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Characteristics of Pools Used by Adult Summer Steelhead Oversummering in the New River, California

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Abstract. - I assessed characteristics of pools used by oversummering adults of summer steelhead *Oncorhynchus mykiss* between July and October 1991 in the New River, northwestern California. Most fish occupied channel confluence pools and other pools of moderate size (200-1,200 m^2); these pools had less than 35% substrate embeddedness and mean water depths of about 1.0–1.4 m. Microhabitat occupied during daylight hours included cover provided by bedrock ledges and boulders where water velocity averaged 9.3 cm/s (range, 1-34 cm/s); steelhead densities under this cover were highest at the higher velocities. Fish also occupied areas with riparian shading and waters deeper than 1 m. I observed localized areas of cool water in some of the study pools. The availability of coolwater areas in pools did not increase adult fish use of those pools. The results of this study indicate that the distribution of summer steelhead in the New River during July–October is more strongly controlled by physical habitat characteristics than by the availability of thermal refugia.

Steelhead *Oncorhynchus mykiss* comprise winter and summer races. Summer steelhead begin their upstream migration between May and October in a sexually undeveloped state and oversummer in the river prior to spawning in January and February (Barnhart 1986). In recent years, summer steelhead populations in California have declined substantially (Moyle et al. 1989; Nehlsen et al. 1991) and may now meet the state criteria for being listed as threatened or endangered (Moyle et al. 1989). Declines in summer steelhead populations have been linked to excessive sport harvest and poaching, and to habitat degradation brought about by water development projects, poor timber harvest practices, mining operations, and road construction (Everest 1973; Gibbons and Salo 1973; Yee and Roelofs 1980; Roelofs 1983; Barnhart 1986; Moyle et al. 1989). In addition to causing habitat degradation, road construction has provided anglers and poachers access to previously inaccessible areas. Increased sedimentation from poor land management practices has increased channel aggradation and pool filling. Further, the California drought, which was in its 5th year during 1991 (NOAA 1992), resulted in low summer flows, elevated summer water temperatures, and fewer flushing flows.

Adult summer steelhead typically oversummer in the deepest pools (Jones 1980; Freese 1982) where instream cover or riparian shading is available (Freese 1982). Maximum water temperature may also determine habitat use (Hooper 1973; Freese 1982; Barnhart 1986). This study was undertaken to characterize oversummering habitat of adult summer steelhead in the New River and to examine the relative importance of water temperature and other physical environmental variables as determinants of habitat use.

Study Area

The New River is a fifth-order tributary to the Trinity River in northwestern California (Figure 1). Elevation in the New River drainage decreases from 1,646 m at the headwaters to 213 m at the mouth. The mouth of the New River is located 70.2 km upstream from the confluence of the Klamath and Trinity rivers. The New River drains 448,070 km^2 and flows southwesterly through deeply incised, V-shaped canyons. During the summer, mean river width is 9 m and mean depth is 1 m; some pools are as deep as 6 m. Large woody debris and vegetative canopy are lacking throughout most of the drainage. Boulder and bedrock banks are common. Annual discharge is normally 0.8-31.9 m^3/s (U.S. Fish and Wildlife Service, unpublished data) and is predominantly influenced by rainfall.

Fishes of the New River include summer and winter steelhead, rainbow trout (nonanadromous *O. mykiss*), speckled dace *Rhinichthys osculus*, Klamath smallscale sucker *Catostomus rimiculus*, Pacific lamprey *Lampetra tridentata*, and a remnant run of spring chinook salmon *O. tshawytscha.* The abundance of summer steelhead in the New River seems to have declined substantially since the early 1900s (Roelofs 1983). Presently, about 200–700 adult summer steelhead enter the river annually (U.S. Fish and Wildlife Service, un-

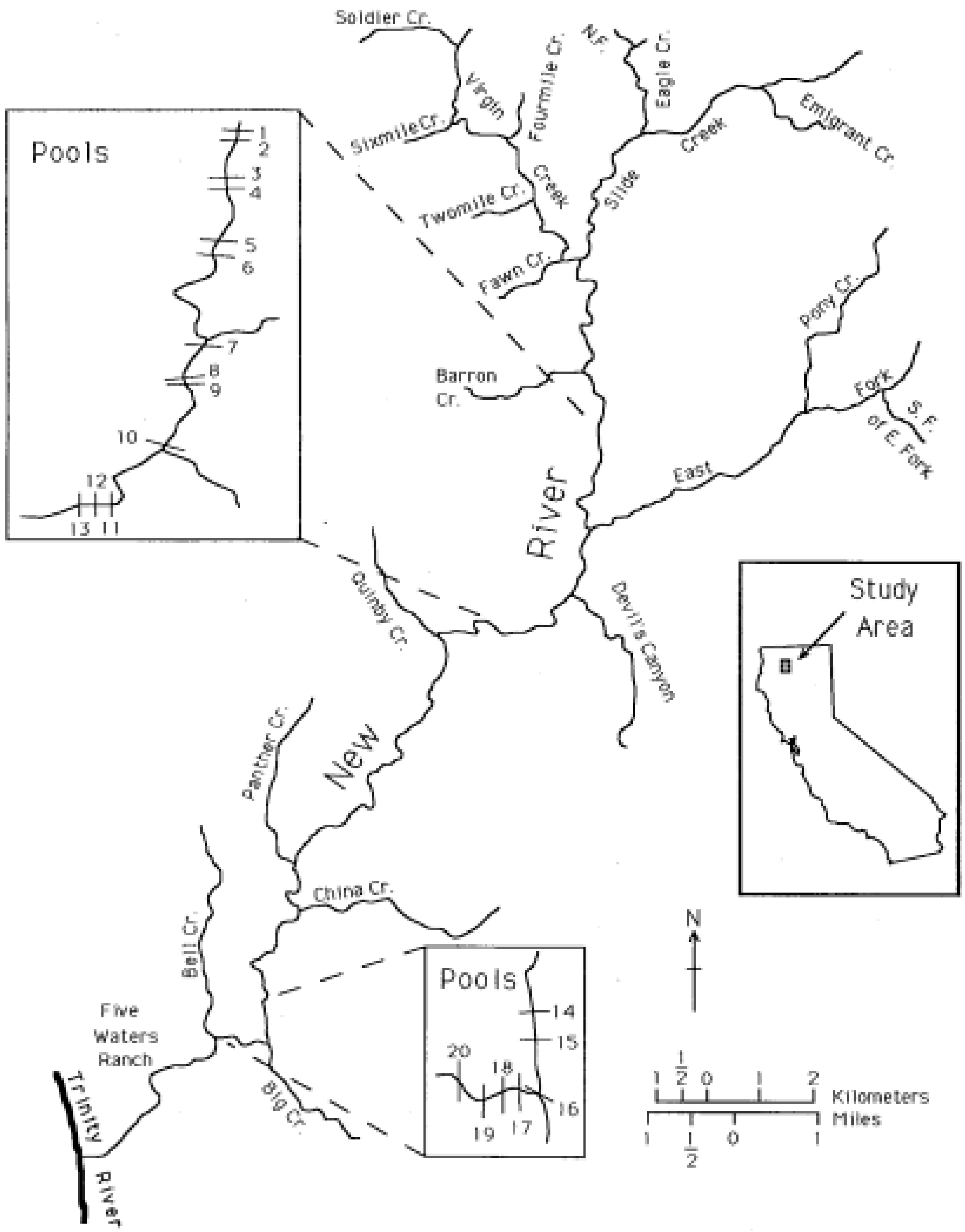

FIGURE 1.-The New River in northwestern California, its tributaries, and the study pool locations. (Cr. = Creek; N.F. = North Fork; S.F. = South Fork.)

TABLE 1.-Habitat availability and use by adult summer steelhead during a preliminary mask-and-snorkel survey of the New River, from the confluence of Virgin and Slide creeks to the confluence with the Trinity River, July 8-11, 1991.

Habitat type[a]	Number of habitats counted	Number of steelhead observed	Proportional use: Expected	Actual[b]	95% CI[c]
Low-gradient rife	128	1	0.195	0.002*	0.000-0.008
High-gradient riffle	26	0	0.024	0.000*	0.000-0.000
Cascade	56	0	0.028	0.000*	0.000-0.000
Trench or chute	1	0	0.001	0.005	0.000-0.011
Plunge pool	7	0	0.003	0.000*	0.000-0.000
Lateral-scour pool					
Bedrock-formed	94	80	0.196	0.187	0.132-0.243
Boulder-formed	91	87	0.107	0.204*	0.185-0.224
Glide	35	0	0.070	0.000*	0.000-0.000
Run	31	1	0.022	0.002*	0.000-0.008
Step run	14	0	0.031	0.000*	0.000-0.000
Midchannel pool	60	159	0.215	0.368*	0.366-0.378
Channel confluence pool	1	92	0.002	0.215*	0.158-0.224
Pocket water	53	6	0.069	0.014*	0.000-0.031
Corner pool	8	1	0.035	0.002*	0.000-0.008
Step pool	2	0	0.002	0.000*	0.000-0.000

[a] Habitat types after McCain et al. (1990). Habitat availability data were obtained from the U.S. Fish and Wildlife Service, Coastal California Fisheries Resource Office, Arcata. Habitat types not present in the New River were secondary channel pool, backwater pool, log-formed and rootwad-formed lateral-scour pools, dammed pool, and edgewater.

[b] When the expected proportional use does not lie within the confidence interval for actual use, proportions of expected and actual use are significantly different, as denoted by an asterisk (alpha = 0.05*).

[c] Simultaneous 95% confidence intervals (CI) for actual habitat utilization calculated with the Bonferroni approach (Byers and Steinhorst 1984).

published data). On the basis of the criteria of Nehlsen et al. (1991), New River summer steelhead seem to be at moderate risk of extinction.

Methods

Preliminary survey.–On July 8-11, 1991, I used a mask and snorkel during daylight hours to assess the distribution and abundance of adult summer steelhead in the New River from the confluence of Virgin and Slide creeks to the confluence with the Trinity River (Figure 1). The section of river between Quimby Creek to just downstream of China Creek was omitted from the survey because intensive suction-dredge mining increased turbidity and made it difficult to observe the fish. Elsewhere, underwater visibility was excellent and adult steelhead were clearly visible. A submersible flashlight was used to illuminate fish under cover. I classified habitat type according to McCain et al. (1990) and recorded the number of adult summer steelhead present in each habitat. Habitat locations were recorded in reference to numbered flags placed on the riverbank at intervals of about 100-150 m. The results of the mask-and-snorkel survey indicated that, during daylight hours, most adult summer steelhead occupied pools (Table 1). On the basis of these results, I randomly selected 20 pools from the 263 pools identified during the survey. Ten of these pools were selected from among those occupied by two or more adult summer steelhead (occupied pools) and 10 pools were selected from among those that held less than two adult summer steelhead (unoccupied pools).

Monitoring surveys. - Between July 24 and October 15, 1991, I counted adult summer steelhead in each of the 20 study pools once every 2 weeks and recorded cover use on hand-drawn maps. Cover was defined as bedrock ledges, boulders, or waters more than 1 m deep covering enough area to conceal two or more adult steelhead; shaded areas covering more than one-third of the total surface area of the pool were also considered to be cover. I also established fixed reference points in each pool where I recorded water level biweekly.

In 11 of the 20 pools, water temperatures were monitored continuously with seven-channel programmable data loggers equipped with encapsulated thermistors (accuracy, ±0.08°C). In each of the 11 pools, one data logger and two strings of three thermistors monitored water temperatures at the surface, middle, and bottom (i.e., at 0.25, 0.50, and 0.75 of depth), at two locations in the thalweg. These temperatures were averaged to obtain hourly mean pool temperature. In occupied pools, the seventh thermistor monitored water temperature where adult summer steelhead were typically observed holding or cruising. In unoccupied pools, the seventh thermistor monitored water temperature in cover similar to that used by steelhead in other pools; if no such cover was present, the thermistor monitored air temperature. In the nine other study pools, water temperature was monitored every 2 weeks in the thalweg, at the surface, middle, and bottom, with a portable three-channel data logger equipped with a single string of three thermistors. During each biweekly assessment, the thermistors were placed in the pool and allowed to equilibrate for 15 min before temperature data were recorded. Temperature was recorded for 10 min, and then the thermistor string was moved to another location in the pool for a second set of measurements.

Pool characteristics.-Morphological data for all of the study pools were collected during October 17-29 to avoid disturbing the adult steelhead during the monitoring phase of the study. Pool surface area was calculated from a minimum of three proportionally spaced length measurements and three proportionally spaced width measurements. Two to six proportionally spaced depth measurements were recorded along each width transect to estimate mean pool depth and pool volume. Additional transects, spaced 2-5 m apart, were established perpendicular to the thalweg to estimate dominant substrate size. A minimum of 100 rocks were randomly selected (about 1 rock every 0.5 m; Wolman 1954), measured, and assigned to 1 of 11 substrate size-classes on the basis of their largest diameter. The size-classes (modified from Platts et al. 1983) were as follows: <0.063 mm (silt), 0.063-4 mm (sand), >4-8 mm (fine gravel), > 8-64 mm (gravel), > 64-128 mm (small cobble), > 128-256 mm (large cobble), >256-512 mm (small boulder), >512-1,024 mm (medium boulder), > 1,024-2,048 mm (large boulder), >2,048-4,096 mm (very large boulder), and >4,096 mm (bedrock). Mean substrate embeddedness for a pool was estimated to the nearest 5% by two observers, and paired estimates were averaged to obtain the final estimate of embeddedness. Embeddedness rates the degree to which boulder, cobble, or gravel is surrounded or covered by finer sediment (Platts et al. 1983).

Water velocity was measured with an electromagnetic current meter (accuracy, ±2%). Water velocity was measured across a minimum of three width transects. I positioned the current meter at 0.25, 0.50, and 0.75 of channel width along each transect and recorded velocities at surface, mid-water, and bottom. Water velocity was also measured under cover used by adult summer steelhead and under similar cover in pools that were unoccupied by adult summer steelhead. The area of cover provided by bedrock ledges and boulders in each pool was measured with a stadia. Pool gradient was estimated with a handheld clinometer. Percent riparian canopy cover was estimated with a spherical densiometer (Lemmon 1956). Densiometer readings were usually taken along the thalweg at the head, middle, and tail of the pool and were averaged for the pool.

Statistical analyses. - Habitat use relative to habitat availability was assessed with the adult summer steelhead data collected during July 8-11 and with the habitat availability data (unpublished) collected by the U.S. Fish and Wildlife Service, Coastal California Fishery Resource Office, Arcata, during the summer low-flow periods from 1988 to 1990. The U.S. Fish and Wildlife Service assessed habitat availability according to the methods of McCain et al. (1990), from the confluence of Virgin and Slide creeks to the confluence with the Trinity River. Habitat distribution and availability in the New River probably did not change appreciably between 1988 and 1991 because of depressed stream runoff associated with the California drought (Tom Shaw, U.S. Fish and Wildlife Service, personal communication). Habitat use and availability data were evaluated with the Bonferroni approach (Byers and Steinhorst 1984). This approach provides simultaneous 95% confidence intervals for the proportional use of all measured habitat types. The expected and actual uses differ significantly when the expected proportional use for a particular habitat type does not lie within the interval.

Temperature data from the six thermistors located in the thalweg of each continuously monitored pool were averaged to obtain mean hourly temperatures for those pools. Diurnal water temperature fluctuation was defined as the difference between the minimum and maximum daily water temperatures in the pool. Temperature data from pools monitored biweekly with the portable data logger were regressed against data from the nearest continuously monitored pool of similar size and morphology to estimate mean hourly pool temperature. All regression equations for estimating pool temperatures in these nine pools had adjusted r^2 values greater than 93.5%. For each of the continuously monitored pools, analysis of variance (ANOVA; Minitab 1991) was used to compare the mean hourly temperature for each thermistor with the mean hourly temperature for the other thermistors in the pool, to identify areas of thermal stratification. Differences in daily temperature fluctuation between occupied and unoccupied pools were identified with ANOVA**.** Mean hourly pool temperatures and fish densities were combined by assessment date, and linear regression (SAS Institute 1985) was used to assess the relationship between mean hourly pool temperature and adult summer steelhead density (adults/m^3). 1 adjusted mean and maximum pool depth data according to biweekly water level changes. Dichotomous dummy variables were created for discrete variables and proportional data were arcsine transformed. Fish densities (adults/m^2) were averaged over the six assessment periods for each of the 20 study pools, and stepwise linear regression (SAS Institute 1985) was used to assess the relationship between adult fish densities and the pool descriptors. The overall level of significance was set at 0.05 for all analyses.

Results and Discussion

Adult summer steelhead enter the New River as early as June. Generally by August adult summer steelhead in the New River have reached the pools in which they will oversummer (Freese 1982). Premonitoring was conducted during July 8-11 to maintain relative certainty that adult summer steelhead had reached the pool in which they were going to oversummer and to ensure that the monitoring period extended over the warmest part of the summer.

I observed 427 adult summer steelhead in the New River during the July survey. These fish occupied channel confluence pools, midchannel pools, and boulder-formed lateral-scour pools in a significantly greater proportion than the availability of these habitats (Table 1). Bedrock-formed lateral-scour pools and trench habitats were occupied in proportion to their availability and all others were used less frequently than would be predicated by their availability.

Stepwise regression analysis demonstrated that adult steelhead density *(D*, adults/m^3) was best predicted by the equation:

$$D = -0.02527 - 0.00003X_1 - 0.01529X_2 + 0.06371X_3 + 0.03169X_4;$$

X_1 = habitat surface area (m^2), X_2 = substrate embeddedness (%), X_3 = mean habitat depth (m), and X_4 = habitat type as channel confluence pool (Table 2; adjusted R^2 = 0.61). The variables selected by the stepwise regression indicated that the highest adult densities were found in channel confluence pools. Further, adults occupied pools of moderate surface area (200-1,200 m^2) with less than 35% embeddedness and mean water depth of 0.97-1.37 m. During the monitoring phase, adults vacated 4 of 10 pools (pools 8, 11, 13, and 15) that they occupied during the preliminary survey (Table 3); also, 8 of 10 pools that were initially unoccupied by adult summer steelhead remained unoccupied throughout the monitoring period; pools 1 and 14 were the exceptions. Some move-

TABLE 2.-Results of stepwise regression for predicting the relationship between adult summer steelhead density (number/m^3) and habitat descriptors in the New River, July 24–October 17, 1991.

Variable[a]	Sequence	R^2	P
Channel confluence pool	1	0.23	0.0332
Embeddedness (%)	2	0.38	0.0561
Mean pool depth (m)	3	0.44	0.2104
Pool surface area (m^2)	4	0.61	0.0211
Maximum pool depth (m)	5	0.64	0.3115
Mean hourly pool temperature (°C)	6	0.68	0.2602
Pool gradient (%)	7	0.69	0.4040

[a] Dominant substrate size (mm), mean water velocity (cm/s), and percent riparian canopy cover did not meet the minimum level of significance (0.50) for entry into the model.

TABLE 3.-Number of adult summer steelhead observed in each study pool, by assessment period, in the New River, July-October 1991. NA = no assessment. An asterisk indicates a pool that contained two or more adult steelhead during the preliminary survey (Jul 8–11).

Pool	Jul 24	Aug 6	Aug 20	Sep 4	Sep 18	Oct 2	Oct 15
1	NA	0	1	6	0	0	0
2	40	25	35	36	28	38	40
3	NA	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	NA	1	0	0	0	0	0
7*[a]	22	8	8	5	8	0	9
8*	7	7	0	0	0	0	0
9*	4	2	1	4	3	5	4
10	NA	0	1	0	0	0	0
11*	NA	6	8	2	0	0	0
12*	50	50	60	51	67	93	60
13*	NA	6	4	1	1	0	0
14	0	0	0	0	0	2	0
15*	0	0	0	0	0	0	0
16*[a]	40	30	30	52	52	21	40
17	NA	0	0	0	0	0	0
18*	NA	28	24	19	15	16	12
19	NA	0	0	0	0	0	0
20[a]	0	0	0	0	0	0	0

[a] Pool containing coolwater area.

TABLE 4.- Characteristics of the 20 study pools, and use of the pools by adult summer steelhead, in the New River, October 20-29, 1991.

Pool	Use[a]	Surface area (m^2)	Pool volume (m^3)	Mean depth (m)	Mean water velocity (cm/s)	Dominant substrate	Pool gradient (%)	Embed-dedness (%)	Riparian cover (%)	Dominant cover[b]
I	U	502	826	0.6	7.9	Gravel	1.0	40	46	Boulder
2	O	316	558	1.2	12.2	Small cobble	1.0	25	46	Bedrock ledge
3	U	19	58	0.7	29.7	Bedrock	1.0	10	31	Boulder
4	U	317	881	0.6	8.2	Gravel	0.5	55	23	
5	U	214	510	1.0	8.1	Bedrock	2.0	35	44	Boulder
6	U	112	31	0.7	11.8	Gravel	1.0	50	36	
7	O	1,166	1,522	1.3	1.7	Gravel	0.5	25	51	Bedrock ledge
8	U	122	342	0.7	11.8	Gravel	2.0	15	32	Boulder
9	O	455	994	1.0	7.2	Gravel	1.0	25	12	Boulder
10	U	248	544	0.9	9.6	Bedrock	2.0	30	35	Bedrock ledge
11	U	142	322	0.8	11.8	Gravel	1.0	25	30	Bedrock ledge
12	O	317	881	1.4	9.6	Bedrock	1.0	10	21	Bedrock ledge
13	U	1,431	925	1.0	9.9	Bedrock	1.0	35	26	Boulder
14	U	417	860	0.9	2.9	Sand	0.0	30	24	
15	U	171	577	0.6	15.2	Large cobble	1.0	15	15	
16	O	344	627	1.2	3.6	Bedrock	2.0	30	30	Shade
17	U	1,429	2,488	2.4	3.8	Gravel	0.0	40	26	
18	O	202	446	1.0	6.4	Large cobble	2.0	10	19	Bedrock ledge
19	U	190	386	0.9	12.4	Large cobble	1.5	15	31	
20	U	2,011	1,996	1.9	3.1	Large cobble	1.0	30	20	

[a] O = occupied by two or more adult summer steelhead for at least five of six assessment periods; U = occupied by less than two adult summer steelhead for five or six of the six assessment periods.
[b] Any dominant cover other than that of water more than 1 m deep (which was characteristic of all the pools).

ment of steelhead among pools was expected. Adult summer steelhead enter the New River as early as June but most do not reach the pools in which they will oversummer until August (Freese 1982). All of the study pools occupied by two or more adult steelhead throughout my study-that is, those occupied for at least five of six assessment periods -conformed to the previously determined criteria for surface area, mean depth, and embeddedness (Table 4). Pools that did not conform to those criteria were unoccupied or were vacated during the study. Pool dimensions were a major factor in determining summer steelhead densities in Wooley Creek, California (Dunn 1981), and in the Eel River, California (Jones 1980). Freese (1982) reported that large pools afford the adult summer steelbead greater protection from predators than small pools. However, adults were not found in the largest pools in the New River. Unlike Wooley Creek and the Eel River, the New River is heavily affected by suction dredge mining. The deepest pools in the New River are collection basins for small substrate recruited from suction dredge mining, streambanks, and mass waste areas. This accumulation of sediment in the pools fills the interstices between larger rocks, decreases the complexity (roughness) of the stream bottom, and decreases cover.

Throughout the monitoring period, 99% of the adult steelhead observed were using cover. Forty-three percent (range, 33-50%) were using bedrock or boulder, 42% (range, 25-63%) were at water depths greater than 1 m, and 14% (range 0-32%) were in the shade from vegetation. These results are in agreement with those of Freese (1982), who reported that densities of summer steelhead in the New River pools were positively related to availability of instream cover and shading. All of the pools included in the monitoring phase contained areas where water was more than 1 m deep, and 7 of the 14 pools that were unoccupied throughout the study contained cover provided by boulders, bedrock ledges, or riparian shading (Table 4). However, the availability of cover alone did not always result in the presence of adult summer steelhead.

Water velocity measurements suggest that adult steelhead use cover associated with flow. Velocity measured under bedrock ledges and boulders occupied by adult steelhead averaged 9.3 cm/s (range, 1-34 cm/s), and the higher densities of the steelhead were observed at the higher velocities. Water

TABLE 5.-Water temperatures in the 20 study pools, and use of the pools by adult summer steelhead, in the New River, July–October 1991.

Pool	Temperature monitoring frequency[a]	Use[b]	Mean (range) of water temperatures, °C					
			Jul 24-Aug 6	Aug 7-20	Aug 21-Sep 4	Sep 5-18	Sep 19-0ct 2	Oct 3-16
1	B	U	20.1 (17.8-22.7)	19.7 (17.5-22.0)	18.5 (15.8-21.6)	17.0 (14.4-20.8)	15.8 (13.8-18.3)	13.8 (11.5-16.3)
2	C	O	19.7 (17.5-22.2)	19.2 (17.2-21.5)	18.1 (15.6-21.1)	16.7 (14.2-20.5)	15.6 (13.7-18.6)	13.7 (11.5-17.1)
3	C	U	19.4 (17.3-21.8)	19.1 (17.0-21.3)	18.2 (15.9-21.1)	17.1 (14.8-20.5)	16.1 (14.3-18.6)	14.5 (12.6-17.1)
4	C	U	19.7 (17.3-22.3)	19.3 (17.0-21.8)	18.3 (15.8-21.5)	17.1 (14.6-20.8)	16.0 (14.0-18.8)	14.3 (12.1-17.1)
5	C	U	19.8 (17.3-22.9)	19.4 (17.0-22.5)	18.4 (15.7-22.3)	17.2 (14.5-21.6)	16.1 (13.9-19.5)	14.3 (12.0-20.8)
6	B	U	20.0 (16.3-23.0)	19.4 (15.9-22.2)	18.0 (14.0-21.4)	16.3 (12.3-20.7)	14.7 (11.4-18.2)	12.1 (8.7-16.3)
7	C	O	19.8 (17.2-23.0)	19.2 (16.8-22.2)	18.3 (15.3-21.4)	16.9 (14.2-20.7)	15.7 (13:6-18.2)	13.8 (11.6-16.3)
8	C	U	20.2 (17.3-23.6)	19.7 (16.9-23.0)	18.7 (15.5-22.8)	17.4 (14.4-21.8)	16.3 (13.8-19.4)	14.3 (11.7-17.4)
9	C	O	20.3 (17.4-23.6)	19.8 (17.0-23.0)	18.8 (15.6-22.7)	17.5 (14.6-21.8)	16.4 (13.8-19.4)	14.4 (11.8-17.4)
10	B	U	20.4 (17.5-23.5)	19.9 (17.2-22.9)	18.9 (15.8-22.7)	17.7 (14.8-21.8)	16.6 (14.1-19.5)	14.6 (12.2-17.5)
11	C	U	21.6 (18.4-24.6)	21.1 (18.1-24.6)	20.2 (16.6-24.3)	18.9 (15.6-23.5)	17.7 (14.7-21.2)	15.5 (12.7-18.9)
12	C	O	20.4 (17.3-23.4)	20.0 (17.0-23.4)	19.0 (15.6-23.1)	17.8 (14.5-22.3)	16.6 (13.7-20.1)	14.5 (11.7-17.8)
13	B	U	22.3 (17.6-26.6)	21.6 (17.3-26.5)	20.2 (15.1-26.3)	18.4 (13.5-25.0)	16.6 (12.3-21.8)	13.4 (9.4-18.5)
14	C	U	22.4 (19.8-25.3)	21.7 (19.2-24.9)	20.6 (17.4-24.6)	19.3 (16.4-24.3)	18.0 (15.5-21.5)	16.6 (12.8-19.0)
15	C	U	22.4 (19.9-25.4)	21.8 (19.3-25.0)	20.7 (17.5-24.7)	19.4 (16.4-24.4)	18.1 (15.6-21.5)	15.7 (12.8-19.3)
16	C	O	21.6 (19.1-24.6)	21.0 (18.6-24.2)	19.9 (16.8-23.8)	18.7 (15.9-23.5)	17.4 (15.0-20.7)	15.2 (12.5-18.6)
17	B	U	22.2 (19.7-25.1)	21.5 (19.1-24.7)	20.5 (17.4-24.4)	19.3 (16.4-24.2)	18.0 (15.6-21.3)	15.7 (12.9-19.1)
18	B	O	22.0 (19.7-24.7)	21.4 (19.1-24.3)	20.4 (17.5-24.0)	19.3 (16.6-23.8)	18.1 (15.8-21.2)	16.0 (13.4-19.1)
19	B	U	22.4 (19.8-25.4)	21.7 (19.2-24.9)	20.6 (17.5-24.7)	19.4 (16.4-24.4)	18.0 (15.6-21.5)	15.7 (12.8-19.2)
20	C	U	22.3 (19.7-25.4)	21.5 (19.2-24.6)	20.5 (17.5-23.8)	19.2 (16.5-23.7)	17.8 (15.7-20.6)	15.5 (12.9-18.4)

[a] B = monitored every 2 weeks; C = monitored continuously.
[b] As defined in Table 4.

velocity under unoccupied bedrock ledges and boulders averaged 1.3 cm/s (range, 0-3 cm/s). For example, pool 12 contained a bedrock ledge that covered 10.5 m^2. Flow under the ledge averaged 23 cm/s and adult densities under the ledge averaged 3.9 adults/m^2. In contrast, pool 10 contained a bedrock ledge that covered 17.4 m^2. Water velocity under the ledge averaged only 1.4 cm/s and was 0 cm/s at several points. Only one adult steelhead was observed under this ledge. Mean bottom water velocities, from measurements taken along the thalweg, were compared between the occupied and unoccupied pools where depth was the dominant form of cover (pools 2, 12, and 16 versus pools 5, 13, 17, and 20). Mean bottom water velocity in pools occupied by adult steelhead (7 cm/s; range, 4-9 cm/s) was greater than in unoccupied pools (3 cm/s; range, 1-6 cm/s).

Maintaining position against the current cannot be accomplished without some energetic cost (Allen 1969; Facey and Grossman 1990). In the present study, adults occupied areas with cover and moderate water velocity and were absent from areas of low or high water velocities. The range of water velocities selected during periods of elevated water temperature probably reflects an attempt by the steelhead to balance energetic cost against the greater availability of oxygen in the more rapidly moving water.

Mean temperatures (July–October) for the 20 study pools ranged from 8.7 to 26.6°C in the water (Table 5) and from 7.6 to 41.8°C in the air. Water temperatures throughout most of the monitoring period exceeded the optimum range for steelhead (which is 10-15°C; Barnhart 1986). Mean hourly pool temperature in pools occupied by adult summer steelhead (18.0°C) was significantly different from that in unoccupied pools (18.3°C), but the biological significance of a difference of 0.3°C is questionable. Furthermore, linear-regression analysis indicated that there was no significant relationship between adult fish density and mean hourly pool temperature. Diurnal water temperature fluctuations in occupied pools (mean, 3.7°C; range, 1.7–5.8°C) were significantly different than in unoccupied pools (mean 4.2°C; range 1.5–9.8°C).

Comparison of mean hourly thermistor temperatures identified coolwater areas in three of the continuously monitored pools. A lateral seep created a coolwater area in pool 7 which averaged 0.8°C cooler than the mean hourly pool temperature. The coolwater area in pool 16 was formed by the cold inflow from Big Creek and averaged 3.8°C lower than the mean hourly pool temperature. Pool 20 (maximum depth, 4.8 m) was among the deepest pools found in the river and the coolwater area may have been formed by overnight cooling and slow heating of the deeper water during the daylight hours. Mean hourly temperatures at the bottom of pool 20 were 0.2°C cooler than surface and midwater temperatures. In pool 20, bottom water velocity averaged 0.8 cm/s, whereas surface and midwater velocities averaged 4.3 cm/s. These differences in water velocity suggest slow mixing of surface and bottom water, which would help maintain the coolwater area during the warmer daylight hours.

The occurrence of coolwater areas in stream pools has been documented by other researchers (Keller and Hofstra 1982; Bilby 1984). Use of coolwater areas by adult summer steelhead has been documented in the Eel River (Jones 1980), but other researchers reported no preference for coolwater areas (Kaya et al. 1977; Bilby 1984). In the present study, use of the coolwater areas by adult summer steelhead was variable but tended to increase with water velocity and cover availability. Pool 20 lacked bedrock and boulder cover and the mean water velocity in the coolwater area was low (0.8 cm/s). No adult steelhead were observed in pool 20. Adult steelhead consistently occupied the coolwater area in pool 7. Water velocity in the coolwater area averaged 1.0 cm/s and a bedrock ledge provided cover. Throughout the monitoring period, an average of 8.6 adults occupied pool 7. The mean number of adult steelhead (37.9) in pool 16 was among the highest observed in this study. Water velocity in the coolwater area averaged 1.7 cm/s. Bedrock and boulder cover were not available in pool 16 but mature alder around the mouth of Big Creek provided shade.

In conclusion, the highest pool use by adult summer steelhead was associated with moderately (1.0–1.4-m) deep habitats of intermediate size (200–1,200 m^2) that contained cover associated with moderate flows (9.3 cm/s) and low streambed substrate embeddedness (<35%). Regression analysis suggested that mean hourly pool temperature was not significantly related to adult steelhead densities. Furthermore, stepwise regression analysis indicated that mean hourly pool tempe--ature accounted for an insignificant amount of the observed variability in adult summer steelhead densities when considered in conjunction with other pool descriptors. Thus, in the New River, physical habitat characteristics (e.g., pool size, substrate, cover, and flow) are stronger factors in habitat use by adult summer steelhead than the availability of thermal refugia.

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