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ABSTRACT

We described redds of 20-40 cm brown trout Salmo trutta in a mountain stream in the Central Rocky Mountains. Average redd length was 147 cm, water depth 16 cm, and water velocity 34 cm/s, but variation was substantial. Brown trout selected water depths of 12-18 cm and velocities of 24-37 cm/s and avoided depths less than 6 cm and velocities less than 12 cm/s. Water depths and velocities measured over redds in 1987 and 1988 were similar to those measured in 1975 despite a 50-100% increase in the minimum flow during the 1987 and 1988 spawning periods.

INTRODUCTION

Spawning behavior of brown trout (Salmo trutta) has been described by Jones and Ball (1954) and others, but few investigators have provided quantitative descriptions of brown trout redds in streams. The surface characteristics of brown trout redds were described by Ottaway et al. (1981) and Crisp and Carling (1989) in Great Britain, by Shirvell and Dungey (1983) in New Zealand, by Smith (1973) in Oregon, and by Witzel and MacCrimmon (1983) in Ontario.

Reiser and Wesche (1977) reported the surface characteristics of 121 brown trout redds in our study stream, Douglas Creek, during the 1975 spawning season. Since then, an increase in the required minimum flow downstream from Rob Roy Reservoir (from 0.028 to 0.141 m^3/s) has resulted in substantial increases in average fall flows in the study area. Depending on the location, discharge during spawning was 1.5 to 2.0 times greater in 1987 and 1988 than in 1975 thereby increasing the availability of deep water and creating faster velocities (Wolff et al. 1989).

The purpose of our study was to quantitatively describe the surface features of brown trout redds constructed by a resident population in Douglas Creek (a moderate-sized stream in the central Rocky Mountains) and to compare our measurements with those made by Reiser and Wesche (1977) before the increase in minimum flow. The specific objectives were to describe spawning habitat used (water depth, water velocity, and substrate type) by brown trout and to assess selection for spawning habitat features.

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METHODS

Brown trout redds were studied over a 20-km reach of Douglas Creek at elevations of 2700 to 3100 m above mean sea level in the Medicine Bow Mountains, Medicine Bow National Forest, southeastern Wyoming during 1987 and 1988. Five study sites were selected on Douglas Creek, including the downstream portions of two tributary streams, Lake Creek and Muddy Creek.

Four of the sites were downstream from Rob Roy Dam, which released a constant 0.14 m^3/s hypolimnetic discharge, except in May when a flushing flow of about 3.7 m^3/s was released for three consecutive days. During the rest of the year, the dam and reservoir moderated the hydrograph at sites downstream from the dam. During fall sampling, the average discharge was 0.16 m^3/s at the upstream end of the study area and 0.31 m^3/s at the downstream end.

Brown trout redds were studied during October and November in 1987 and 1988. Redds were identified by clean substrate and the presence of a tailspill and pit. Spawning was considered complete when adult fish were no longer seen over redds and no further excavation was detected on previously formed redds (Reiser and Wesche, 1977). Size and identity of fish over redds were determined by visual inspection. However, to differentiate between redds of brown trout and brook trout (Salvelinus fontinalis), we collected eggs whenever possible and hatched them in the laboratory for species identification (Martinez 1984). The dominant surface substrate in the pit and tailspill was visually classified into one of five possible categories: sand (1-5 mm in diameter), fine gravel (6-25 mm), coarse gravel (26-75 mm), rubble (76-300 mm), and boulder (> 300 mm).

We described redd morphology as follows: the pit front was the upstream end of the pit where substrate disturbance ended; pit bottom was the deepest part of the pit; tailspill crest was the point of shallowest water over the tailspill; and the tailspill end was the downstream point where clean tailspill gravel ended. At each of the four locations studied, we measured water depth to the nearest 1.5 cm and mean water velocity (at 0.6 depth) and bottom water velocity (with the transducer resting on bottom) to the nearest 3 cm/s with a Marsh-McBirney model 201 current meter.

To assess available habitat, we sampled nine reaches for water depth, water velocity, and substrate during August and September 1988. Transects were perpendicular to the thalweg and habitat was measured at evenly spaced points along each transect. We measured water depth, water velocity, and substrate at each point using the same procedures used to describe redds. Availability of habitat was calculated by using the physical habitat simulation system described by Milhouse et al. (1984).

Brown trout were sampled by electrofishing in August and September 1988 in the nine reaches. All fish 15 cm long or longer were measured to construct a length frequency distribution. Using length-at-maturity data (Avery 1985), we estimated the proportion of fish in each size class that were expected to be sexually mature and constructed a length frequency distribution for mature brown trout.

To evaluate habitat selection, we used the linear index of electivity (L) proposed by Strauss (1979) using water depth and mean velocity measured at the pit front because they approximated pre-redd conditions. The t-statistic was used at the appropriate degrees of freedom to determine if electivity indices differed from zero.

RESULTS

Redd characteristics were described from fall measurements of completed redds (Table 1). The total length of redds averaged 147 cm, the pit composed 38% of the total redd length. Mean water depth over redds was 16 cm; mean water velocity at the pit front was 34 cm/s. Coarse gravel dominated in the substrate of the pit in 79% of redds; fine gravel dominated in the tailspill of 59% of redds.

Table 1. Summary of surface characteristics for brown trout redds in Douglas Creek. Sample size was 80 except for maximum width, for which it was 53. Standard deviations are given in parantheses.

Characteristics and Units	Mean	Range
Total length (cm)	147 (42)	70-259
Tailspill length (cm)	91 (34)	43-219
Maximum width (cm)	54 (17)	30-122
Mean depth (cm)[a]	16 (5)	7-29
Pit front	17 (5)	7-30
Pit bottom	20 (5)	10-34
Tailspill crest	11 (5)	3-25
Mean velocity (cm/s)		
Pit front	34 (15)	6-70
Pit bottom	30 (13)	5-67
Tailspill crest	45 (17)	12-82
Bottom velocity (cm/s)		
Pit front	22 (11)	5-61
Pit bottom	13 (9)	0-44
Tailspill crest	39 (14)	9-73

[a]Mean depth = (pit front + tailspill end)/2

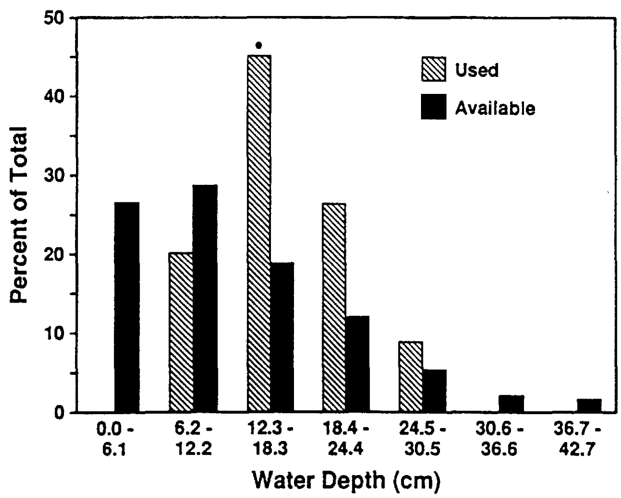

Figure 1. Distribution of water depths measured at the front of redds compared with water depths over the entire study reach of Douglas Creek. The asterisk indicates a significant ($P \leq 0.01$) Strauss' electivity index.

Water depth was used disproportionately to its availability (Figure 1). Strauss' index was significantly positive ($P \leq 0.01$) for depths of 12.3 to 18.3 cm but not significant for any other water depth increment. Although water depths < 6 and > 30.5 cm were available, no redds were observed at these depths. Water velocity was also used disproportionately to its availability; Strauss' index was significantly negative ($P \leq 0.05$) for the increment 0.0 to 12.2 cm/s and significantly positive for 24.5 to 36.6 cm/s (Figure 2). In contrast, substrate types were used in relative proportion to their availability (Figure 3). Strauss' index was not significant for any substrate type. Therefore, brown trout spawning site selection was greatest for water depths of 12 to 18 cm and mean water velocities of 24 to 37 cm/s, and avoidance was greatest for water depths < 6 cm and mean water velocities of 0 to 12 cm/s.

Of the 563 brown trout ≥ 15 cm captured during population surveys, we estimated that 31% were sexually mature (Table 2). The distribution shows that most mature trout were 20-40 cm long, an estimate supported by observations of spawning fish on about half of the 80 redds examined.

DISCUSSION

Inasmuch as the physical characteristics of a redd may be related to the size of the fish building it (Ottaway et al. 1981, Crisp and Carling 1989), inferences regarding the redd characteristics observed in this study should be limited to the length range of the mature fish present. Redd lengths and widths were similar to those reported for similar-sized fish by Reiser and Wesche (1977) in the same study area, and by Ottaway et al. (1981) in Great Britain. Hobbs (1948) reported that larger redds (total lengths of 100 to 585 cm) were constructed by larger brown trout in New Zealand.

Pit and tailspill depths were similar to those reported by Avery (1980) for fish of similar size. In contrast, Smith (1973) reported deeper average pit front depth (43 cm) for brown trout redds in Oregon, but the size of the fish was not stated. Smith (1973) suggested a minimum depth criteria of 24 cm for spawning brown trout, while our study showed that 12-18 cm depths were preferred. No redds were found in water < 6 cm deep. Likewise, Crisp and Carling (1989) observed that salmonids did not spawn in water depths less than their body depth.

Water depth over redds in 1987 and 1988 were similar to those reported by Reiser and Wesche (1977) in Douglas Creek in 1975. The most frequent water depths used in both periods were 12.3-18.3 cm, but in 1975 more sampled redds were at depths < 12.2 cm and > 30.5 cm. The range of depths used for spawning became narrower and shifted slightly toward deeper water after the flow increase.

Mean water velocity at the pit front (34 cm/s) was similar to that reported in other studies. Ottaway et al. (1981) also reported velocities of 22 to 38 cm/s, whereas Smith (1973) reported slightly faster velocities (mean, 44 cm/s). At the tailspill crest, Shirvell and Dungey (1983) reported a mean velocity of 39 cm/s (range 15 - 75 cm/s) -- virtually identical to our measurements. Brown trout also avoided water velocities of < 12 cm/s -- a phenomenon also reported by Crisp and Carling (1989), who suggested that salmonids had a minimum velocity requirement of 15-20 cm/s for spawning regardless of their size. Reiser and Wesche (1977) reported that the mean water velocity over brown trout redds sampled in 1975 in Douglas Creek was 31 cm/s. When our data were compared with those from 1975, the frequency distributions were nearly identical.

Inasmuch as Reiser and Wesche (1977) classified surface substrate adjacent to redds, their results probably represent conditions before redd construction. In contrast, our measurements were made inside the redd to describe the surface substrate of completed redds; consequently our samples contained less sand than the substrate samples collected

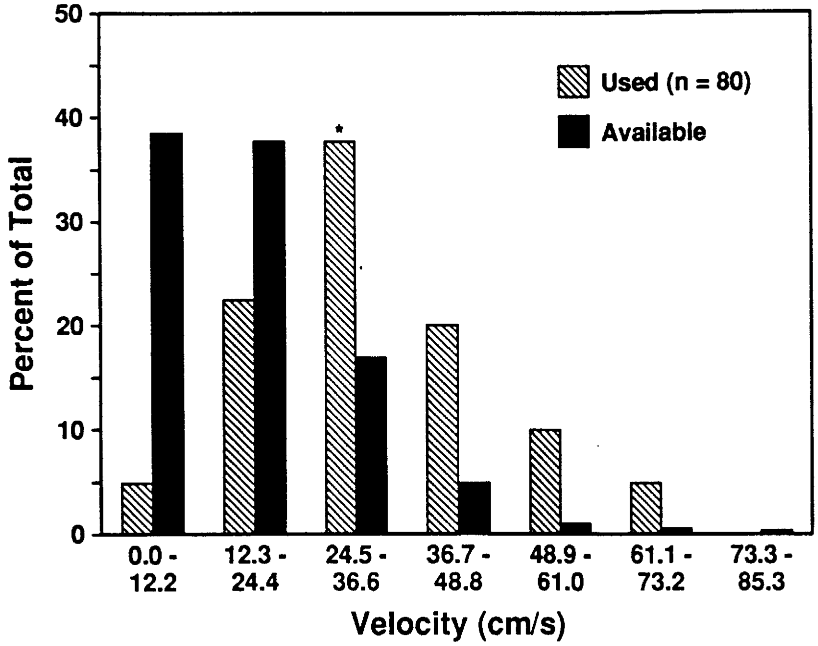

Figure 2. Distribution of mean water velocities measured at the front of redds compared with water velocities over the entire study reach of Douglas Creek. The asterisk indicates a significant ($P \leq 0.01$) Strauss' electivity index.

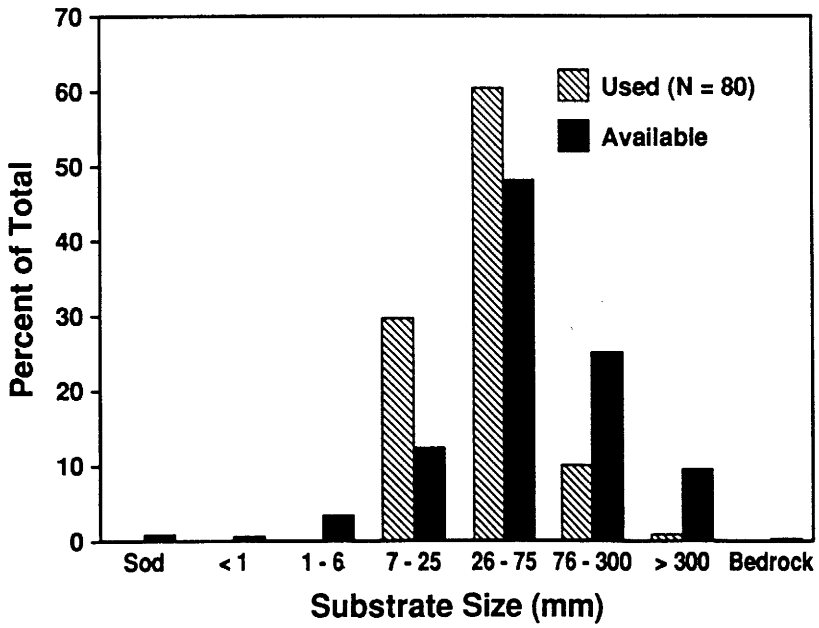

Figure 3. Distribution of dominant surface substrate sizes in redds compared with available substrates over the entire study reach of Douglas Creek.

Table 2. Estimation of the length frequency distribution of mature brown trout in Douglas Creek. Average percent mature in each length class was derived from Avery (1985.)

Length class (cm)	Average percent mature	Number of fish sampled	Estimated number of mature fish
15.0-17.5	0	190	0
17.6-20.0	6	111	7
20.1-22.5	31	98	30
22.6-25.0	68	51	35
25.1-27.5	86	45	39
27.6-30.0	88	24	21
30.1-32.5	91	7	6
32.6-35.0	100	15	15
35.1-37.5	100	12	12
37.6-40.0	100	5	5
40.1-42.5	100	1	1
42.6-45.0	100	2	2
45.1-47.5	100	0	0
47.6-50.0	100	1	1
50.0	100	1	1

from outside the redds by Reiser and Wesche (1977). When the pit and tailspill were considered separately, the pit was dominated by coarse gravel and the tailspill by finer gravel -- confirming observations by Hobbs (1948), Jones and Ball (1954), and Ottaway et al. (1981).

Substrate was used in proportion to its availability and no preference was indicated -- an observation also made by Shirvell and Dungey (1983). However, preference was apparent for water depths of 12-18 cm and mean water velocities of 24-37 cm/s. These are the same ranges that Reiser and Wesche (1977) found in 1975 when the fall flow in Douglas Creek was less than during our study.

A minimum flow enhancement beginning in 1986 increased average fall flows in the study area and thereby the availability of deeper water and faster velocities (Wolff et al. 1989). Our observation that habitat used for spawning was similar to that described by Reiser and Wesche (1977) suggests that spawning habitat preferences remain consistent over time and in different flow regimes -- an observation also reported by Shirvell and Dungey (1983). These observations suggest that spawning habitat was no more limited before flow enhancement than after it. The low incidence of redd superimposition (estimated to be 20-30%) further suggests that spawning habitat was not limited.

Since both depth and velocity seemed important in spawning site selection, one can only speculate about which variable is most important. Strauss' electivity index suggested that brown trout were selecting more strongly for depth, indeed not even using depths < 6 cm. A Kolmogarov-Smirnov test showed that distributions of depth from 1975 and 1987-1988 were significantly different ($P \leq 0.01$), but those for velocity were not different. The narrowing of the depth range used after the flow increased (while the velocity range remained unchanged) suggests the importance of water depth. However, Reiser and Wesche (1977) suggested that brown trout were selecting most strongly for water velocity. The combined importance of depth and velocity confirms the conclusion of Shirvell and Dungey (1983) that spawning microhabitat preferences of brown trout equally include water depth and velocity.

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