacent larger class.

Hartley's test, at a significance level of $P < 0.05$, was used to determine if each microhabitat variable among study sites for each month could be pooled (Sokal and Rohlf 1981). Because variances were widely different for each collecting period (Bartlett test; $P < 0.05$), a Kruskal–Wallis test ($P < 0.05$) was used to determine differences among focal point variables with time (Zar 1984).

Movement of juvenile chinook salmon.—To assess movement of age-0 chinook salmon from summer to winter habitat in 1985, we marked chinook salmon in three different 150-m reaches of the North Fork. The upper-most reach (Bridge Creek site) was located at river km 51.5, the second (Red River corral site) at km 49.4, and the third (sediment trap site) at km 32.8. Each reach was divided into three 50-m marking sites; a small side channel located along the sediment trap (km 32.8) also was used as a marking site. Ten different fin clips corresponded to these 10 marking sites.

Fish were collected at each marking site on 10–18 October by electrofishing and then were marked. On 4–15 November, the three reaches and the side channel plus 300 m of stream above and below the reaches were electrofished to relocate marked fish.

Streambed alteration.—To evaluate the relationship between sediment and winter habitat selection by juvenile chinook salmon, we modified two subsites of site 4 in 1985. The upper site was a riffle that was about 23 m long and had a mean width of 5 m, an average depth (±SD) of 28 ± 10 cm, and an average water velocity (±SD) of 34 ± 8 cm/s. The total benthic area of 112 m^2 included an exposed region (104 m^2) and a region under the stream banks (8 m^2). The lower site was a 31-m-long glide with a mean width of about 4 m, an average depth of 41 ± 12 cm, and an average water velocity of 26 ± 6 cm/s. There the total benthic area of 129 m^2 was divided between exposed (119 m^2) and overhung (10 m^2) regions. In September 1985, the riffle had a mean embeddedness rating of 70% while the glide had a mean rating of 90%.

On 24 September 1985, the sites were altered by the addition of cobble (mean maximum diameter, 19 cm; range, 9–37 cm) piled 26 cm deep in both the exposed benthic area and the area under the banks. Four percent of the exposed area had cobble placed randomly in nine 1-m^2 plots located in center stream, and approximately 30% of the benthic area under the banks was randomly altered.

We estimated the size of the fish population on 15 September and 7 November 1984 and 4 March 1985 by a three-pass electrofishing method and on 21 September 1985 by snorkeling. After addition of cobble, we estimated populations on 10 October and 8 November 1985 and on 17 March 1986 by three-pass electrofishing. Numbers of fish using altered and unaltered areas in the glide and riffle were tested for statistical significance ($P <$

TABLE 1.—Numbers, densities (fish/100 m^2 of stream surface), and biomasses (g wet weight/m^2 of stream surface) of age-0 chinook salmon collected at three sites on the Red River, Idaho, in 1985. Blanks indicate no data.

Month, site	Number 1984	Number 1985	Density 1984	Density 1985	Biomass 1985
August					
2	248	330	52	69	0.7
3	296	347	64	75	0.8
4	241	296	52	65	0.6
Mean±SD	261±29	324±25	56±6	69±5	0.7±0.1
October					
2		109		23	0.8
3		116		25	0.9
4		98		21	0.8
Mean±SD		107±9		23±2	0.8±0.1
November					
2	66	48	14	10	0.3
3	69	42	15	9	0.3
4	74	65	16	14	0.2
Mean±SD	70±4	52±11	15±1	11±3	0.3±0.1

0.05) with a model-I, three-factor analysis of variance (Sokal and Rohlf 1981).

Results

Chinook Salmon Density, Biomass, and Growth

Variability in density of chinook salmon among the three sampling stations was small (Table 1); the greatest deviations occurred in August 1984 (range, 52–64 fish/100 m^2) and August 1985 (65–75 fish/100 m^2). November densities in 1984 ranged from 14 to 16, whereas 1985 densities ranged from 9 to 14.

Chinook salmon densities in the summer of 1985 were greater than in summer 1984 (Table 1). For example, mean density in August 1984 exceeded 50 fish/100 m^2 whereas mean summer density in 1985 exceeded 65 fish. Mean summer biomass of chinook salmon in 1985 was 0.7 g/m^2.

With the onset of winter (November), mean chinook salmon densities declined by 73 and 84% in 1984 and 1985, respectively (Table 1). Mean density in November 1984 on the North Fork was 15 fish/100 m^2, whereas mean winter density in 1985 was 11 fish. In 1985, mean chinook salmon biomass declined 57% in November compared with August.

In 1985, mean fish length at site 3 increased from 59 mm in August to 67 mm in October; growth slowed in November as stream temperature dropped below 2°C (Figure 2). Growth at this site appeared to represent that at all sites.

Summer Habitats

During summer (July through September), 95% of the age-0 chinook salmon were concentrated in

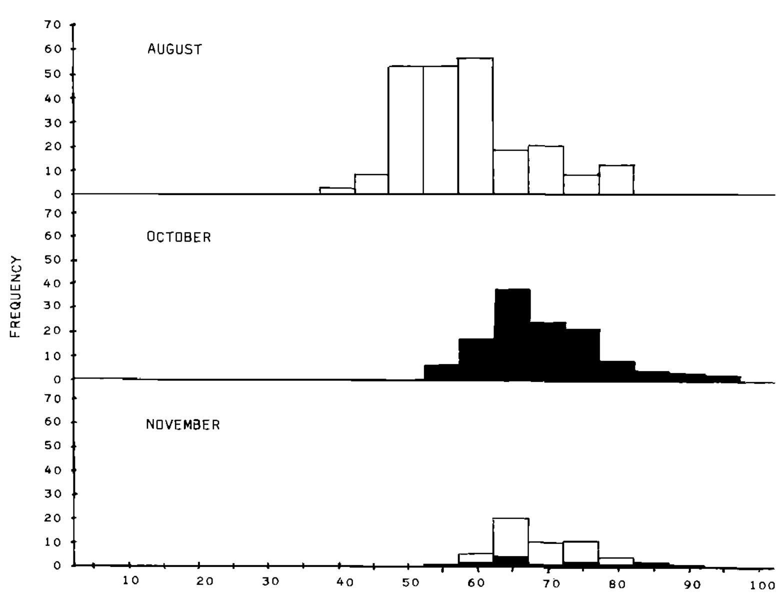

FIGURE 2.—Length frequencies of age-0 chinook salmon collected immediately above site 3 in 1985. Black bars for October indicate fish marked and released. For November, black bars represent recaptured marked fish, whereas white bars indicate captured unmarked fish.

TABLE 2.—Percent uses of habitat types by age-0 chinook salmon at sites 1–9 from July through November 1985, Red River, Idaho. Habitat types were determined by criteria outlined in Helm (1985).

Month	Sample size	Secondary channel pool	Back-water pool	Plunge pool	Lateral-scour pool	Dam-formed pool	Glide	Secondary channel riffle	Low-gradient riffle	Rapids
Jul	94	7	6	0	44	0	36	0	7	0
Aug	101	2	2	3	46	0	41	0	6	0
Sep	86	5	2	3	46	0	38	0	6	0
Oct	68	7	0	7	58	0	28	0	0	0
Nov	52	0	0	0	54	0	7	26	13	0

pool and glide habitats (Table 2). They were focused along the fringes of pools (glides), predominantly along the sides and tail-ends. Few chinook salmon used the anterior fringes or the bottom of the pools; these areas were occupied by adult rainbow trout, mountain whitefish, and brook trout. About 5% of the chinook salmon inhabited riffles (Table 2), and these fish were found behind boulders greater than 25 cm diameter, where water velocities were comparable to velocities used by juveniles in glides and pools.

In July, age-0 steelhead used the same habitat as chinook salmon, and the two species were aggregated. During this period, both species were 30–65 mm long. By September, few steelhead were present, and none were seen in October and November.

The use of depth, velocity, and substrate by age-0 chinook salmon did not differ significantly from July through September. As the fish grew, however, they showed consistent tendencies (indicated by mean values) to occupy greater water depths (Figure 3) and velocities (Figure 4). Mean focal point elevation (±SD) increased from 5 ± 3 cm in July to 6 ± 3 cm in August and 8 ± 4 cm in September, which was reflected by declining relative depths (Figure 5). During this period, most chinook salmon were found over a sand–gravel substrate (0.83 to 76.0 mm: Figure 6). The fish progressively increased their distance from cover (undercut banks) from an average of 88 cm in July to 172 cm in September (Figure 7), indicating lateral movement from the banks as size increased.

Most chinook salmon (90%) in pools and glides concentrated in clusters of one dozen to several dozen individuals that, when agitated, moved to

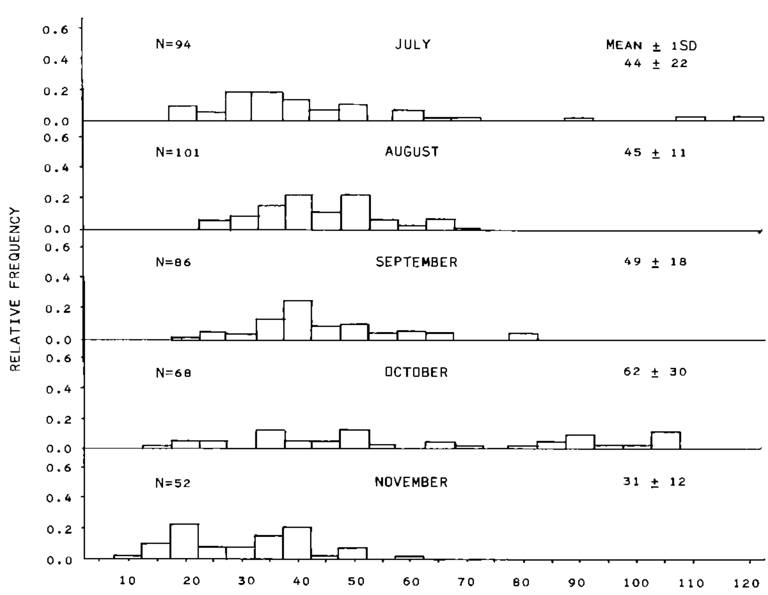

FIGURE 3.—Frequency distributions of water depths (cm) used by age-0 chinook salmon in sites 1–9 from July through November 1985 in Red River, Idaho; N = sample size.

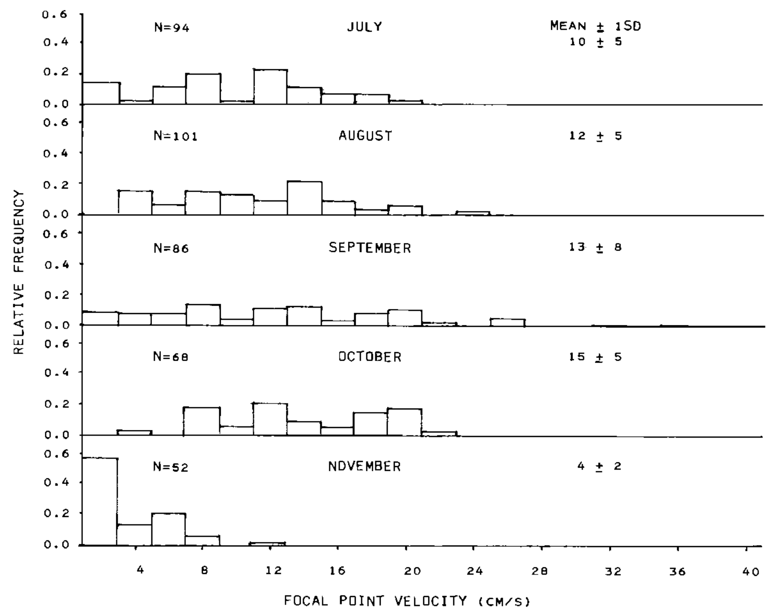

FIGURE 4.—Frequency distributions of water velocities (cm/s) at focal-point elevations used by age-0 chinook salmon in sites 1–9 from July through November 1985 in Red River, Idaho; N = sample size.

undercut banks for cover. Chinook salmon that utilized riffles were distributed individually and, when disturbed, moved a short distance and then returned to their station almost immediately.

Winter Habitats

With the onset of colder stream temperatures (October), juvenile chinook salmon used different habitats. That month, stream temperatures were

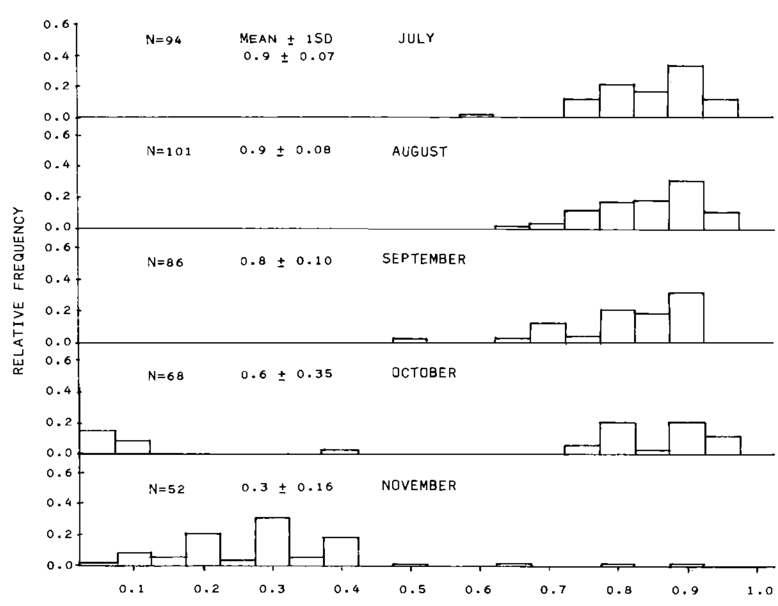

FIGURE 5.—Frequency distributions of relative depths ([total depth − focal-point elevation]/total depth) used by age-0 chinook salmon in sites 1–9 from July through November 1985 in Red River, Idaho; 0.0 = fish at the surface; 1.0 = fish in contact with the bottom; N = sample size.

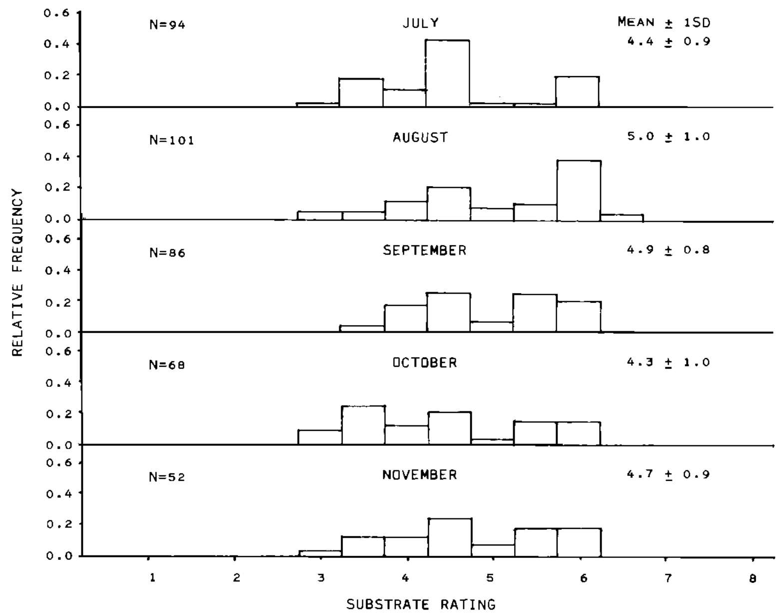

FIGURE 6.—Frequency distributions of substrate types used by age-0 chinook salmon in sites 1–9 from July through November 1985 in Red River, Idaho. Substrate codes 1 through 8 are plant detritus, mud, silt, sand, gravel, cobble, boulder, and bedrock, respectively (Bovee and Cochnauer 1977). Intermediate codes indicate a mixture of adjacent substrate types; N = sample size.

below 4°C, and fish were located mostly in lateral-scour pool and glide habitats (Table 2), but they generally selected a wider spectrum of microhabitats than in summer (Figures 3–6). Depths from 14 to 107 cm were used at this time (Figure 3), and fish were located both at the water surface and the stream bottom (Figure 5). Where water depths were greater than 70 cm, fish were consistently very near the stream surface. Pools deeper than 70 cm usually had large rainbow trout (>20 cm long) stationed near the substrate. Juvenile chinook salmon consistently maintained a distance greater than 50 cm above these fish. No chinook salmon were found in riffle habitat.

In October 1985, the juvenile chinook salmon in the pools were in dense clusters of up to 250 individuals per group and they displayed little reaction when disturbed, often moving a distance of 50–100 cm and then returning to their original location almost immediately. Water velocities

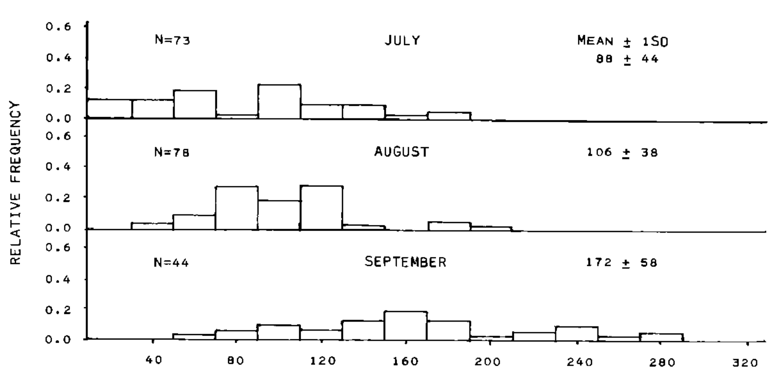

FIGURE 7.—Frequency distributions of distance to cover (cm) for age-0 chinook salmon in sites 1–9 from July through September 1985 in Red River, Idaho; N = sample size.

ranged between 4 and 23 cm/s (Figure 4). Most fish were found over a sand–gravel substrate (Figure 6).

As in 1984, in November 1985 when water temperatures were below 2°C, over 90% of the juvenile chinook salmon were located along undercut banks where dense growths of sedges and grasses draped over the bank and extended below the water surface. Fish avoided bare undercut banks without vegetation and stationed themselves in dense vegetation close to the surface of the water column (Figure 5) where focal point velocities were less than 12 cm/s (Figure 4). If the water velocity was greater than 12 cm/s, no fish were found even if vegetation extended below the water surface. Chinook salmon were found at depths ranging from 10 to 62 cm (Figure 3) and over substrates varying from silt to cobble (Figure 6). They were distributed individually with no clustering.

Movements of Juvenile Chinook Salmon

Of the 354 age-0 chinook salmon marked by fin clipping on 10–18 October 1985 on the North Fork, only 21% were recovered within the marking sites on 4–15 November after water temperatures dropped below 4°C (Table 3). Three percent of the marked fish that left the marking sites were found within 20 m directly below the sites in which they were marked, and the remaining 76% were never located. No marked fish were found 300 m upstream of the sites. Due to high levels of embeddedness (>70%), it is unlikely that fish were existing in pockets in the substrate.

The side channel located at river km 32.8 (sediment trap site) had the greatest fraction (55%) of marked fish that remained at the site (Table 3). The stream margins of this site retained fish in the abundant vegetation extending below the surface of the water. No chinook salmon were found in sites that lacked undercut banks and vegetation that extended below the water surface.

The exodus of chinook salmon was not size related; rather fish of all lengths moved out of the marking sites (Figure 2). However, more marked chinook salmon of lengths 63–73 mm moved out of the sites than did fish of other lengths.

Stream Bed Alteration

After we altered two subsites of site 4 by adding cobble in September 1985, winter rearing densities in the glide area increased eightfold over those recorded the previous winter (Table 4) and ninefold over densities recorded during the same period in unaltered areas (Table 5). Densities on 8 November 1985 (after streambed alteration) were 32 and 22 fish/100 m^2 of surface water in the glide and riffle, respectively, whereas on 7 November 1984 (before streambed alteration) they had been 4 and 0, respectively. Densities of fish in September of 1984 and 1985, before the onset of colder (<4°C) stream temperatures, were 52 and 54 fish/100 m^2, respectively.

Densities on 4 March 1985 (before alteration) were not significantly different from densities calculated on 17 March 1986 (after alteration) (group comparison t-test; $P < 0.05$). We noted on 17 March 1986 that ice scouring had displaced some of the added cobble on the exposed substrate 0.5–1.5 m downstream. Cobble in this area was severely embedded by sand and silt, with less than 20% of the cobble exposed. No fish were collected in this area. Cobble placed under the banks was not as severely embedded, with 60% of the cobble exposed and fish using the available pockets.

Comparing late summer densities (September 1985) to winter densities (November 1985), we noted a reduction of 52% in the glide and a 35% reduction in the riffle (Table 4). Densities on 17

TABLE 3.—Numbers and densities (fish/100 m^2 of stream surface) of age-0 chinook salmon collected in October and November 1985 at 10 sites in Red River, Idaho. All fish were marked by fin clips in October. Numbers in parentheses for November are numbers of marked fish recaptured (they are included in the total number).

	Bridge Creek			Red River corral			Sediment trap			
Measure	Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower	Side channel
				10–18 October 1985						
Number	35	21	25	24	58	65	23	18	9	76
Density	22	18	16	12	23	25	5	4	2	40
				4–15 November 1985						
Number	12(5)	13(7)	15(3)	11(3)	20(7)	27(6)	4(1)	0(0)	0(0)	46(42)
Density	8	11	10	6	8	10	1	0	0	24

TABLE 4.—Population estimates and densities of chinook salmon and other salmonids in Red River, Idaho, before and after (*) addition of cobble to the substrate on 23 September 1985. Shock = electrofishing; snorkel = visual observation by divers.

Date	Method	Number of fish ± 95% confidence interval: Chinook salmon Age 0	Chinook salmon Age 1+	Rainbow trout	Cutthroat trout	Brook trout	Bull trout	Density of salmonids/100 m^2 of surface area
				Glide				
7 Nov 1984	Shock	5 ± 1	0	0	0	0	0	4
4 Mar 1985	Shock	4 ± 0	0	0	0	0	0	3
21 Sep 1985	Snorkel	85 ± 53	3 ± 0	0	0	0	0	67
10 Oct 1985*	Shock	53 ± 4	0	0	0	2 ± 0	5 ± 1	46
8 Nov 1985*	Shock	40 ± 2	0	0	0	1 ± 0	1 ± 0	32
17 Mar 1986*	Shock	6 ± 1	0	0	0	0	0	5
				Riffle				
7 Nov 1984	Shock	0	0	0	0	0	0	0
4 Mar 1985	Shock	0	0	0	0	0	0	0
21 Sep 1985	Snorkel	41 ± 43	0	0	0	1 ± 1	0	34
10 Oct 1985*	Shock	28 ± 2	0	0	0	2 ± 0	0	24
8 Nov 1985*	Shock	25 ± 1	0	0	2 ± 0	0	0	22
17 Mar 1986*	Shock	1 ± 0	0	0	0	0	0	0.8

March 1986 had decreased by 93% in the glide and 98% in the riffle.

A significantly higher density of age-0 chinook salmon (up to five times more fish) used interstitial spaces in the altered area than in the unaltered area (Table 5). Also, a significantly higher density of fish occurred under banks where cobble had been placed than in exposed areas. This was most apparent on 17 March when nearly all chinook salmon that were present used the cobble under the banks (Table 5). Although not significant, nearly twice as many chinook salmon utilized the glide than used the riffle during the collecting periods.

TABLE 5.—Numbers and (in parentheses) densities (fish/m^2 of substrate) of age-0 chinook salmon found within altered (cobbles added) and unaltered areas of winter habitats on 10 October and 8 November 1985 and 17 March 1986, Red River.

Date	Exposed benthic substrate: Altered	Exposed benthic substrate: Unaltered	Underbank benthic substrate: Altered	Underbank benthic substrate: Unaltered
		Glide		
10 Oct	12(2.4)	0(0)	33(10.3)	8(1.3)
8 Nov	16(3.1)	0(0)	20(6.3)	4(0.6)
17 Mar	0(0)	0(0)	5(1.6)	1(1.6)
		Riffle		
10 Oct	10(2.4)	0(0)	18(8.2)	0(0)
8 Nov	8(1.9)	0(0)	16(7.3)	1(0.2)
17 Mar	0(0)	0(0)	1(0.5)	0(0)

Discussion

Everest and Chapman (1972) found that juvenile chinook salmon in summer selected faster and deeper water in Crooked Fork, Idaho, a stream with coarser sediment than Red River, than we did for fish in Red River. They observed densities of 10–50 age-0 chinook salmon/100 m^2 in water velocities of less than 50 cm/s and depths of 30–100 cm. We found densities exceeding 60 chinook salmon/100 m^2 in water velocities of less than 20 cm/s and depths that ranged from 20 to 80 cm. Both studies indicated that chinook salmon select faster, deeper water as they grow, a shift that may be food related (Chapman and Bjornn 1969).

Everest and Chapman (1972) concluded that disparate spawning times of chinook salmon and steelhead create discrete intra- and interspecific size-groups of presmolts, which minimizes the potential for social interaction. Lister and Genoe (1970) recorded similar size-group differences between underyearling chinook salmon and coho salmon *Oncorhynchus kisutch* in the Big Qualicum River, British Columbia. They concluded that species differences in emergence time and size resulted in a high degree of spatial segregation. During July and August we found chinook salmon and steelhead aggregating in Red River. Because equal-sized juveniles of both species use the same physical space (Everest and Chapman 1972), the potential for interspecific interaction may be high during this period. Because declining numbers of juvenile steelhead were observed from August through October, we suspect the steelhead moved downstream.

Underyearling chinook salmon were first noted leaving the study sites when temperatures dropped below 8°C in late August. The greatest exodus occurred in October when stream temperatures dropped to 4°C. Chapman and Bjornn (1969) also reported that fall–winter emigration of juvenile salmon and steelhead from most smaller streams in Idaho coincides with decreasing water temperature.

The exodus of chinook salmon may also be a behavioral response to the lack of available winter cover. Bjornn (1971) documented that movements of juvenile trout and salmon correlate best with the amount of available habitat in the form of large cobble substrate. Contrarily, Reimers (1957) reported that adverse and exhausting physical conditions are the primary cause of salmonid emigration in California streams.

Tschaplinski and Hartman (1983), Martin et al. (1986), and Heifetz et al. (1986) reported that the amount of winter habitat available for juvenile salmonids depends to a large degree on the amount of large organic debris available. Bustard and Narver (1975a) observed that coho salmon and steelhead in a west-coast Vancouver Island stream moved closer to cover as water temperatures decreased from 9 to 2°C. They noted that upturned tree roots and logs were used as winter cover, although debris accumulations and overhanging banks also were used. In contrast, we found few juvenile chinook salmon using the sparse debris accumulations, logs, and tree roots on Red River. Instead, over 90% of the fish used submerged sedge and grasses overhanging undercut banks. Fish were located in areas with water velocities of less than 12 cm/s.

Our results from adding cobble supplement agree with those of Chapman (1966), Edmundson et al. (1968), Chapman and Bjornn (1969), Bjornn (1971), Bustard and Narver (1975b), Bjornn et al. (1977), and Rimmer et al. (1983), who reported the use of interstitial spaces in the substrate by juvenile salmonids during periods of cold stream temperatures. We found significantly more juvenile chinook salmon utilizing interstitial spaces in the cobble placed under banks than any other area, altered or not. Bjornn (1971) documented the emigration of underyearling salmonids from Big Springs Creek, which contained no cobble, but he observed no emigration of salmonids in the Lemhi River, which had cobble.

Our results further indicate that, during periods of cold stream temperatures, age-0 chinook salmon utilize pockets among cobble to a greater extent than vegetated undercut banks, but the available interstitial habitat among cobble was only temporary. Exactly when the cobble became embedded is unknown, but by March 1986, cobble placed center stream was displaced and fully embedded whereas cobble placed underbanks was nearly 50% embedded. The fine sediment deposited over the cobble piles resulted in March densities of chinook salmon not significantly different from those recorded March 1985 when no cobble had been added. This finding is consistent with those of Bjornn et al. (1977), who showed that by increasing embeddedness levels in laboratory channels, the interstices filled with fine sediment and fish densities decreased.

The hiding behavior demonstrated by juvenile chinook salmon in cold water has obvious adaptive value. Reimers (1957), Hartman (1963), and Bustard and Narver (1975a) indicated that a fish spending the winter in near-freezing water has a lowered metabolism, reduced food requirements, and less energy available for activity. The hiding response is probably a means of avoiding predators and unprofitable energy expenditure, of preventing physical damage by scouring and ice, and of reducing downstream displacement during freshets (Chapman and Bjornn 1969; Bustard and Narver 1975a).

The relationship between fine sediment and densities of rearing chinook salmon indicates the importance of winter habitat to their production and suggests a reason for the fall–winter exodus in streams with high sediment loads. As fine sediment fills the interstitial spaces between the cobble, juvenile chinook salmon may be forced to leave the site or to utilize cover that may be more susceptible to ice scouring.

Acknowledgments

The project was designed in cooperation with the staff of the U.S. Forest Service, Intermountain Forest and Range Experiment Station, Boise, Idaho. R. Stowell, D. Hair, and P. Moroz of the Nez Perce Forest also provided input throughout this project. A special thanks goes to R. Reynolds, R. Torquemada and crew, T. Workman, C. Breckenridge, and L. Offenbacker for their assistance during data collection. Helpful discussion and reviews of the manuscript were provided by D. W. Chapman, G. W. Minshall, H. W. Li, T. D. Roelofs, and an anonymous reviewer. The project was funded by the U.S. Forest Service, Intermountain

Forest and Range Experiment Station, Boise, Idaho.

References

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., and six coauthors. 1977. Transport of granitic sediment in streams and its effects on insects and fish. University of Idaho, Idaho Cooperative Fisheries Research Unit, Completion Report, Project B-036-IDA, Bulletin 17, Moscow.

Bovee, L. D., and T. Cochnauer. 1977. Development and evaluation of weighted criteria, probability-of-use curves for instream flow assessments: fisheries. U.S. Fish and Wildlife Service Biological Services Program FWS/OBS-77/63.

Bustard, D. R., and D. W. Narver. 1975a. 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.

Bustard, D. R., and D. W. Narver. 1975b. Preference of juvenile coho salmon (*Oncorhynchus kisutch*) and cutthroat trout (*Salmo clarki*) relative to simulated alteration of winter habitat. Journal of the Fisheries Research Board of Canada 32:681–687.

Chapman, D. W. 1966. Food and space as regulators of salmonid populations in streams. American Naturalist 100:345–357.

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.

Edmundson, E., F. H. 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.

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.

Hall, J. D., and R. L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. Pages 355–375 *in* T. G. Northcote, editor. Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver.

Hartman, G. F. 1963. Observations on behavior of juvenile brown trout in a stream aquarium during winter and spring. Journal of the Fisheries Research Board of Canada 20:769–787.

Hausle, D. A., and D. W. Coble. 1976. Influence of sand in redds on survival and emergence of brook trout. Transactions of the American Fisheries Society 105:57–63.

Heifetz, J., M. L. Murphy, and K. V. Koski. 1986. Effects of logging on winter habitat of juvenile salmonids in Alaskan streams. North American Journal of Fisheries Management 6:52–58.

Helm, W. T. 1985. Glossary of stream habitat terms. American Fisheries Society, Western Division, Bethesda, Maryland.

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

Martin, D. J., L. J. Wasserman, and V. H. Dale. 1986. Influence of riparian vegetation on posteruption survival of coho salmon fingerlings on the west-side streams of Mount St. Helens, Washington. North American Journal of Fisheries Management 6:1–8.

Moyle, P. B., and D. M. Baltz. 1985. Microhabitat use by an assemblage of California stream fishes: developing criteria for instream flow determinations. Transactions of the American Fisheries Society 114: 695–704.

Phillips, R. W., R. L. Lantz, E. W. Claire, and J. R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout fry. Transactions of the American Fisheries Society 104: 461–466.

Platts, W. S., W. F. Megahan, and G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. U.S. Forest Service General Technical Report INT-138.

Reimers, N. 1957. Some aspects of the relation between stream foods and trout survival. California Fish and Game 43:43–69.

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.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry, 2nd edition. Freeman, New York.

Tschaplinski, P. J., and G. F. Hartman. 1983. Winter distribution of juvenile coho salmon (*Oncorhynchus kisutch*) before and after logging in Carnation Creek, British Columbia, and some implications for overwinter survival. Canadian Journal of Fisheries and Aquatic Sciences 40:452–461.

Wickham, M. G. 1967. Physical microhabitat of trout. Master's thesis. Colorado State University, Fort Collins.

Zar, J. H. 1984. Biostatistical analysis, 2nd edition. Prentice-Hall, Englewood Cliffs, New Jersey.

Received September 23, 1986
Accepted May 8, 1987