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Habitat Features and Trout Abundance Relative to Gradient in Some Wyoming Streams

Abstract

Channel gradient has been shown to have a negative relation to trout standing stocks indicating that separation of stream channels into gradient classes may provide a better understanding of the relationships between habitat and trout abundance. Our major objective was to determine if there are significant differences in habitat features and standing stocks of trout > 100 mm between two classes of channel gradient, low (0.1-1.4% channel slope) and moderate (1.5-4.0%). We also determined statistical relations between habitat features and trout standing stocks in each class of channel for unaltered streams on the Medicine Bow National Forest, Wyoming. Low-gradient reaches were found to have deeper nearshore water depths, more undercut banks, and more trench pools than moderate-gradient reaches, while moderate-gradient reaches had more cobble substrate, dammed pools formed by woody debris, and plunge pools. The mean standing stock was 267 kg/ha in low-gradient reaches and 102 kg/ha in moderate-gradient reaches. Habitat features correlated with trout standing stocks differed between the two gradient classes. Our results demonstrate that separation of stream segments into reaches of similar gradient are important in identifying features of trout habitat that are otherwise obscured by variation over a wider gradient range.

Introduction

Various investigators have found the gradient of stream channels to be negatively correlated with the abundance of brown trout *Salmo trutta* and brook trout *Salvelinus fontinalis* (Kennedy and Strange 1982, Hermansen and Krog 1984, Chisholm and Hubert 1986, Fausch in press). The results suggested that habitat features and structural elements were different among channels of differing gradients. In other studies Reeves and Everest (1986) used a channel-typing system (Rosgen 1985) in western Oregon coastal streams and found differences in microhabitat and salmonid abundance between channels of different gradients. We felt that the separation of stream channels by gradient could provide a better means to understand the factors influencing trout abundance and to predict brook trout and brown trout standing stocks in Rocky Mountain streams. Our main objective was to determine if there are significant differences in habitat features and standing stock of trout > 100 mm total length between two classes of channel gradient, low (0.1-1.4% channel slope) and moderate (1.5-4.0%). We also determined statistical relations between habitat features and trout standing stocks in each class of channel.

Study Area

All study streams were in Medicine Bow National Forest (MBNF), south of Wyoming Highway 130 on the Snowy Range and east of the Continental Divide on the Sierra Madre. No native salmonids were in the study area, but brook trout and brown trout have been introduced. Populations are maintained by natural reproduction. Only brook trout inhabit the streams at elevations of > 2,450 m. At lower elevations reaches are inhabited by both brook trout and brown trout, while others have only brown trout.

Potential study streams extended from 2350 to 3000 m above mean sea level within the North Platte River drainage in MBNF. About 8 percent of all stream channels in the study area have a low gradient (0.1-1.4% channel slope) and 90 percent have a moderate gradient (1.5-4.0%). We selected 15 watersheds that had been minimally affected by human activity with no history of clearcut logging, overgrazing, or mining. Potential study reaches were selected from U.S. Forest Service records and U.S. Geologic Survey topographic maps. Low-gradient and moderate-gradient reaches at least 200 m in length were marked on the maps. Specific sampling sites were

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selected to represent the range of drainage basin areas (0.7-100 km^2) and elevations occurring in the study area. Selected study reaches and the upstream watershed area were ground truthed to confirm the lack of human effects. Channel gradients were assessed with a surveyor's level prior to field sampling.

A total of 16 low-gradient reaches and 32 moderate-gradient reaches were selected for study. The 16 low-gradient reaches were classified as C3 channels using Rosgen's (1985) channel classification system, while the moderate-gradient reaches were classified as B2 and B3 with 16 reaches in each class. Low-gradient reaches ranged from 2420 to 2975 m above mean sea level and tended to be in either headwater or foothill regions. The wetted widths during late summer ranged from 0.4 to 6.8 m (drainage basin area range = 0.7-95.0 km^2). Moderate-gradient reaches ranged from 2377 to 2963 m in elevation and had wetted widths of 1.1 to 9.3 m (drainage basin area range = 2.2-96.2 km^2).

The underlying geology and the riparian zone contributed to differences between the two gradient classes. The low-gradient channels were almost exclusively in meadow areas with alluvial soils where large trees were lacking, but dense growths of willows, sedges, and grasses allowed overhanging banks to form as meander processes occurred. Subsequently, low-gradient channels tended to have undercut banks and trench pools with accumulation of fine sediment substrate that could support aquatic vegetation, but woody debris was generally lacking. In contrast, moderate-gradient channels were almost exclusively in coniferous forest, where large trees were present at or near the water's edge, with geologic formations preventing meander processes from having a pronounced effect. So moderate-gradient channels tended to have more dammed pools and plunge pools formed by geologic formations and woody debris, coarser substrates with less fine sediment, more riffle habitat, limited amounts of undercut bank and trench pools, and less aquatic vegetation than low-gradient channels.

Methods

We used the transect method to measure stream habitat features over 200-m reaches (Platts *et al.* 1983). Riffles marked the upper and lower ends of study reaches. In 1985 we spaced transects 2 m apart and made point measurements at 0.3-m intervals; in 1986 the intervals were 4 m apart and the point measurements were made at seven equally spaced locations not including the banks.

Water-depths were measured at each point; shore-depth measurements were excluded from calculations of mean depth. At each point interval across a transect, we visually classified cover, dominant substrate, embeddedness, and microhabitat. Cover was classified into three categories: aquatic vegetation, woody debris, or boulder. Substrate was classified into six categories (after Platts *et al.* 1983; diameter in parentheses): small fine sediment (diameter $\leq$ 0.8 mm), large fine sediment (0.9-4.7 mm), gravel (4.8-76.0 mm), cobble (77-304 mm), small boulder (305-609 mm), and large boulder ($\geq$ 610 mm). Embeddedness (amount of fine sediment surrounding the underlying substrate particles) was rated from zero to 100% (Platts *et al.* 1983). We classified habitat types according to Bisson *et al.* (1982). Shore depth, undercut bank, and overhanging vegetation were measured at each bank with a measuring staff. Bank angle was determined with a clinometer (Platts *et al.* 1983).

We measured the length of each pool and riffle and noted the physical structure associated with the formation of the pool—such as geologic formations (bedrock, boulders) or woody debris (log check dams, natural log deflectors, and debris jams). We also computed the percentages of pool habitat created by geologic controls and woody debris; most woody debris probably overlaid geologic formations, but where it was the evident feature governing pool formation, the location was identified.

We used the removal method of DeLury (1951) to estimate trout standing stock over the study reaches during late summer and early autumn while the streams were at base flow. Each reach was blocked at the upper and lower end with small-mesh seines to prevent upstream or downstream movement of trout. Three depletion passes were made with a Coffelt Model BP-2 backpack electroshocker. Fish from each pass were individually weighed to the nearest gram and measured (total length) to the nearest millimeter. Only fish longer than 100 mm were used in population estimates. We used program CAPTURE of White *et al.* (1982) to estimate trout populations, choosing model M(bh) because it allowed for variability in behavioral responses of fish to the first capture attempt.

We used Scheffe's test for comparison of means between low-gradient and moderate-gradient reaches (Zar 1984). An arcsine transformation was performed on all proportional data, but means of measured values were reported. Pearson product-moment correlation analyses were performed to determine univariate relations between stream habitat features and standing stocks of trout. Stepwise discriminant function analyses were performed to identify the major differences in habitat features between low-gradient and moderate-gradient channels (Nie *et al.* 1975). The univariate comparisons of means provided insight into habitat differences, but the results were confounded by the lack of independence among the variables. Discriminant function analysis was used to eliminate the confounding effect of intercorrelation among habitat variables. Stepwise multiple-regression analyses were used to develop models that accounted for variation in trout standing stock using variables identified as important in the discriminant function analyses (Nie *et al.* 1975). All statistical differences were accepted as significant at $P \leq 0.05$.

Results

Habitat Differences

Twenty-nine habitat variables were analyzed to determine if they differed in abundance between low-gradient and moderate-gradient channels (Table 1). The habitat variables were separated into four groups—channel morphology, cover, substrate and habitat type—based on the channel features they described.

Four of the six channel-morphology variables were significantly different between the low-gradient and moderate-gradient channels that we studied (Table 1). The low-gradient channels were deeper and narrower, a larger proportion of the bank adjoined deep water, and the banks tended to have more overhang than the moderate-gradient channels. The best discriminant function to describe differences in habitat features between low-gradient and moderate-gradient channels used two variables, mean shore depth and the percentage of bank with a bank angle < 45°. This discriminant function properly classified 39 of 48 study reaches.

Of the eight cover features measured, three were significantly different between the two channel types (Table 1). Both undercut banks and aquatic vegetation were more abundant in low-gradient reaches than in moderate-gradient reaches. Woody debris formed an average of only 4 percent of the pool habitat (includes all pool types) in low-gradient reaches, but 24 percent in moderate-gradient reaches. Discriminant function analysis identified three cover variables as the best to distinguish between the two channel types—percentage of undercut bank, pool habitat 30 cm deep, and woody debris forming pool habitat. This discriminant function correctly classified 43 of 48 study reaches.

As would be expected, substrate features differed between the two gradient classes (Table 1). The abundance of large and small sediment was greater in low-gradient channels, as well as embeddedness, while cobble was more abundant in moderate-gradient channels. Only one substrate variable, cobble, was identified in the discriminant analysis and this variable correctly classified 41 of 48 study reaches.

The abundance of four habitat types differed significantly between the two classes of channel gradients (Table 1). Low-gradient reaches tended to have more trench pools, but fewer riffles, plunge pools, and dammed pools than in moderate-gradient reaches. The best discriminant function to describe habitat differences between the two gradient classes included trench pools, secondary channel pools, and plunge pools. This discriminant function properly classified 45 of 48 study reaches.

Trout Standing Stocks

The mean standing stock of trout differed significantly between low-gradient and moderate-gradient reaches. The mean in low-gradient reaches was 267 kg/ha (SD = 175, range = 50-611) and in moderate-gradient reaches was 102 kg/ha (SD = 49, range = 36-204).

Brook trout and brown trout standing stocks in low-gradient and in moderate-gradient reaches were evaluated separately where allopatric and sympatric populations occurred (Table 2). Among allopatric populations, mean brook trout standing stocks were more than twice as great in low-gradient than in moderate-gradient; however, mean brown trout standing stocks were similar, but the sample sizes were small with only 3 and 4 reaches in each category. Among sympatric populations of brook trout and brown trout,

TABLE 1. Means for channel morphology, stream cover, substrate, and habitat variables measured in low-gradient (0.1-1.4%) and moderate-gradient (1.5-4.0%) stream reaches on the Medicine Bow National Forest, Wyoming. Asterisk indicates a significant difference using Scheffe's test ($P \le 0.05$).

	Channel gradient (%)			
	0.1-1.4		1.5-4.0	
Variable	Mean	Range	Mean	Range
Channel morphology				
Water depth (cm)*	19.7	10.9-33.8	14.6	8.3-23.8
Bank angle < 90° (%)*	53.5	24.4-90.2	29.0	9.2-63.8
Bank angle < 45° (%)*	20.2	8.0-31.4	12.7	2.6-25.4
Width-to-depth ratio	7.0	2.0-23.5	10.6	2.5-22.1
Shore depth (cm)	12.8	8.4-19.6	7.8	5.2-12.7
Shore depth ≥ 15.2 cm (%)	36.8	18.2-66.3	16.8	5.5-63.3
Cover				
Undercut bank (%)*	53.0	24.4-90.2	26.0	7.9-63.8
Overhanging vegetation (%)	44.1	9.9-77.9	29.7	4.0-75.9
Boulder cover (%)	0.2	0.0- 1.0	0.9	0.0- 6.6
Woody cover (%)	3.2	0.0-13.9	4.5	0.0-11.6
Aquatic vegetation cover (%)*	11.5	0.0-62.7	3.8	0.0-34.7
Pool ≥ 30.5 cm deep (%)	34.4	0.0-87.3	20.6	0.0-51.8
Pools with cover (%)	13.9	0.0-55.4	12.8	0.0-28.6
Woody debris control (%)*	4.0	0.0-40.0	24.5	0.0-54.4
Substrate				
Large boulder (%)	0.9	0.0-11.5	4.0	0.0-27.5
Small boulder (%)	4.9	0.0-28.6	11.6	0.6-27.1
Cobble (%)*	21.4	2.6-44.9	40.3	24.1-67.6
Gravel (%)	47.0	7.6-77.4	36.0	10.8-67.9
Large fine sediment (%)*	12.8	0.3-36.7	2.4	0.0- 8.8
Small fine sediment (%)*	13.0	0.0-53.1	1.0	0.0- 6.2
Embeddedness (%)*	58.7	26.9-97.5	21.4	14.7-61.4
Habitat type				
Riffle (%)*	25.4	7.7-54.8	39.9	13.9-61.6
Rapid (%)	0.2	0.0- 2.1	1.9	0.0-10.7
Secondary channel pool (%)	0.3	0.0- 1.5	0.9	0.0- 4.9
Backwater pool (%)	8.2	0.0-20.9	14.4	2.8-27.2
Trench pool (%)*	30.3	7.7-67.0	5.2	0.0-20.8
Plunge pool (%)*	0.5	0.0- 2.9	4.0	0.0-17.3
Dammed pool	1.5	0.0-11.3	5.2	0.0-22.1
Glide (%)	31.6	18.2-45.1	27.4	11.1-58.6

brook trout standing stocks were about three times greater in low-gradient channels and standing stocks of both species together averaged almost four times greater in low-gradient reaches.

The habitat features that were correlated with trout abundance differed between low-gradient and moderate-gradient reaches (Table 3). Total standing stock increased with increasing amounts of deep nearshore area, undercut bank, overhanging vegetation, trench pools, and plunge pools, but decreased with increasing water depth, width-to-depth ratio, and riffle abundance among the

TABLE 2. Mean standing stocks (kg/ha) of allopatric and sympatric population of brook trout and brown trout in low-gradient and moderate-gradient stream reaches on the Medicine Bow National Forest, Wyoming.

		Allopatric		Sympatric		
Channel gradient		Brook trout	Brown trout	Brook trout	Brown trout	Both trout
Low	Mean	283	61	224	128	352
	SD	103	8	175	34	190
	n	7	3	6	6	6
Moderate	Mean	131	57	43	42	85
	SD	42	16	33	23	28
	N	14	4	14	14	14

low-gradient reaches. In the moderate-gradient reaches, standing stock was positively correlated with deep nearshore area, overhanging vegetation, aquatic vegetation, fine sediment, embeddedness, and glide habitat, but negatively correlated with width-to-depth ratio, deep pools, boulder and cobble substrate, and backwater pools. A few variables were correlated with trout abundance in both gradient classes; deep nearshore areas and overhanging vegetation were positively correlated, while width-to-depth ratio was negatively correlated.

Brook trout standing stocks were found to be correlated with only one habitat feature among low-gradient reaches (Table 3); as width-to-depth ratio increased brook trout abundance declined.

TABLE 3. Statistically significant ($P \leq 0.05$) correlation coefficients for relations between trout standing stock and measured habitat features in low-gradient and moderate-gradient reaches on the Medicine Bow National Forest, Wyoming.

	Channel gradient (%)					
	1.0-1.4			1.5-4.0		
Variable	Total trout (n = 16)	Brook trout (n = 13)	Brown trout (n = 9)	Total trout (n = 32)	Brook trout (n = 28)	Brown trout (n = 18)
Channel morphology						
Water depth (cm)	—0.57		—0.89			0.47
Width-to-depth ratio	—0.61	—0.75		—0.37	—0.52	
Bank angle < 90° (%)	0.60					—0.40
Shore Depth ≥ 15.2 cm (%)	0.44			0.38	0.37	
Cover						
Undercut bank (%)	0.60					
Overhanging vegetation (%)	0.48			0.40	0.54	
Aquatic vegetation cover (%)			0.75	0.44	0.45	
Pool habitat ≥ 30.5 cm deep (%)			—0.89	—0.40	—0.41	
Pools with cover (%)			0.65			—0.47
Substrate						
Small boulder (%)			0.60	—0.34		
Cobble (%)				—0.30		
Large fine sediment (%)				0.50	0.39	
Small fine sediment (%)				0.48	0.44	
Embeddedness (%)				0.51	0.39	
Riffle (%)	—0.44					
Backwater pool (%)			0.72	—0.31		
Trench pool (%)	0.48		0.61			
Plunge pool (%)	0.45		0.62			
Glide (%)				0.46	0.47	—0.45

Several habitat features were correlated with brook trout abundance in moderate-gradient reaches. In moderate-gradient reaches brook trout abundance increased with greater proportions of shore depth $\geq$ 15.2 cm deep, overhanging vegetation, aquatic vegetation, aquatic vegetation cover, large and fine sediment, embeddedness, and glide habitat. Brook trout abundance went down as width-to-depth ratio increased and the abundance of pool habitat $\geq$ 30.5 cm deep increased.

The habitat features correlated brown trout standing stocks differed from those related to brook trout abundance. Among low gradient reaches, brown trout standing stocks increased with greater proportions of aquatic vegetation cover, pools with cover, boulder cover, backwater pools, trench pools, and plunge pools. Within low-gradient reaches, brown trout abundance was negatively correlated with water depth and the amount of pool habitat $\geq$ 30.5 cm deep. A different set of variables was correlated with brook trout abundance in moderate-gradient reaches; the only habitat feature positively correlated with abundance was water depth. Among moderate-gradient channels, brown trout standing stock declined as the abundance of bank with an angle < 90°, pools with cover and glide habitat increased.

The discriminant function analyses of habitat differences between low-gradient and moderate-gradient reaches identified nine variables that can be used to separate the two channel types: mean shore depth, the percentages of bank with a bank angle < 45°, undercut bank, pools formed by woody debris, cobble substrate, trench pools, secondary channel pools and plunge pools. These nine variables were used in a stepwise multiple-regression analysis of all 48 stream reaches to determine which ones may be of most value in accounting for variation in trout standing stocks. Two regression models that accounted for substantial variation in standing stock of trout (S) were identified. The first equation ($R^2 = 0.64$) included undercut bank (U), trench pools (T) and pools $\geq$ 30 cm deep (P):

$$S = 38.3 + 2.75\ U + 3.81\ T - 1.40\ P$$

The second equation ($R^2 = 0.67$) included trench pools and pools $\geq$ 30 cm deep, as well as secondary channel pools (S) and mean shore depth (D):

$$S = -11.6 + 2.96\ T - 2.47\ P - 24.67\ S + 21.20\ D.$$

These two equations illustrate that habitat variables included in habitat assessment models are to a great degree separating stream reaches into low-gradient and moderate-gradient classes and accounting for variation due to differences between the two classes. When the nine variables was used in stepwise multiple-regression analyses involving only reaches in individual gradient classes, there were fewer variables that accounted for variation in trout standing stocks and the amount of variation that was accounted for was much less. The equation which best accounted for variation in trout standing stocks among low-gradient channels ($R^2 = 0.36$) had only one variable, undercut bank; the best in moderated-gradient channels ($R^2 = 0.15$) had two variables, pools <30 cm deep and mean shore depth. Less variation in both standing stock estimates and measured values of the habitat variables within a gradient class contributed to the reduced ability of the habitat variables to account for variation in standing stock.

Discussion

Channel morphology, cover, substrate, and habitat types differed between low-gradient (0.1-1.4%) and moderate-gradient (1.5-4.0%) channels sampled in MBNF. We also found differences in standing stocks of trout in channels with low and moderate gradients. We believe the greater standing stocks of trout in low-gradient reaches was due to a greater abundance of pool habitat and cover in these reaches. Total pool habitat of all types was more abundant in low-gradient reaches (mean = 41% of transect points) than in moderate-gradient reaches (mean = 30%). Also within low-gradient reaches, cover within pool habitat—undercut bank and aquatic vegetation—tended to be more abundant than in moderate-gradient channels.

Measures of the nine habitat variables that we found to discriminate between low-gradient and moderate-gradient channels are frequently found in trout-habitat models developed in the central Rocky Mountains. For example, they are incorporated in the cover and substrate attributes of the habitat quality index of Binns and Eiserman (1979), the overhead bank cover and instream rubble-boulder-aquatic vegetation variables of the trout cover rating of Wesche (1980), the overhead bank cover and deep water components of the modified habitat suitability index model for brown trout by Wesche *et al.* (1987), as well as the substrate and undercut bank variables in the production and biomass models of Scarnecchia and Bergersen (1987). We believe that these variables in the various habitat models are to a great degree accounting for natural changes in habitat resulting from differences in channel gradient.

Our data show that habitat features correlated with trout abundance differ between low-gradient and moderate-gradient channels, as well as between brook trout and brown trout. We believe that the separation of stream segments into reaches with similar gradient may enable the identification of features related to salmonid abundance that are otherwise obscured by variation over a wider range of gradient. Habitat models that predict salmonid abundance should define the range of channel gradient to which they are applicable, and perhaps be developed for specific gradient classes or channel types, as well as defining the species of trout for which they are applicable.

Accessibility of streams to the public in southeastern Wyoming has been related to trout standing stocks (Wesche *et al.* 1987), with standing stocks declining as accessibility increases. We expect that the trout standing stocks among our study sites were greater than in many other streams in MBNF because the sites tended to be remote without nearby road access, thus fished less. Comparison to data from Binns and Eiserman (1979), Chisholm (1985) and Lanka (1985) confirm this belief.

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Literature Cited

Binns, N. A., and F. M. Eiserman. 1979. Quantification of fluvial trout habitat in Wyoming. Trans. Amer. Fish. Soc. 108:215-228.

Bisson, P. A., J. L. Nielsen, R. A. Palmason, and L. E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. *In* N. B. Armantrout, (ed.). Acquisition and utilization of aquatic habitat inventory information. American Fisheries Society, Western Division, Bethesda, Maryland. Pp. 62-73.

Boussu, M. F. 1954. Relationship between trout populations and cover on a small stream. J. Wildl. Manage. 18:229-239.

Chisholm, I. M. 1985. Winter stream conditions and brook trout habitat use on the Snowy Range, Wyoming. Univ. of Wyoming, Laramie. M.S. Thesis.

Chisholm, I. M., and W. A. Hubert. 1986. Influence of stream gradient on standing stock of brook trout in the Snowy Range, Wyoming. Northw. Sci. 60:137-139.

DeLury, D. B. 1951. On the planning of experiments for estimation of fish populations. J. Fish. Res. Board Can. 8:281-307.

DeVore, P. W., and R. J. White. 1978. Daytime responses of brown trout (*Salmo trutta*) to cover stimuli in stream channels. Trans. Amer. Fish. Soc. 107:763-771.

Dixon, W. J. 1981. BMDP statistical software. University of California Press, Berkeley.

Fausch, K. D. In press. Do gradient and temperature affect distributions of, and interactions between, brook char (*Salvelinus fontinalis*) and other resident salmonids in streams? *In* Proceedings of the International Symposium on Charr and Masu Salmon, October 1988, Supporo, Japan.

Hermansen, H., and C. Krog. 1984. Influence of physical factors on density of stocked brown trout (*Salmo trutta fario* L.) in a Danish lowland stream. Fish. Manage. 15:107-110.

Kennedy, G. J. A., and C. D. Strange. 1982. The distribution of salmonids in upland streams in relation to depth and gradient. J. Fish Biol. 20:579-591.

Lanka, R. P. 1985. Modeling trout standing stock in small Wyoming streams based upon easily measured habitat and geomorphological characteristics. Univ. of Wyoming, Laramie. M.S. Thesis.

Lanka, R. P., W. A. Hubert, and T. A. Wesche. 1987. Relations of geomorphology to stream habitat and trout standing stock in small Rocky Mountain streams. Trans. Amer. Fish. Soc. 116:21-28.

Lewis, S. L. 1969. Physical factors influencing fish populations in pools of a trout stream. Trans. Amer. Fish. Soc. 98:14-19.

Nie, N. H., C. H. Hull, J. G. Jenkens, K. Steinbrenner, and D. H. Best. 1975. SPSS (Statistical package for the social sciences), 2nd edition. McGraw Hill, New York.

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, Ogden, Utah.

Reeves, G. H., and F. H. Everest. 1986. Stream type as a predictor of habitat conditions and anadromous salmonid populations in western Oregon streams. U.S. Forest Service, Pacific Northwest Research station, Corvallis, Oregon.

Rosgen, D. L. 1985. A stream classification system. *In* R. R. Johnson, C. D. Ziebell, D. R. Palton, P. F. Folliott, and R. H. Hamre, (eds.). Riparian ecosystems and their management: reconciling conflicting uses. First North American Riparian Conference, Tucson, Arizona. U.S. Forest Service General Technical Report RM-120, Fort Collins, Colorado. Pp. 91-95.

Scarnecchia, D. L., and E. P. Bergersen. 1987. Trout production and standing crop in Colorado's small streams, as related to environmental features. No. Amer. J. Fish. Manage. 7:315-330.

Wesche, T. A. 1980. The WRRI trout cover rating method: Development and application. University of Wyoming, Water Research Institute, Water Resources Series 78, Laramie.

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Wesche, T. A., C. M. Goertler, and W. A. Hubert. 1987. Modified habitat suitability index model for brown trout in southeastern Wyoming. No. Amer. J. Fish. Manage. 7:232-237.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory LA-8787-NERP, Los Alamos, New Mexico.

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