Patrick D. Saffel[1] and **Dennis L. Scarnecchia,** Department of Fish and Wildlife Resources, University of Idaho, Moscow, Idaho 83843

Habitat Use by Juvenile Bull Trout in Belt-Series Geology Watersheds of Northern Idaho

Abstract

Bull trout (*Salvelinus confluentus*), a native char of the Pacific Northwest, has declined in abundance and distribution in recent years. Little is known about the habitat use by salmonids in streams with substrate characterized by Belt-Series geology. Such information could be used by managers to evaluate potential effects of land use practices on the species, or to enhance or protect existing habitat. A total of 28 pools, 60 riffles, and 46 runs was sampled in 14 reaches of four streams to determine habitat use of age 0 and age ≥1 juvenile bull trout in three habitat types (pools, runs, and riffles) and in channel margins and main channels. Age 0 bull trout used habitat types in equal proportion to availability, whereas age ≥1 juvenile bull trout selected pools and avoided riffles. Lateral position within the stream channel differed with age class: 88% of the age 0 fish were in the channel margins, whereas 91% of the age ≥1 fish were in the main channel. In addition to the habitat use study, 18 reaches in six streams were studied to determine habitat characteristics that influence abundance and distribution of juvenile bull trout. Reaches with high densities (3.9 to 11.2 fish/100 m^2) of bull trout had maximum summer temperatures ranging from 7.8 to 13.9°C, whereas most reaches with low densities (< 1.0 fish/100 m^2) had higher maximum summer temperatures (18.3 to 23.3°C). Density of juveniles in reaches increased with the number of pocket pools/100 m. The combination of number of pocket pools and maximum summer temperature explained nearly two-thirds of the variation in density of juvenile bull trout.

Introduction

The bull trout (*Salvelinus confluentus*), a native char of the Pacific Northwest, has declined in abundance and distribution during the past 30 years (Goetz 1989), especially in southern portions of its range (Rode 1988). Several factors have been implicated in their decline, including habitat degradation (Cardinal 1980; Enk 1985), competition with introduced species (Dambacher et al. 1992), and exploitation (Allan 1980; Carl 1985). Bull trout gained their southern distributions during the Miocene and Pleistocene epochs when major river systems of the Northwest were connected and the climate cooler (Goetz 1989). As temperatures warmed, bull trout took refuge in cold headwater streams. Some populations of bull trout are year-round stream residents, whereas others are migratory, requiring downstream passage from natal streams to a river or lake to grow to maturity and upstream passage to return for spawning. McPhail and Murray (1979) suggested that lack of rearing habitat may limit the overall number of bull trout in a population. However, compared to most other salmonids, little is known about the specific rearing requirements of bull trout.

When evaluating the habitat requirements of bull trout, the geology of watersheds should be considered. Much of northern Idaho and northwestern Montana consists of Belt-Series geology characterized by cobble-sized sediments. Little is known about the habitat use by salmonids in streams with Belt-Series type substrate. Such information could be used by managers to evaluate potential effects of land use practices on the species, or to enhance or protect existing habitat. The objectives of this study were to 1) characterize habitat use of age 0 and older juvenile bull trout in summer and 2) identify the physical attributes of streams that are most closely associated with the distribution and abundance of bull trout. Although habitat for juvenile bull trout can be limiting in any season (e.g., winter), the emphasis in this study was on late spring and summer, when conditions for growth of juveniles were most favorable.

Study Area

The study was conducted in 18 reaches of six different tributary streams (Grouse Creek, North Fork

[1] Current address: Shoshone-Bannock Tribes, Fisheries Department, Fort Hall, Idaho 83203

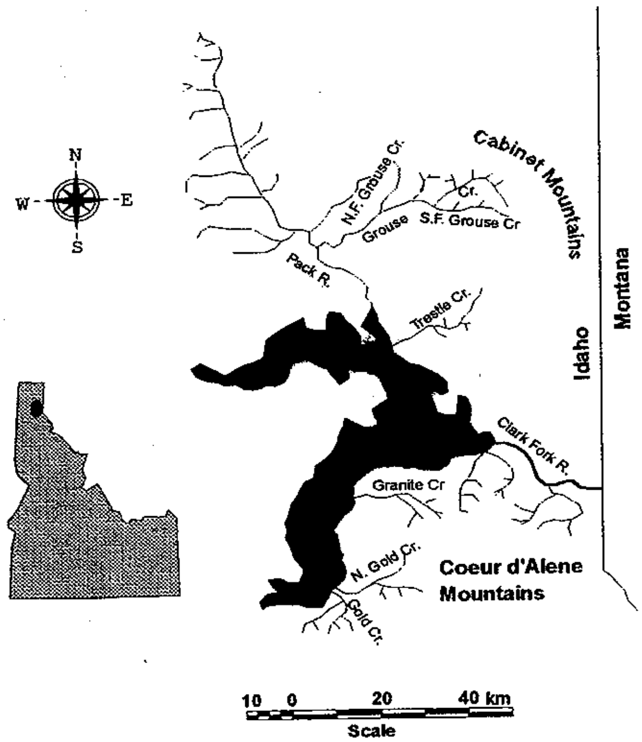

Figure 1. Map of study area including geographic location of Lake Pend Oreille, its major tributaries, and the study streams.

Grouse Creek, Trestle Creek, Granite Creek, North Gold Creek, and Gold Creek) of the Lake Pend Oreille drainage in northern Idaho (Figure 1). In these and other Lake Pend Oreille tributaries, juvenile bull trout most often occur sympatrically with resident and juvenile adfluvial westslope cutthroat trout (*Oncorhynchus clarki lewisi*), resident and juvenile adfluvial rainbow trout (*O. mykiss*), and occasionally with brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) (Pratt 1985). Most bull trout in these systems are adfluvial, typically remaining in streams as juveniles from one to three years, and migrating to the lake to grow (often up to 65.0 cm in length) and mature (Hoelscher and Bjornn 1989). Maturity occurs within two to four years after reaching the lake, so adult fish are typically five to seven years old. Adult bull trout have strong homing instincts (Scott and Crossman 1973), returning to their natal streams during spring through early fall and spawning during September and October.

Streams were chosen to represent the range of habitats accessible to and occupied by adfluvial bull trout in the Belt-Series geology type rock formation located on the eastern side of Lake Pend Oreille (Figure 1; Table 1). Details of the study streams are presented in Saffel (1994). Eighteen stream reaches to be sampled were systematically placed within the stream distance available to adfluvial bull trout. Length of study reaches was approximately 100 m in thalweg length. However, one reach at the lower end of Granite Creek was divided into two, smaller reaches because a large spring in the middle of the original reach reduced the water temperature by 5°C.

Methods

Density of Juvenile Bull Trout

Numbers of juvenile bull trout were estimated within each study reach by snorkeling and bank observation at night between 6 July and 4 September 1992. Night snorkeling was shown to be a consistently better method of enumerating juvenile bull trout than day snorkeling or electrofishing in three Lake Pend Oreille tributaries (Bonneau 1994). Snorkel counts were made by moving upstream through the reach, spotting fish with a flashlight, and whenever possible, confirming the length with an object of known length. A bank observer followed approximately 15 m behind the snorkeler and counted fish in the channel margins on both banks. To avoid duplicate counting of fish, the bank observer and snorkeler communicated and used hand signals to indicate fish locations and counts. Bull trout would remain motionless when observed with a light from underwater and from above, facilitating identification and length estimation. Bull trout were categorized according to total length as: Age 0 (< 75 mm) and age ≥ 1 (75 to 270 mm). Fish were later consolidated into one group, juvenile bull trout (age 0 and age ≥ 1 combined), for analysis of abundance and distribution. Length at age categories were confirmed by a small sample of otoliths collected from study streams. Length of age 0 fish was typically 40 to 60 mm with the largest being 75 mm. Counts of fish were recorded according to observation method (snorkeling or from the bank), species, and size class. Age 0 bull trout were distinguished from other age 0 salmonids by an overall darker, mottled body color, the absence of markings on dorsal fin, a laterally compressed body form, and the presence of a black, triangular-shaped mark on the caudal fin. Hybrid bull trout x brook trout were differentiated from bull trout by spotting on the dorsal fin (Cavender

TABLE 1. Key physical, chemical, and biological attributes of the six study streams. Geologic types are, UGB, unglaciated belt; GB, glaciated belt; and GM, granitic mix. Other trout species are: ctt, cutthroat trout; rbt, rainbow trout; brt, brook trout; and hyb, brook trout x bull trout hybrids. Discharge was measured on 27 and 28 August.

Creek	Geologic type	August discharge (m^3/s)	Conductivity μmhos cm^{-1}	Percent gravel[a]	Range of gradient (%)[b]	Elevation lower-upper (m)[c]	Other trout species observed
Gold	UGB	0.23	99	47.1	3.8	628 - 725	ctt
North Gold	UGB	0.11	107	49.6	6.4	628 - 670	ctt
Granite	UGB	0.23	88	36.2	1.9 - 5.4	628 - 805	ctt, rbt
Trestle	GB	0.21	34	30.0	3.1 - 8.3	628 - 1,158	ctt,rbt
Grouse	GM	0.21	17	13.5	1.6 - 3.6	902 - 1,228	ctt,rbt,hyb
N.F. Grouse	GM	0.05	90	35.2	3.5-5.0	750 - 878	rbt,brt,hyb

[a] Dominant gravel substrate includes both pea gravel and gravel (Overton 1992). This size range corresponds with dominant substrates characterizing bull trout redds (Goetz 1989).

[b] Gradients are those reported by Hoelscher and Bjornn (1989) that corresponded with sections in this study and are approximations.

[c] Elevations are approximations as reported by Hoelscher and Bjornn (1989).

1978; Markle 1992). Densities (fish/100 m^2) were calculated based on the dimensions of each reach in which fish were counted.

Temperature

Water temperature in the 18 study reaches was monitored with 14 maximum-minimum thermometers and four Ryan Tempmentors. A thermometer or Tempmentor was placed directly below each study reach by 18 June and removed on 10 and 11 September. Maximum-minimum thermometers were read every two weeks. Tempmentors recorded hourly temperatures. Temperatures throughout study reaches were confirmed with a hand-held thermometer at times of snorkeling. Maximum summer temperature was chosen for analysis because it has been cited as a controller of juvenile bull trout distribution (Goetz 1989) and is commonly used in relating fish abundance to habitat.

Use of Habitat Types

To determine use of habitat types, twenty-eight pools, 60 riffles, and 46 runs were sampled from 14 reaches in four streams during July and August of 1992. Habitat typing followed the procedure described by Overton (1992). This procedure used information from Bisson et al. (1981) and Sullivan (1986) to determine habitat types.

To determine physical features of the pools, riffles, and runs, three equidistant transects parallel and perpendicular to flow were placed in each habitat unit. As a result, nine points within each habitat unit were measured for water depth, bottom water velocity (2 cm above bottom), and dominant substrate. Depth was measured with a meter stick, velocity with a Marsh-McBirney flow meter, and dominant substrate was estimated visually within a 0.3 m^2 area around each point. Length was measured along the thalweg, wetted stream width was measured at each perpendicular transect, and bankfull channel width was measured at each one-half transect.

Mean depth, geometric mean substrate size, and mean velocity was determined for each habitat unit. Mean depth (cm) of habitat units was calculated as the sum of the nine depths divided by 12 to account for 0 depth at the bank (Platts et al. 1983). Geometric mean substrate size was determined using ranked classifications described by Overton (1992): sand/silt (< 0.2 cm; rank = 1), pea gravel (0.2 - 0.6 cm; rank = 2), gravel (0.6 - 7.5 cm; rank = 3), rubble (7.5 - 15.0 cm; rank = 4), cobble (15.0 - 30.0 cm; rank = 5), boulder (> 30 cm; rank = 6), and bedrock (rank = 7). Mean velocity was equal to the sum of velocity measurements in a habitat unit divided by nine.

Reaches

To determine habitat features of reaches most closely associated with abundance and distribution of bull trout, six habitat variables were measured for each study reach. Mean depth, mean velocity, and substrate diversity were calculated from transect measurements in habitat units. Other measurements included volume of large woody debris (volume/100 m^2) within bankfull width, water temperature, and number of pocket pools.

Mean depth and mean velocity in a reach were calculated from data collected for habitat units. Diversity of substrate was estimated using the reciprocal of Simpson's index (Hill 1973), $D=1/\Sigma (P_i^2)$; where, P_i is the proportion of substrate measurements in category *i*.

Volume of large woody debris within bankfull discharge was estimated for each reach. Pieces measured were defined as either a bole or rootwad. Boles were greater than 10 cm in diameter at one-third the distance from the base and either (1) equal to or longer than 3 m in length or (2) two-thirds the stream width (Overton 1992). Root wads were attached to logs less than three meters in length. Diameter was measured at one meter from the base. The volume was estimated using the formula for determining the volume of a cylinder; $\pi(r^2)(l)$; where, r = the radius at one-third (bole) or one meter (root wad) the distance up from the base and l = the length.

The total number of pocket pools was determined for each study reach. Pocket pools were small, low velocity areas formed by channel obstructions including boulders, woody debris, and irregular bank formation (Overton 1992). Pocket pools were characterized by less turbulence, smaller substrate, and generally greater depth than surrounding areas and were in riffle and run habitat types.

Analyses

Chi-square contingency tables and goodness-of-fit tests were used to determine whether use of habitat types by bull trout was independent of age class (age 0 and age $\geq$ 1). Use was determined by pooling habitat unit counts from Granite Creek, Trestle Creek, North Gold Creek, and Gold Creek. Reaches 1 and 2 from both Grouse and North Fork Grouse creeks were excluded because factors other than physical habitat features (i.e., high temperatures and presence of brook trout) may have limited bull trout numbers there. Observed values by age class were equal to the number of fish counted in a habitat type. Expected values were calculated based on the proportion of area sampled of a habitat type. The null hypothesis was that use of habitat type was in proportion to the availability of a particular habitat type. If use of habitat types by an age class was significantly different (i.e., $P \leq 0.05$), Bonferroni confidence intervals around frequency of use were used to determine if bull trout age classes were selecting, neutral, or avoiding habitat types (Neu et al. 1974). Selection for a habitat type was indicated if availability of a habitat type was lower than the lower bound of the confidence interval. Conversely, avoidance was indicated when availability of a habitat type was higher than the upper bound. Neutral selection was indicated when the frequency of the habitat type was within the bounds of the confidence interval.

To test for differences in mean velocity, mean depth, and geometric mean dominant substrate size between habitat types, the Kruskal-Wallis test was used because of unequal variances and non-normal distributions of samples. Dunn's test was used for multiple comparisons of ranked values with unequal sample size. Each test was considered significant at $P \leq 0.05$.

Regression techniques were used to relate bull trout densities to the six habitat variables (volume of large woody debris/100 m^2, mean depth, substrate diversity, maximum summer temperature, mean velocity, and number of pocket pools/100 m). Multiple best subsets regression, with Mallow's C(p) statistic as a criterion, was used to choose the five best models with two independent variables. For multiple and simple linear regression tests, density of juvenile bull trout was the dependent variable (Y) and habitat features were the independent variables (X). Multiple and simple linear regression results were considered significant at $P \leq 0.05$.

Normality and homoscedasticity assumptions were evaluated to determine the validity of regression analyses and the need for transformations. Transformations of density of juvenile bull trout and volume of large woody debris were necessary to normalize distributions and stabilize variance. Density of bull trout was transformed using a square root (Y + 0.5) transformation and volume of large woody debris was transformed using $\log_{10}$. For regression procedures the constant variance assumption was visually determined using residual plots (Zar 1984).

Results

Use of Habitat Types

A total of 190 age 0 and 253 age ≥ 1 juvenile bull trout was observed during July and August in 14 reaches of four streams (Table 2). Use of habitat types was dependent on age (size) of bull trout (χ^2 = 28.26; 2 df; P < 0.001), so different age classes used habitat types differently. Age 0 bull trout showed no selection for a habitat type (χ^2 = 3.83; 2 df; P > 0.10). Age ≥ 1 bull trout, in contrast, were found more often than expected in pools and less than expected in riffles (χ^2 = 24.43; 2 df; P < 0.001). Use of channel margins and main channels by juvenile bull trout was also related to age class. Eighty-eight percent of the age 0 fish were observed in the channel margins, whereas 91% of the age ≥ 1 were found in the main channel.

For Granite, North Gold, Gold, and Trestle Creeks combined, riffle habitat was most abundant (3,793.5 m^2) followed by runs (2,344.1 m^2) and pools (962.5 m^2). Significant differences were found between habitat types in mean velocity (H = 51.7; 2 df; P < 0.001; Figure 2), geometric mean substrate size (H = 29.1; 2 df; P < 0.001), and in mean depth (H = 44.4; 2 df; P < 0.001). Mean comparisons indicated similarities in mean depth and mean velocity between pools and runs, whereas

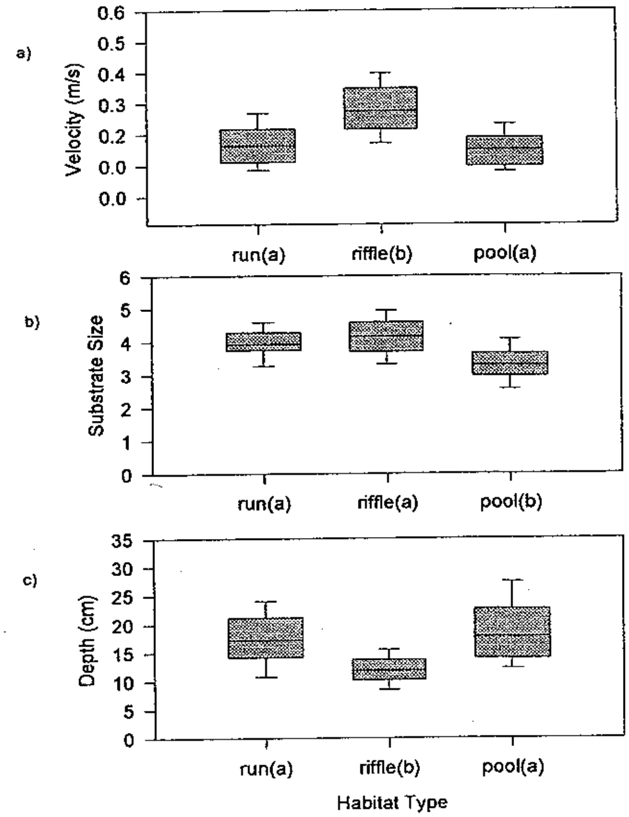

Figure 2. Box plots showing 10th, 25th, 50th, 75th, and 90th percentiles (horizontal lines) for a) mean velocity, b) geometric mean substrate size, and c) mean depth by habitat type (pool, riffle, and run) for four streams during July and August. Different small case letters next to habitat types indicates significant differences between those types. Dunn's test was used for multiple comparisons.

TABLE 2. Availability of three habitat types and use by juvenile bull trout in four streams during July and August 1992.

	Pool	Riffle	Run	Totals
n	28	60	46	134
Habitat area (m^2)	962.5	3,793.5	7.100.2	11,856.2
Available (%)[a]	13.6	53.4	33	
Age 0 bull trout				
n	17	111	62	190
Use (%)	9.0	58.4	32.6	
Age ≥1 bull trout				
n	61	115	77	253
Use (%)	24.1	45.5	30.4	
Confidence interval	17.7 - 30.6[b]	37.9 - 53.0[c]	23.5 - 37.4	

[a] Percent of total habitat area
[b] Selection for pool habitat
[c] Avoidance of riffle habitat

riffles were shallower and had higher velocities. Substrate size was significantly larger in both runs and riffles than in pools. Therefore, in combination with the habitat use results, it can be concluded that age ≥ 1 juvenile bull trout were found more often than expected in deeper, slower habitat types with smaller substrate (i.e., pools). Conversely, age ≥ 1 juvenile bull trout were observed less often than expected in shallower, faster habitat types with larger substrate (i.e., riffles).

Reaches

Juvenile bull trout were found at elevations ranging from 628 m to 1158 m and gradients ranging from 1.9% to 8.3% (Table 1). Densities of juvenile bull trout (age 0 and age ≥ 1 combined) ranged from zero to 11.2/100 m² (Table 3). Two variables, maximum summer temperature and number of pocket pools/100 m, were significantly related with density of juvenile bull trout using simple linear regression. None of the other four habitat variables (mean depth, mean velocity, substrate diversity, or $\log_{10}$ volume of large woody debris) was significantly related to density of bull trout.

The density of juvenile bull trout was negatively related with maximum summer temperature ($r^2 = 0.33$; df = 17; $P = 0.01$). However, a non-linear, dome shaped relationship or barrier effect (temperatures are either too low or high to support the species) is more likely (Figure 3). Density of bull trout increased with increasing temperature below 14°C and decreased with increasing temperature above 18°C. The highest densities of bull trout were found in Trestle and Gold Creeks where maximum summer temperatures ranged from 10 to 13.9°C. Lower densities of bull trout were found with decreasing maximum summer temperatures below 13.9°C in North Gold Creek and portions of Granite Creek and with maximum summer temperatures above 18°C in the Grouse Creek drainage and in one reach of Granite Creek. No reaches were sampled that had maximum summer temperatures between 14 and 18°C. This may be due to the relatively warm

TABLE 3. Physical characteristics and densities of juvenile bull trout in 18 stream reaches of six Lake Pend Oreille tributaries.

Creek	Reach	Length (m)	Mean width (m)	Mean depth (cm)	Substrate diversity	Mean velocity (m/s)	Volume of large woody debris/100 m²	Maximum summer temperature (°C)	Number of pocket pools/100 m	Juvenile bull trout/ 100 m²
Granite	1	43.6	6.38	14.93	2.96	0.20	1.92	12.2	6.88	5.39
Granite	2	64.9	6.19	16.34	1.92	0.11	0.96	18.3	0	0.75
Granite	3	105.8	5.55	15.49	3.02	0.21	2.24	13.9	0	0.85
Granite	4	111.8	5.13	15.10	4.25	0.18	2.44	11.0	14.31	4.01
Granite	5	92.4	5.92	16.82	3.24	0.20	2.12	9.2	20.56	4.94
Grouse	1	89.0	7.37	13.52	3.11	0.17	0.80	20.0	20.22	0.30
Grouse	2	83.0	6.25	10.39	3.67	0.12	0.20	20.0	28.92	0.96
N.F. Grouse	1	88.7	4.76	10.12	3.61	0.30	2.44	23.3	6.76	0.00
N.F. Grouse	2	90.1	4.92	10.88	4.56	0.25	3.12	20.0	6.66	0.23
North Gold	1	95.7	5.01	12.57	2.45	0.12	9.84	7.8	0	0.42
North Gold	2	100.9	4.85	14.93	3.73	0.18	6.92	7.8	6.94	3.88
Gold	1	108.6	6.65	11.92	3.59	0.22	0.48	10.0	21.18	7.89
Gold	2	89.3	3.90	15.63	2.90	0.23	3.12	11.1	24.64	11.20
Trestle	1	103.6	6.57	17.06	3.73	0.17	2.40	13.0	25.10	8.96
Trestle	2	128.6	5.05	13.20	4.00	0.23	4.92	13.3	30.33	7.55
Trestle	3	123.6	5.22	16.22	3.90	0.24	4.88	13.9	20.23	11.16
Trestle	4	101.5	4.43	11.72	3.49	0.20	6.08	12.2	12.81	6.23
Trestle	5	105.3	4.16	8.23	3.71	0.18	16.28	12.1	17.09	9.82

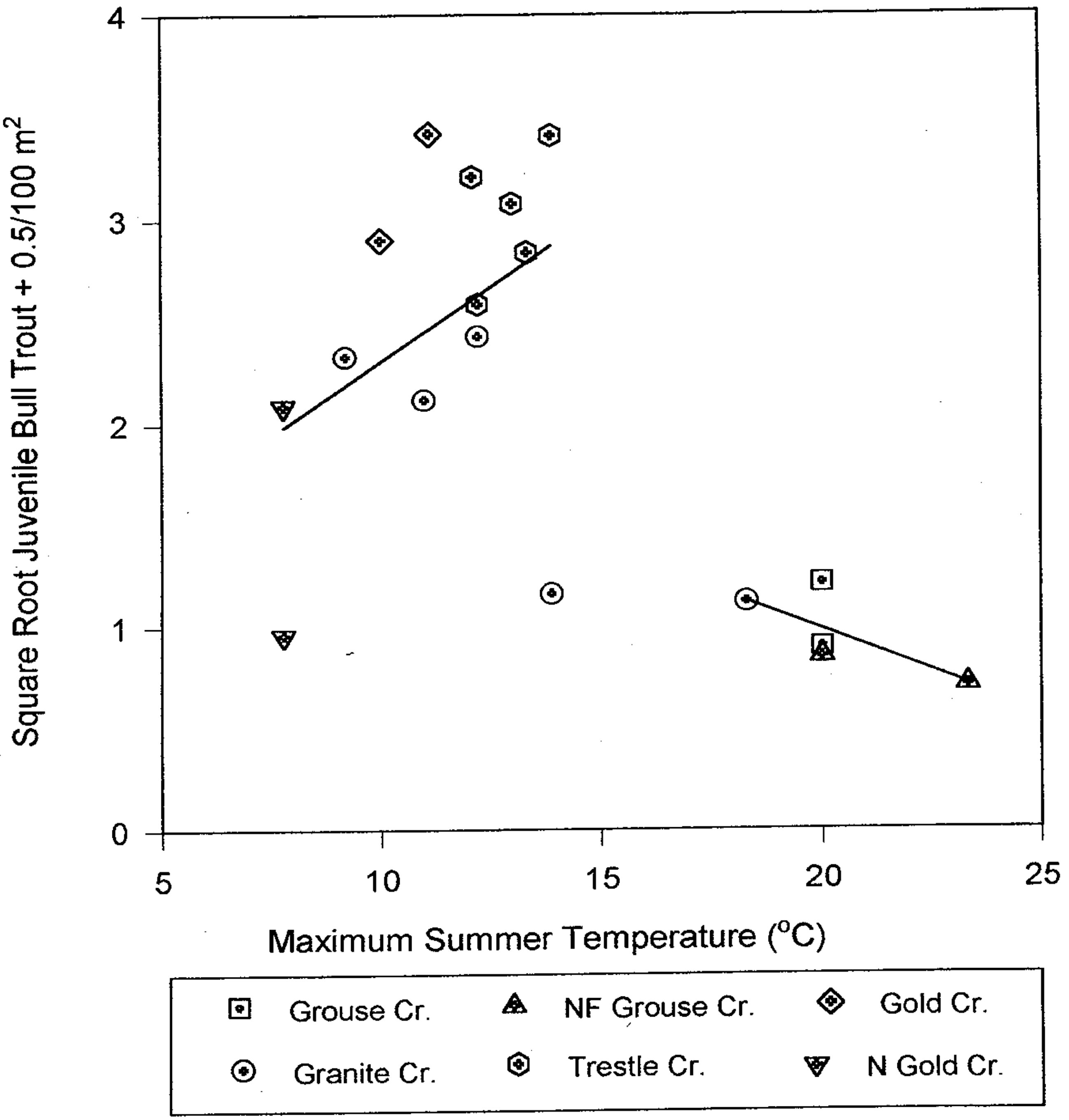

Figure 3. Scatter plot of maximum summer temperature and transformed juvenile bull trout density for 18 reaches of six streams. Lines indicate trends in density of juvenile bull trout in reaches with maximum summer temperatures <14°C (increasing trend) and >18°C (decreasing trend).

summer climate in the Lake Pend Oreille drainage. Low elevation (690 m at lake level) and consistently warm summer air temperatures (often above 30°C) may result in warm stream temperatures except where influence of cold ground water is significant or the stream is shaded from sunlight.

The density of juvenile bull trout was positively related with number of pocket pools/100 m ($r^2 = 0.33$; df = 17; P = 0.01; Table 4; Figure

TABLE 4. Results of simple linear regression between density of juvenile bull trout (Y) and independent variables (X) for 18 reaches (df = 17) of six streams.

Independent Variable (X)	r^2	F	Probability	Equation
No. of pocket pools/100 m	0.33	7.87	0.01	Y = 1.26 + 0.06(X)
Mean bottom velocity	0.04	0.59	0.46	Y = 1.33 + 3.75(X)
Mean depth	0.06	1.01	0.33	Y = 0.84 + 0.09(X)
Substrate diversity	0.05	0.88	0.36	Y = 0.87 + 0.35(X)
Volume of large woody debris ($\log_{10}$)	0.09	1.6	0.22	Y = 1.63 + 1.65(X)

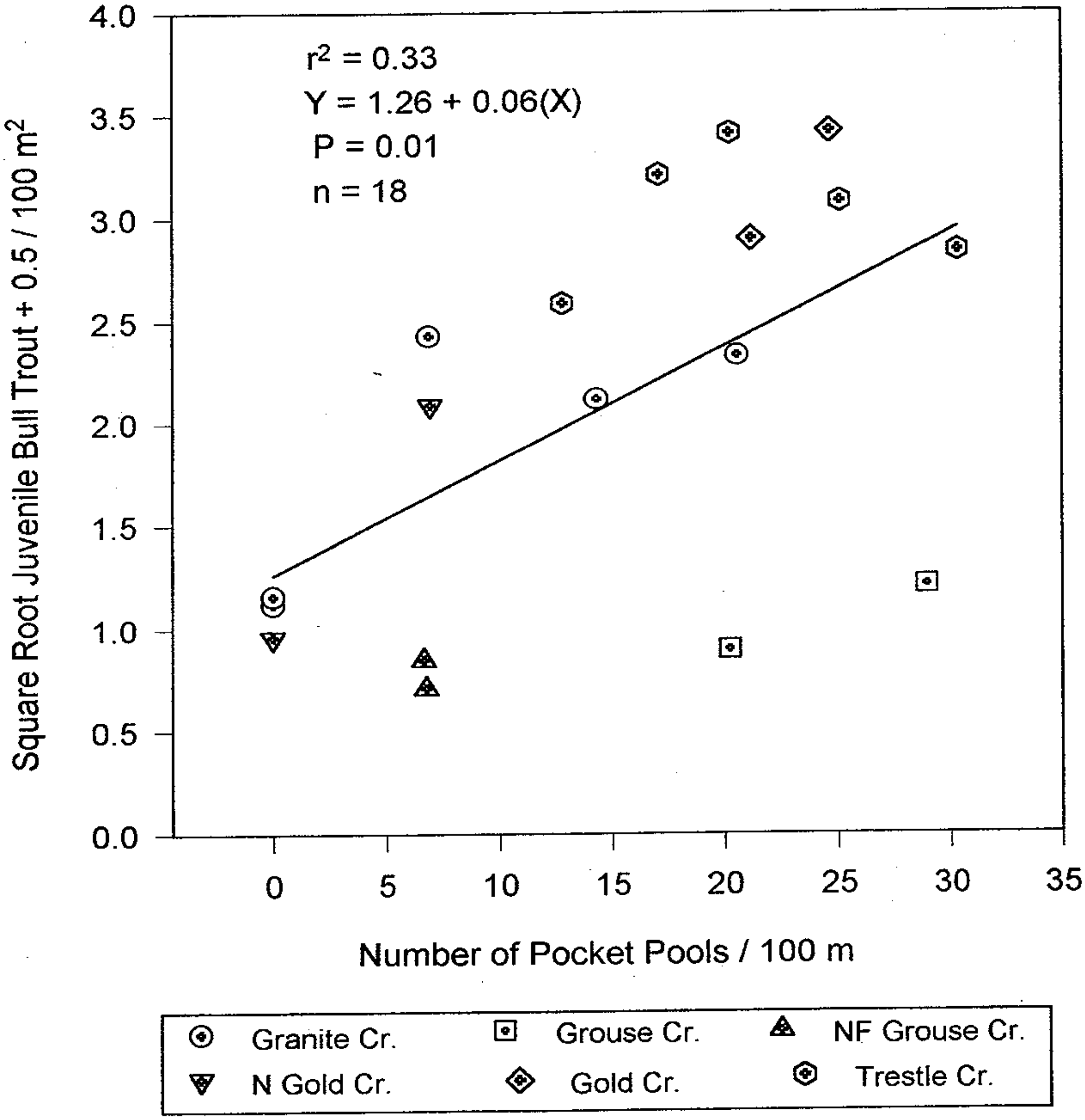

Figure 4. Relationship between number of pocket pools/100 m and transformed juvenile bull trout density for 18 reaches of six streams.

4). Density of juvenile bull trout in the four reaches within Grouse Creek and North Fork Grouse Creek was poorly described by the linear model and decreased the amount of variation explained (r^2). These four reaches differed from the others in that maximum summer temperatures were > 18°C whereas the other reaches had maximum summer temperatures of <14°C.

Using multiple best subsets linear regression, transformed juvenile bull trout density (Y) was best predicted by the model: $Y = 2.919 - 0.119(X_1) + 0.055(X_2)$ where X_1 = maximum summer temperature, and X_2 = number of pocket pools/100 m ($R^2 = 0.64$; df = 16; $P < 0.001$; Table 5; Figure 5). Number of pocket pools accounted for 33% of the variation and maximum summer temperature accounted for 31%. Colinearity between number of pocket pools and maximum summer temperature was insignificant ($r = -0.02$; $P > 0.90$). Model numbers 2 through 5 (Table 5) were also significant, however, in each case either maximum summer temperature or number of pocket pools were included in the model and accounted for most of the variation.

The interpretation of the temperature data in this study is limited because of the dependence of maximum summer temperature on streams (indicated by the clustering of individual reaches by stream in Figures 4 and 5) and by the absence of maximum summer temperature data between 14 and 18°C. Clustering of individual stream reaches is not unexpected because sections of streams accessable to bull trout were relatively short, resulting in little variation in water temperatures within a stream. An exception was Granite Creek, which consisted of cold stream temperatures (maximum summer temperatures of 9.2 and 11°C) at the upper reaches, warm stream temperatures (13.9 and 18.3°C) in the middle reaches, and low temperatures (12.2°C) at the lowermost reach, where the stream was influenced by a large, cold water spring. Densities of bull trout were highest in the upper and lowermost reaches where temperatures were coolest, and lowest in the middle two reaches.

Discussion

Age 0 bull trout used habitat differently than age ≥ 1 bull trout. Age 0 fish were found primarily in the channel margins of runs and riffles, whereas the older juveniles selected deeper, slower pool areas and exhibited an avoidance of riffles and runs. Segregation of habitat between larger, older salmonids and younger, smaller salmonids has been reported for bull trout in the upper Arrow Lakes drainage, British Columbia (McPhail and Murray 1979), for age 0 and older char (bull trout and brook trout) in Sun Creek, Oregon (Dambacher et al. 1992) and for steelhead trout (*O. mykiss*) and chinook salmon (*O. tshawytscha*) in two Idaho streams (Everest and Chapman 1972). Use of higher velocity, main channel areas for food acquisition requires stronger swimming, which may also exclude smaller fish. Channel margins often provide the necessary habitat for salmonid fry to survive. Moore and Gregory (1988) reported that age 0 cutthroat trout (*O. clarki*) were more abundant and had higher biomass in stream margins that provided slow, shallow water, and abundant food. Chapman and Bjornn (1969) and Everest and Chapman (1972) suggested that smaller steelhead trout fry used stream margins in the presence of chinook fry because of reduced predation by the larger chinook fry. In the present study, potential predators of age 0 bull trout included

TABLE 5. Results of multiple best subsets linear regression between transformed juvenile bull trout density (Y) and independent variables (X) for 18 reaches of six streams. Asterisks indicate use of independent variables in the respective models.

Model number	C(p)	R^2	Adjusted R^2	P	Maximum summer temp. (°C)	Vol. of large woody debris/100 m²	Substrate diversity	No. of pocket pools/100 m	Mean depth (cm)	Mean velocity (m/s)
1	4.33	0.64	0.59	0.0005	*			*		
2	11.23	0.49	0.42	0.0066		*		*		
3	14.35	0.42	0.34	0.0168	*					*
4	15.00	0.41	0.33	0.0202	*		*			
5	15.87	0.39	0.31	0.0256				*	*	

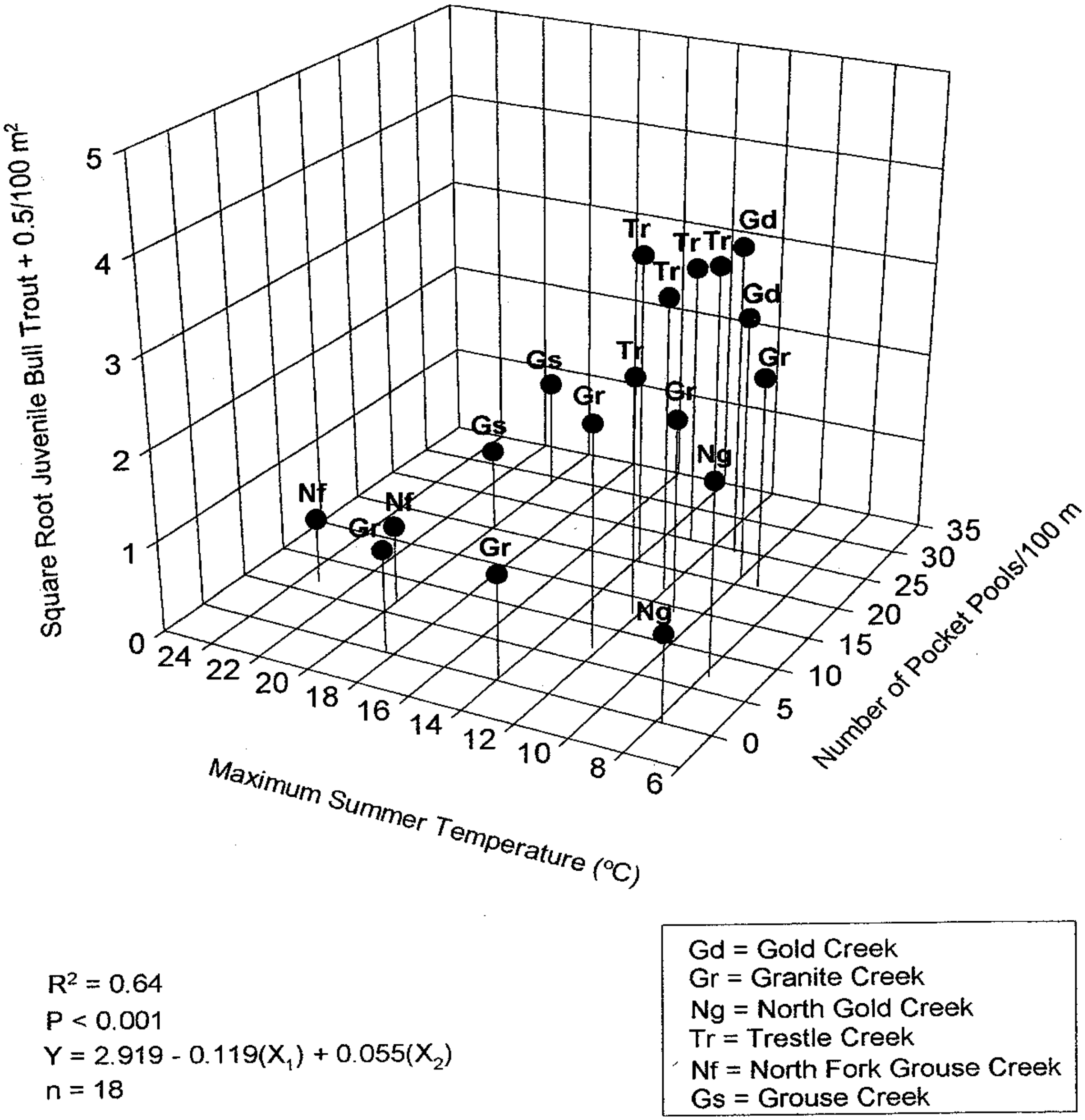

Figure 5. Relationship between maximum summer temperature, number of pocket pools (independent variables) and transformed juvenile bull trout density for 18 reaches of six streams.

cutthroat trout, rainbow trout, brook trout, and larger bull trout. Bull trout greater than 110 mm have been found in other areas to prey upon other bull trout (Horner 1978; Shepard et al. 1984).

The density of juvenile bull trout increased with increased numbers of pocket pools. Pocket pools provided refuge from high current velocities as well as visual isolation among individual fish. Positions of refuge, whether in pools or pocket pools, are preferred by salmonids because they offer access to food with little energy expenditure (Fausch 1984). Pratt (1984) and Shepard et al. (1984) reported that juvenile bull trout commonly use small pockets with low water velocities just above the stream bed. Visual isolation may be particularly important to juvenile bull trout because they may demonstrate a fixed-site territoriality (Pratt 1984). Pratt (1985) suggested that densities of bull trout may be controlled by the availability of areas providing visual isolation and refuge from higher velocities. Unlike cutthroat trout, which are commonly found throughout the water column in pools, juvenile bull trout numbers may be limited in pools by their territorial, bottom dwelling behavior. Pocket pools may thus provide additional rearing space for juvenile bull trout when pool habitat is unavailable. Pool habitat was the least abundant habitat type in all streams except North Gold Creek, where it was the second most abundant (Table 6). Placement of large rocks in nursery streams has been shown to result in the increase in the number of juvenile chinook salmon (Bjornn 1971) and Atlantic salmon (Redmond 1975).

In this study, density of bull trout increased with increasing temperature at lower temperatures and decreased with increasing temperature at higher temperatures. Past investigators have suggested that the relationship of temperature to the distribution of bull trout and other char is a barrier effect (few, if any, fish existing above a certain temperature). In this study, high densities of juvenile bull trout were not present in stream reaches with maximum summer temperatures above 13.9°C. These results are consistent with those of Fraley and Shepard (1989), where a summer maximum temperature of 15°C limited distribution of juvenile bull trout in the Flathead Lake and River system, Montana. Jensen (1981) suggested that a maximum temperature of 14°C controlled the distribution of arctic char *Salvelinus alpinus*. The thermal barrier for brook trout has been reported to be a maximum temperature of 24°C (Ricker 1934; MacCrimmon and Campbell 1969; Meisner 1990). In this study, stream reaches with maximum summer temperatures below 13.9°C showed increasing density of bull trout with increasing temperature. Little is known about how temperature regulates density of fish in the wild. In laboratory channels, Hahn (1977) found a decreasing trend in steelhead trout density with increasing, yet suitable, temperature (opposite of the trend in this study). One plausible explanation is that the increasing trend in densities of bull trout between 7.8 and 13.9°C found in this study is influenced by increased growth and survival (mediated by the availability of food) in stream reaches with increasing maximum summer temperatures up to 13.9°C. The availability of food was not estimated in this study but may be one reason reaches are clustered by stream in Figures 4 and 5. More information is needed on the effect of temperature and availablity of food on density of bull trout.

High water temperatures may be physiologically constraining on juvenile bull trout. Summer is the season in which maximum growth of fish would be expected; however, at temperatures above the preferred range for growth, increased metabolic processes may result in most or all food being used for maintenance. When Shepard et al. (1984) compared temperature and growth of juvenile bull trout in two tributaries of the Flathead River, Montana, they found that at warmer water temperatures, fish growth decreased despite higher primary productivity. In laboratory tests, bull trout fry grew largest and had the greatest survival at colder water temperatures with the greatest growth occurring at 4°C (McPhail and Murray 1979). The

TABLE 6. Area and percent of habitat types sampled in six streams during the summer of 1992.

	Pool		Riffle		Run		
Creek	Percent	Area (m^2)	Percent	Area (m^2)	Percent	Area (m^2)	Total Area (m^2)
Granite	11.3	263.57	53.8	1253.47	34.9	813.13	2330.17
Grouse	3.4	40.02	61.8	730.99	34.9	412.46	1183.47
NF Grouse	17.1	97.45	32.8	186.48	50.0	284.48	568.41
N Gold	27.0	293.55	51.5	559.55	21.5	233.8	1086.9
Gold	13.1	136.07	61.1	634.54	25.7	267.2	1037.75
Trestle	10.2	269.27	50.9	1345.94	38.9	1029.93	2645.14
Totals	12.4	1099.93	53.2	4710.97	34.4	3041.0	8851.84

lowest survival and growth was between 8 to 10°C. Most charrs are well adapted to cold water, and therefore it is plausible that the bull trout's preference would also be for cold water.

Water temperature may also be a decisive factor in influencing competitive advantage between bull trout and other coexisting species, such as brook trout and rainbow trout. Low bull trout densities and high temperatures were found in reaches of North Fork Grouse, Grouse Creek, and Granite Creek. Brook trout inhabited North Fork Grouse Creek and are likely competitors with juvenile bull trout for food and space (Wallis 1948; Dambacher et al. 1992). In addition, hybrids (bull trout x brook trout) were observed in both Grouse and North Fork Grouse Creeks. At higher temperatures, brook trout may have a competitive advantage over bull trout. Similarly, low temperatures may limit distributions of competitive species and result in only bull trout being present. Ziller (1992) studied creeks of the Sprague River subbasin, Oregon and reported that stream sections with August and September temperatures less than 5°C contained only bull trout, whereas brown trout and rainbow trout were found in sections with warmer temperatures. Brown trout and brook trout have similar temperature preferences, and similar upper lethal limits (MacCrimmon and Marshall 1968; MacCrimmon and Campbell 1969; Coutant 1977) and habitat use (Nyman 1970; Fausch and White 1981). Interspecific competition, mediated by temperature, may thus play an important role in bull trout distribution and abundance. A more detailed combination of field and laboratory studies is needed to test this hypothesis.

Other factors may influence the number of juvenile bull trout in streams. Low productivity, which was characteristic of all streams included in this study, may act to limit juvenile densities by regulating the amount of food available. In addition, canopy cover may limit the amount of solar input, thus reducing aquatic production and food for fish. Low numbers of aquatic insects and little algal growth was observed in North Gold Creek indicating low productivity, probably because of the almost complete canopy cover. Subsequently, low productivity, resulting in little food, may reduce the number of juvenile bull trout which can survive in North Gold Creek. Conversely, Gold Creek is largely spring fed with low temperatures and little canopy cover. Gold Creek had abundant potential food and the highest density of juvenile bull trout.

A shortage of spawning habitat is another factor that can limit abundance of juvenile fish. In this study, only Grouse Creek appeared to be limited in spawning habitat (Figure 6). Grouse Creek,

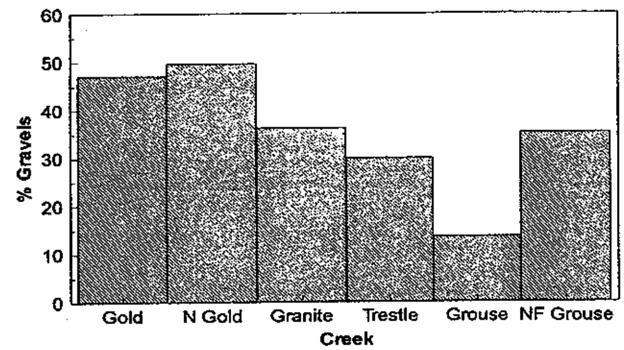

Figure 6. Percent of stream bed dominated by pea gravel and gravel in six streams of the Lake Pend Oreille drainage.

however, also had high maximum summer temperatures and very low conductivities, both of which might also result in lower densities of bull trout.

Results of this study indicate that juvenile bull trout 1) use habitat differently depending on their age (size), 2) increased in density with increasing number of pocket pools in a stream reach, and 3) were associated with stream reaches that had cool temperatures. Age 0 bull trout did not select for a particular habitat type and were mostly found in the channel margins. Age ≥ 1 bull trout selected pools, avoided riffles, and were mostly found in the main channel. Pocket pools were important because they may have provided additional feeding and resting areas. The highest densities of juvenile bull trout were in reaches within Trestle and Gold Creeks which had maximum summer temperatures ranging from 10 to 13.9°C. Although the relationship between temperature and density of juvenile bull trout was inconclusive in this study, other investigators have had similar results with bull trout and closely related species. Further investigation is needed to determine the influence of temperature on the density of bull trout (and other salmonids) during summer.

Acknowledgements

We thank Brooks Sanford, Kara Saffel, Brett Turley, and Chris Wells for field assistance. Drs. Christine Moffitt and Dale Everson reviewed earlier drafts of this manuscript. Dr. Douglas Markle provided helpful comments during the editorial review. Funding for this project was provided by the United States Forest Service Intermountain Research Station, Boise, Idaho. The Idaho Panhandle National Forest and Idaho Department of Fish and Game offered information and guidance throughout the study.

Literature Cited

Allan, J. H., 1980. Life history notes on the Dolly Varden charr (*Salvelinus malma*) in the upper Clearwater, River, Alberta. Alberta Energy and Natural Resources, Fish and Wildlife Division, Red Deer, Alberta, Canada.

Bisson, P. A., J. L. Nielsen, R. A. Palmason and L. E. Grove. 1981. A system of naming habitat in small streams, with examples of habitat utilization by salmonids during low streamflow. Pages 62 - 73 *in* N. B. Armantrout, editor, Acquisition and Utilization of Aquatic Habitat Inventory Information. Proceedings of a Symposium, October 28-30, 1981, Portland Oregon. Hagen Publishing Company, Billings, Montana. Pages 62-73.

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.

Bonneau, J. L. 1994. Seasonal habitat use and changes in distribution of juvenile bull trout and cutthroat trout in small, high gradient streams. M. S. Thesis. University of Idaho, Moscow.

Cardinal, P. J. 1980. Habitat and juvenile salmonid populations in streams in logged and unlogged areas of southeastern Alaska. M. S. Thesis, Montana State University, Bozeman.

Carl, L. 1985. Management plan for bull trout in Alberta. Pages 71-80 *in* D. D. MacDonald, editor. Proceedings of the Flathead River Basin bull trout biology and dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of Environment, Cranbrook, British Columbia.

Cavender, T. M. 1978. Taxonomy and distribution of the bull trout, *Salvelinus confluentus* (Suckley), from the American Northwest. California Fish and Game 64(3):139-174.

Chapman, D. W., and T. C. Bjornn. 1969. Distribution of salmon and trout 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 lecture series in fisheries, University of British Columbia, Vancouver.

Coutant, C. C. 1977. Compilation of temperature preference data. Journal of the Fisheries Research Board of Canada 34:739-745.

Dambacher, J. M., M. W. Buktenica, and G. L. Larson. 1992. Distribution, abundance, and habitat utilization of bull trout and brook trout in Sun Creek, Crater Lake National Park, Oregon. Pages 30-36 *in* Howell, P. J. and D. V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis.

Enk, M. 1985. Modelling the effects of forest sediment on bull trout. Page 5 *in* D. D. MacDonald, editor. Proceedings of the Flathead River basin bull trout biology and population dynamics modelling exchange. British Columbia Ministry of the Environment, Fisheries Branch, Cranbrook, British Columbia.

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

Fausch, K. D. 1984. Profitable stream positions for salmonids: relating specific growth rate to net energy gain. Canadian Journal of Zoology 62:441-451.

Fausch, K. D., and R. J. White. 1981. Competition between brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) for positions in a Michigan stream. Canadian Journal of Fisheries and Aquatic Sciences 38:1220-1227.

Fraley, J. J., and B. B. Shepard. 1989. Life history, ecology and population status of migratory bull trout, (*Salvelinus confluentus*) in the Flathead Lake and River system, Montana. Northwest Science 63:133-143.

Goetz, F. 1989. Biology of the bull trout *Salvelinus confluentus*; a literature review. Willamette National Forest, Eugene, Oregon.

Hahn, P. K. J. 1977. Effects of fluctuating and constatnt temperatures on behavior of steelhead trout (*Salmo gairdneri*). Ph. D. dissertation. University of Idaho, Moscow.

Hill, M. O. 1973. Diversity and evenness: a unifying notation and its consequence. Ecology 54:427-432.

Hoelscher, B., and T. C. Bjornn. 1989. Habitat, densities, and potential production of trout and char in Lake Pend Oreille tributaries. Idaho Department of Fish and Game, Job Completion Report Project F-71-R-10.

Horner, N. J. 1978. Survival, densities, and behavior of salmonid fry in streams in relation to fish predation. M. S. thesis. University of Idaho, Moscow.

Jensen, J. W. 1981. Anadromous arctic char *Salvelinus alpinus*, penetrating southward on the Norwegian coast. Canadian Journal of Fisheries and Aquatic Sciences 38:247-249.

MacCrimmon, H. R., and T. L. Marshall. 1968. World distribution of brown trout (*Salmo trutta*). Journal of the Fisheries Research Board of Canada 25:2527-2548.

MacCrimmon, H. R., and J. S. Campbell. 1969. World distribution of brook trout (*Salvelinus fontinalis*). Journal of the Fisheries Research Board of Canada 26:1699-1725.

Markle, D. F. 1992. Evidence of bull trout x brook trout hybrids in Oregon. Pages 58-67 *in* Howell, P. J. and D. V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis.

McPhail, J. D., and C. B. Murray. 1979. The early life-history and ecology of Dolly Varden (*Salvelinus malma*) in the upper Arrow Lakes. Department of Zoology and Institute of Animal Resources, University of British Columbia, Vancouver, British Columbia.

Meisner, J. D. 1990. Potential loss of thermal habitat for brook trout, due to climatic warming, in two southern Ontario streams. Transactions of the American Fisheries Society 119:282-291.

Moore, K. M. S., and S. V. Gregory. 1988. Summer habitat utilization and ecology of cutthroat trout fry (*Salmo clarki*) in Cascade Mountain streams. Canadian Journal of Fisheries and Aquatic Sciences 45:1921-1930.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 38:541-545.

Nyman, O. L. 1970. Ecological interaction of brown trout (*Salmo trutta*) L., and brook trout (*Salvelinus fontinalis*) (Mitchill), in a stream. Canadian Field Naturalist 84:343-350.

Overton. K. in review. R1/R4 standardized stream habitat inventory guide. United States Department of Agriculture, Forest Service, Intermountain Research Station, Boise, Idaho.

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

Pratt, K. L. 1984. Habitat use and species interactions of juvenile cutthroat (*Salmo clarki lewisi*) and bull trout (*Salvelinus confluentus*) in the Upper Flathead River basin. M. S. Thesis, University of Idaho, Moscow.

Pratt, K. L. 1985. Pend Oreille trout and char life history study. Idaho Department of Fish and Game, Boise.

Received 1 March 1995
Accepted for publication 11 July 1995

Redmond, M. A. 1975. Natural production. International Atlantic Salmon Foundation Special Publications Series 6:134-135.

Ricker, W. 1934. An ecological classification of certain Ontario streams. University of Toronto Studies, Biological Series 37. Publication of Ontario Fisheries Research Laboratory 49:7-14.

Rode, M. 1988. Bull trout, *Salvelinus confluentus* (Suckley), in the McCloud River, status and recovery recommendations (draft). Inland Fishing Administration Report, California Department of Fish and Game, Sacramento.

Saffel, P. D. 1994. Habitat Use by Juvenile Bull Trout in Belt-Series Geology Watersheds of Northern Idaho. M. S. Thesis. University of Idaho, Moscow.

Scott W. B., and E. J. Crossman. 1973. Freshwater Fishes of Canada. Journal of the Fisheries Research Board of Canada, Bulletin 184.

Shepard, B., K. Pratt, and J. Graham. 1984. Life histories of westslope cutthroat and bull trout in the upper Flathead River Basin, Montana. Montana Department of Fish, Wildlife, and Parks, Kalispell.

Sullivan, D. 1986. Hydraulics and fish habitat in relation to channel morphology. Ph. D. dissertation. Johns Hopkins University, Baltimore,Maryland.

Wallis, O. L. 1948. Trout studies and a stream survey of Crater Lake National Park. M.S. Thesis. Oregon State University, Corvallis.

Zar, J. H. 1984. Biostatistical analysis. Prentice Hall Incorporated, Englewood Cliffs, New Jersey.

Ziller, J. S. 1992. Distribution and relative abundance of bull trout in the Sprague River Subbasin, Oregon. Pages 18-29 *in* Howell, P. J. and D. V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis.