North American Journal of Fisheries Management 22:1314–1320, 2002

Spawning Characteristics of Redband Trout in a Headwater Stream in Montana

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Abstract.—I investigated the spawning characteristics of redband trout *Oncorhynchus mykiss gairdneri* (a rainbow trout subspecies) during the spring of 1998 in Basin Creek, a third-order headwater stream located in the Kootenai River drainage in northwestern Montana. I examined the timing of spawning as related to discharge and water temperature and analyzed microhabitat selection of 30 completed redds in a low-gradient (0.5–1.5%) reach. Redband trout spawned as flow declined after peak runoff and as mean daily water temperature exceeded 6.0°C and maximum daily temperature exceeded 7.0°C. Redband trout began spawning on 6 June (mean daily discharge = 2.1 m^3/s), 10 d after the peak discharge (8.7 m^3/s) occurred. The last redd was completed on 24 June, when discharge was 1.5 m^3/s. The mean total redd length was 53 cm (SD = 14; range = 31–91 cm), and the mean total area was 51 cm^2 (SD = 8; range = 46–76 cm^2). Eighty percent of the redds were located in pool tailouts, 13% in runs, and 7% in riffles. Spawning redband trout selected redd sites based on substrate size and water depth but not water velocity. Fish selected substrate sizes of 2–6 mm, water depths of 20–30 cm, and water velocities of 40–70 cm/s. My results suggest that redband trout in a low-gradient, third-order mountain stream found suitable spawning habitat in pool tailouts that contained abundant gravels.

The Columbia River redband trout *Oncorhynchus mykiss gairdneri*, a subspecies of rainbow trout *O. mykiss*, is native to the Fraser and Columbia River drainages east of the Cascade Mountain crest and to barrier falls on the Pend Oreille, Spokane, Snake, and Kootenai rivers (Behnke 1992). Like other western salmonids, populations of redband trout have declined because of a complex combination of land and water practices (logging, mining, agriculture, grazing, and dams), overharvest, and hybridization and competition with nonnative fishes (Williams et al. 1989; Behnke 1992). In the Kootenai River drainage in northwestern Montana, introductions of nonnative trout, primarily coastal rainbow trout and eastern brook trout *Salvelinus fontinalis*, have led to intensive competition, species replacement, and hybridization (Allendorf et al. 1980; Sage et al. 1992). Consequently, genetically pure populations persist only in a few locations above barrier falls in headwater streams. Knowledge of the habitat requirements of redband trout is critical for protection of existing populations and restoration of this subspecies to portions of its historic range in Montana and the upper Columbia River drainage. An understanding of the spawning characteristics and preferences of redband trout in headwater streams will aid in management of the subspecies, especially habitat restoration and reintroduction programs.

Recent studies have investigated seasonal habitat use by stream-dwelling redband trout in the upper Columbia River basin (Muhlfeld et al. 2001a, 2001b); however, no studies have focused on the spawning ecology of isolated headwater populations. Information on the spawning characteristics of coastal rainbow trout (Kondolf et al. 1989; Kondolf and Wolman 1993) and inland salmonid subspecies (Rinne 1980; Grost et al. 1991; Thurow and King 1994; Knapp and Vredenberg 1996; Schmetterling 2000) is highly variable, and largely depends on the species (or subspecies), life history, and spawning habitat availability. Documentation of spawning habitat characteristics and environmental factors that elicit spawning is critical to a better understanding of the ecology of redband trout in headwater systems. My objectives were to (1) determine whether the timing of spawning by stream-dwelling redband trout was related to discharge and water temperature and (2) determine whether microhabitat characteristics (depth, substrate particle size, and velocity) of completed redds differed from available habitat in a headwater stream of the upper Kootenai River drainage, Montana.

Methods

I conducted weekly spawning surveys throughout the East Fork Yaak River drainage to determine the timing and location of spawning by redband trout during the spring of 1998 (Figure 1). Low turbidity conditions allowed accurate identification of redds. Basin Creek, a third-order tributary

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Received December 17, 2001; accepted March 14, 2002

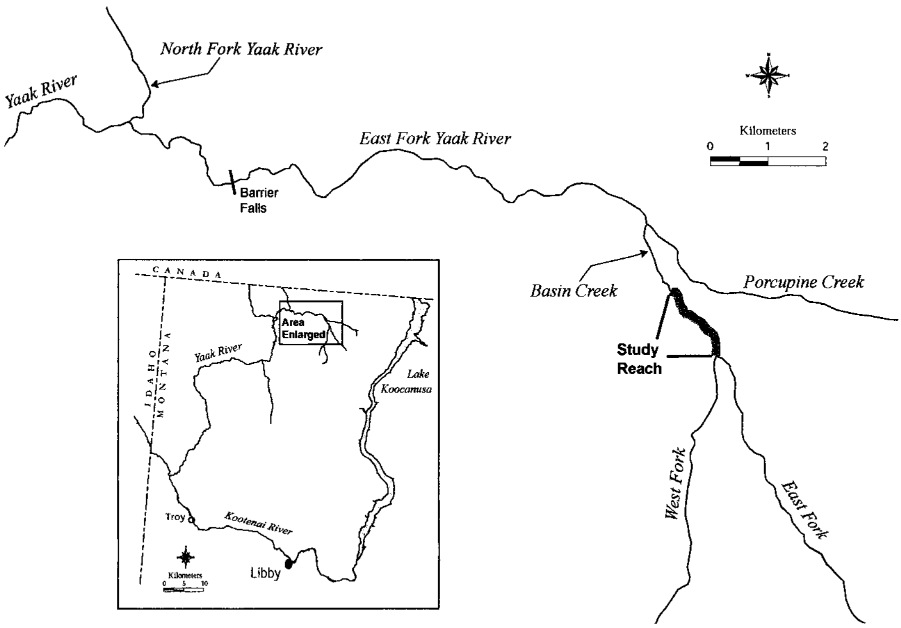

FIGURE 1.—Reach in Basin Creek, Montana, where redband trout spawning and redd characteristics were studied.

to the East Fork Yaak River, originates in the north slopes of the Purcell Mountains and flows north for approximately 30 km to the confluence with the East Fork, approximately 45 km east of Yaak, Montana (Figure 1). Elevation ranges from 976 m at the confluence of the East Fork of the Yaak River to 2,095 m at the Purcell Divide. The Basin Creek drainage has been intensively managed for timber production. The redband trout is the only fish species found in the drainage, and a potential barrier identified 3.6 km upstream from the confluence with the North Fork Yaak River may prevent genetic exchange with other, hybridized assemblages in the Yaak River system (Figure 1). Molecular genetic analyses of redband trout populations indicate substantial differentiation among fish from the upper Yaak River drainage (i.e., Basin Creek) and other populations in Montana, and relatively little divergence within drainages (Knudsen et al. 2002).

Spawning was only detected in a 1.15-km stream reach in Basin Creek, downstream of the confluence with Porcupine Creek (Figure 1). In this section of stream, mean densities of redband trout range from 0.23 to 0.48 fish/m^2 (Muhlfeld et al. 2001a), average reach gradient is 1.0% (range = 0.5–1.5%), average stream widths during base flows range from 4.8 to 5.8 m, and elevations range from1,185 to 1,203 m. Beginning in April, spawning was surveyed once per week until spawning fish were observed, and then the survey frequency increased to three times per week. An observer and I walked along the stream, mapping the locations of redds and fish. Redds were recorded when fish were observed spawning and a definite pit and tailspill were visible (Burner 1951). Fish total length (to the nearest 25 mm) was visually estimated for each fish observed spawning.

Redd characteristics were measured within 2–3 d after fish had abandoned their redds. During redd construction, I measured total water depth (cm) and mean water column velocity (cm/s; measured at 0.6 times the water column depth) immediately upstream of the redd pit. Depth and velocity measurements were taken with a Swoffer model 2100 electronic flowmeter attached to a wading rod. Redd length (cm) was measured from the upstream edge of the pit to the downstream edge of the tailspill, and redd width (cm) was measured from the edges of the pit at the widest location in the redd. The percentage composition of substrates found in the redd was visually estimated and classified as either sand–silt (<2 mm), small gravel (2–6 mm), large gravel (6–75 mm), cobble (75–300 mm), small boulder (300–600 mm), boulder (>600 mm), or bedrock (Overton et al. 1995). Dominant substrate was categorized as the most abundant particle size that each redd contained. Habitat units that spanned the entire channel were classified as a pool, riffle, or run, based on channel characteristics and stream flow (Bisson et al. 1982). Hourly temperatures were recorded with a continuously recording temperature data logger (Onset Hobo) deployed in the middle of the spawning reach from 1 May to 1 July. Daily discharge data were obtained from a U.S. Geological Survey flow station located at the downstream limit of the spawning reach.

Transects were oriented perpendicular to the stream at 50-m intervals beginning with a random start point, to quantify microhabitat resource availability throughout the spawning reach on 25 June (mean daily discharge was 1.5 m^3/s). Depth, mean water column velocity, and dominant substrate type were measured at 10 equally-spaced locations across each transect (n = 230).

Mann–Whitney U-tests were used to test the null hypothesis that redband trout used water depths and velocities in proportion to their availability (Norusis 1990). The chi-square goodness-of-fit test was used to test the null hypothesis that redband trout used dominant substrates in proportion to their availability (Zar 1996). Expected values for substrate classes were calculated as the total proportion of each category sampled in the reach, multiplied by the total count in each category. Observed habitat use was expressed as the total number of observations in that particular substrate category. Jacobs' electivity index (Jacobs 1974) was used to portray redband trout microhabitat selection for total depth, mean velocity, and substrate. Possible values of the index range from −1 to 1, with −1 indicating avoidance of the defined microhabitat category, 0 indicating habitat use in proportion to availability, and 1 indicating exclusive use of the microhabitat category.

Results

Timing of Spawning

Redband trout spawners were first observed on spawning grounds on 1 June 1998, began spawning on 6 June (10 d after the peak discharge of 8.7 m^3/s occurred) and completed the last redd on 24 June. Redband trout spawned after flow declined from peak runoff and after mean daily water temperature exceeded 6.0°C and maximum daily temperature exceeded 7.0°C (Figure 2). Redd construction occurred as mean daily discharge declined from 2.1 to 1.5 m^3/s. During the spawning period, mean daily water temperatures ranged from 6.0°C to 8.2°C, maximum daily temperatures ranged from 7.0°C to 9.3°C, minimum daily temperatures ranged from 5.2°C to 7.0°C, and hourly

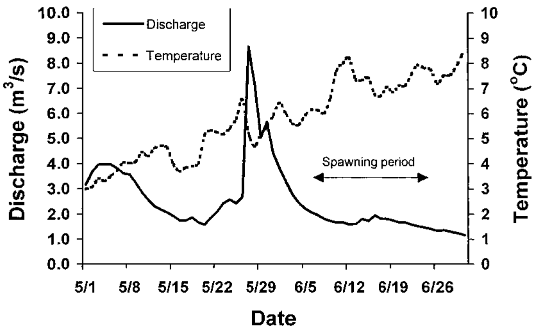

FIGURE 2.—Timing of spawning by redband trout as related to mean daily water temperature (°C) and mean daily discharge (m^3/s) in Basin Creek, Montana.

temperatures fluctuated an average of 1.9°C per day (range = 0.3–3.1°C). Estimated lengths of redband trout observed constructing redds ranged from 150 to 300 mm.

Spawning Habitat Use

I located and measured 30 redds in the spawning reach during the study period. I sampled 230 random resource availability locations in the study reach for each microhabitat variable (depth, velocity, and substrate). Twenty-four (80%) of the redband trout redds were located in pool tailouts. Of the six remaining redds, four (13%) were found along channel margins in runs and two (7%) were located in riffles. The mean total redd length was 53 cm (SD = 14; range = 31–91 cm), and the mean total area was 51 cm^2 (SD = 8; range = 46–76 cm^2).

Redband trout spawned in areas that were significantly shallower than the mean depth available in the spawning reach (Mann–Whitney U = 2,333; df = 1; P = 0.006). Mean water depth of redd sites was 28 cm (SD = 7; range = 20–46 cm), whereas the mean available water depth was 38 cm (SD = 20; range = 5–107 cm). Fish selected depths between 20 and 30 cm, and avoided depths less than 20 cm or greater than 50 cm (Figure 3).

Water velocity measured upstream of redd pits ranged from 23 to 69 cm/s (mean = 51 cm/s; SD = 19) and did not differ significantly (Mann–Whitney U = 3,252; df = 1; P = 0.830) from the mean available velocity (mean = 52 cm/s; SD = 34; range = 0–165 cm/s). Redband trout selected velocities of 40–70 cm/s (Figure 3).

Substrates within redds comprised mostly small gravel (2–6 mm; 76% when averaged across all redds), large gravel (6–75 mm; 15%), and fines (<2 mm; 9%). The predominant substrate particle

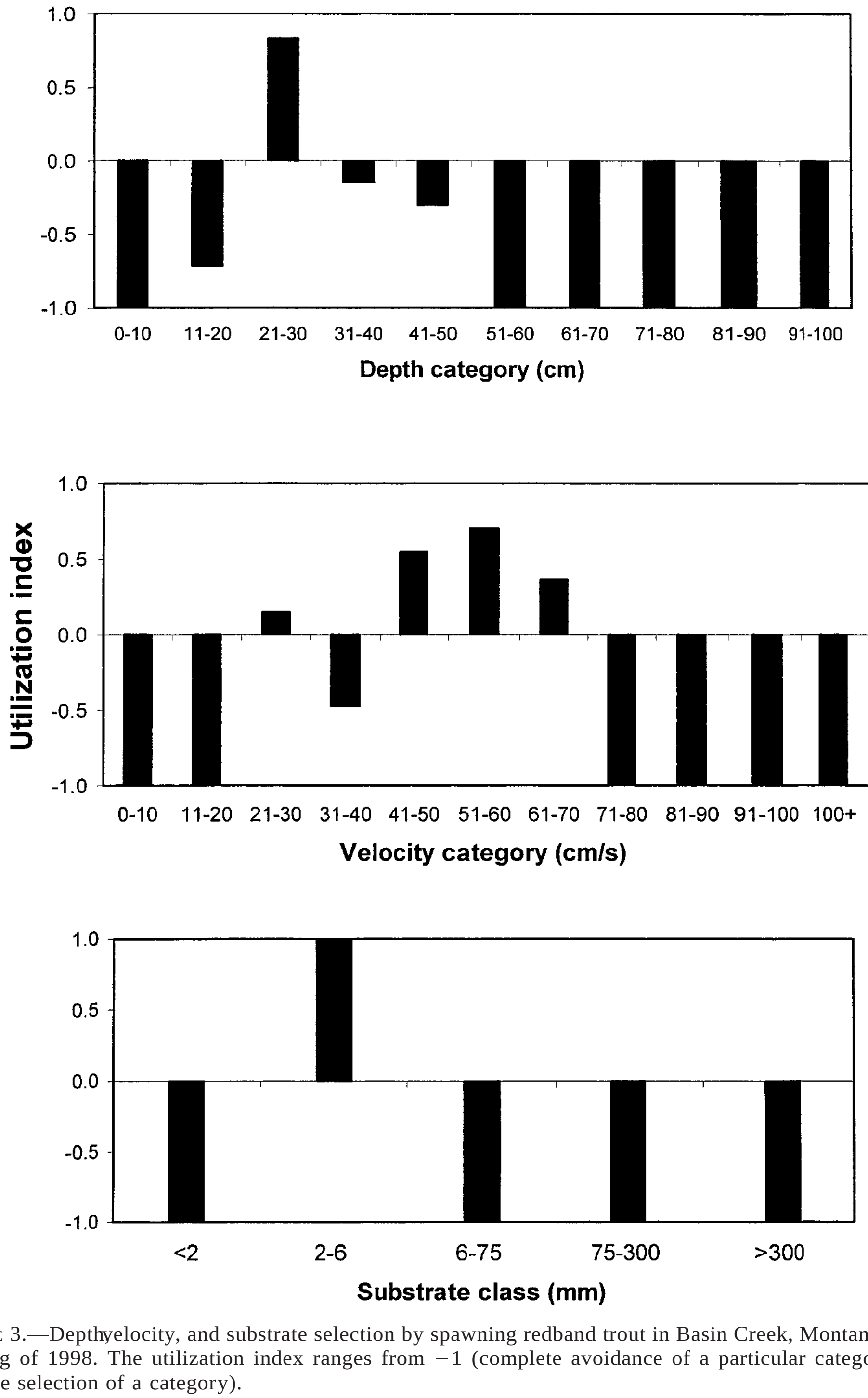

FIGURE 3.—Depth, velocity, and substrate selection by spawning redband trout in Basin Creek, Montana, during the spring of 1998. The utilization index ranges from −1 (complete avoidance of a particular category) to +1 (exclusive selection of a category).

size in redds was significantly different from the predominant available substrate size ($\chi^2 = 100.2$; df = 4; $P < 0.001$). Small gravel (2–6 mm) dominated the redd substrates, whereas the dominant substrates available in the spawning reach were large gravel (37%), small gravel (23%), cobble (20%), fines (17%), and small boulders (3%; Figure 3).

Discussion

Water temperature and stream discharge apparently influenced the timing of spawning by redband trout in Basin Creek during the spring of 1998. Redband trout began spawning once maximum daily temperatures consistently exceeded 7.0°C. This thermal threshold was similar to that reported for Gila trout *O. gilae* (8.0°C; Rinne 1980) and westslope cutthroat trout *O. clarki lewisi* (8.0°C; D. Schmetterling, Montana Fish, Wildlife, and Parks, personal communication), but lower than that reported for other inland trout, such as Yellowstone cutthroat trout *O. clarki bouvieri* (16.0°C; Thurow and King 1994) and California golden trout *O. mykiss aguabonita* (15.0°C; Knapp and Vredenberg 1996). The water temperatures I recorded during redband trout spawning (range = 5.2–9.3°C) were lower than reported for rainbow trout and other stream-dwelling (2.2–20.0°C; Bjornn and Reiser 1991) and anadromous salmonids (4.4–13.9°C; Bjornn and Reiser 1991). The fact that redband trout spawned concurrently with the descending limb of the hydrograph has also been reported for westslope cutthroat trout (Shepard et al. 1984; Schmetterling 2001), Yellowstone cutthroat trout (Thurow and King 1994), and California golden trout (Knapp and Vredenberg 1996). In Montana, migratory westslope cutthroat trout spawned when flows declined following peak discharges in tributaries to the Flathead River (Shepard et al. 1984) and Blackfoot River (Schmetterling 2001) drainages. In contrast, the timing of spawning by coastal rainbow trout was highly variable (January–July) throughout their range (depending on local environmental conditions), with most populations spawning before or during peak flows (Raleigh et al. 1984; Bjornn and Reiser 1991; Behnke 1992; Henderson et al. 2000).

Most redband trout redds (80%) were located in pool tailouts, which provide optimal spawning conditions in terms of water depth, water velocity, and substrate composition. Pool tailouts are important to the survival of salmonid embryos, offering favorable conditions for seepage velocity of interstitial water, oxygenation of eggs, and removal of waste products (Chapman and Bjornn 1969; Sowden and Power 1985; Bjornn and Reiser 1991).

My data suggest that spawning redband trout primarily selected redd sites based on substrate size and water depth in the spawning reach; fish selected shallower depths and smaller gravel than were randomly available. Similarly, Rinne (1980) found that Gila trout selected redd sites based on water depth and substrate in headwater tributaries of New Mexico. The importance of water depth and substrate size as microhabitat factors for spawning redband trout was probably due to the small size of fish in the study area (range = 150–300 mm TL). Larger-bodied salmonid species are able to construct redds in larger substrates, higher water velocities, and deeper water as compared to smaller-bodied fish, which occupy and use narrower ranges of microhabitat features (Crisp and Carling 1989; Bjornn and Reiser 1991).

Redband trout constructed redds in velocities ranging from 23 to 69 cm/s and water depths ranging from 20 to 46 cm. The range of water velocities measured upstream of the redd pits were generally lower than those reported for rainbow trout (48–91 cm/s; Smith 1973), but fall within the velocity ranges documented for other inland salmonids (Smith 1973; Witzel and MacCrimmon 1983; Bjornn and Reiser 1991; Grost et al. 1991; Thurow and King 1994; Knapp and Vredenberg 1996; Schmetterling 2000). Water depths (20–46 cm) used by spawning redband trout were deeper than those reported for golden trout (5–20 cm; Knapp and Vredenberg 1996), westslope cutthroat trout (4–23 cm; Schmetterling 2000), and Gila trout (5–15 cm; Rinne 1980).

Redds were dominated by small gravel (2–6 mm) and contained no substrate particle sizes larger than 75 mm. The particle-size composition of redband trout redds was smaller than that reported for most other stream-dwelling salmonids (Smith 1973; Rinne 1980; Grost et al. 1991; Kondolf and Wolman 1993; Thurow and King 1994; Schmetterling 2000), with the exception of golden trout (Knapp and Vredenberg 1996) and brook trout (Witzel and MacCrimmon 1983). Smith (1973) reported that rainbow trout preferred to spawn in a variety of substrates, ranging from 6 to 52 mm in diameter. The availability of suitable spawning substrate within the basin may also have influenced spawning habitat selection by redband trout (Crisp and Carling 1989; Bjornn and Reiser 1991). Muhlfeld et al. (2001a) found that juvenile and adult redband trout densities were highest (0.26–

0.46 fish/m^2) in the lower reaches of Basin Creek (including the study reach) that were dominated by gravel, and suggested that the observed spatial patchiness in the density of trout within the basin was attributable to the availability of suitable spawning habitat. Relationships among redd distribution, suitable spawning substrates, and trout densities have been reported for other stocks of inland salmonids (Beard and Carline 1991; Magee et al. 1996; Schmetterling 2000).

My results suggest that redband trout in a low-gradient, third-order mountain stream found suitable spawning habitat in pool tailouts that contained abundant gravel. Perhaps this type of spawning habitat may also be important for other redband trout populations inhabiting headwater systems of the upper Columbia River basin. Nonetheless, maintenance of pools with abundant gravel is probably critical for the conservation of the few remaining populations of redband trout in Montana. Minimization of impacts from land-use practices (e.g., logging, road construction, grazing, etc.) that reduce the quality and quantity of pools (Burns 1972; Hartman et al. 1996) would maintain suitable spawning habitat and enhance the survival of redband trout in the upper Kootenai River drainage. My description of redband trout spawning habitat may assist managers to (1) identify and protect important redband trout spawning habitats, (2) locate spawning adults for broodstock development, and (3) construct habitat restoration programs.

Acknowledgments

I would like to thank Bonneville Power Administration, the Montana Department of Fish, Wildlife, and Parks, and the U.S. Forest Service for funding this project, Brian Reeves for assistance in the field, Brad Shepard, Robert Begich, Brian Marotz, Michael Hansen, and John Rinne for their reviews of earlier drafts, and Kim Lindstrom for developing the study area map.

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