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SPAWNING ECOLOGY OF FINESPOTTED SNAKE RIVER CUTTHROAT TROUT IN SPRING STREAMS OF THE SALT RIVER VALLEY, WYOMING

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ABSTRACT.—We studied spawning ecology of cutthroat trout (*Oncorhynchus clarki*) in streams that originate as springs along the Salt River, a Snake River tributary in western Wyoming. We assessed (1) relative numbers of upstream-migrant and resident adults present during the spawning period in spring streams, (2) influence of habitat modification on use of spring streams for spawning, and (3) habitat features used for spawning in spring streams. Four spring streams were studied, 2 with substantial modification to enhance trout habitat and 2 with little or no modification. Modifications consisted primarily of constructing alternating pools and gravel-cobble riffles. Only a small portion of adult fish in spring streams during the spawning period had migrated upstream from the Salt River between March and the middle of June. Larger numbers of adult fish and more redds were observed in the 2 modified streams compared with the 2 streams with little or no modification. Most spawning occurred on constructed riffles with small gravel and over a narrow range of depths and velocities. Cutthroat trout, rainbow trout (*Oncorhynchus mykiss*), and their hybrids were observed in 1 stream with habitat modifications, indicating that measures to halt invasion by rainbow trout, as well as habitat improvement, are needed to preserve this native trout within the Salt River valley.

Key words: cutthroat trout, Oncorhynchus clarki bouvieri, *Snake River, spawning, migration, habitat improvement, redd.*

Cutthroat trout (*Oncorhynchus clarki*) were widespread across western North America with several described subspecies isolated in various watersheds (Behnke 1992). Distribution of finespotted Snake River cutthroat trout overlapped Yellowstone cutthroat trout (*O. c. bouvieri*), so the debate exists whether the finespotted Snake River form is a unique subspecies. The historical range of finespotted Snake River cutthroat trout begins at the Snake River below Jackson Lake and continues downstream to Palisades Reservoir. It also includes the downstream portions of tributaries from the Gros Ventre River to the Salt River (Behnke 1992). Large-spotted Yellowstone cutthroat trout occur naturally in the headwaters of several Snake River tributaries in this area (Behnke 1992).

Finespotted Snake River cutthroat trout exhibit both fluvial and fluvial-adfluvial migratory patterns (Varley and Gresswell 1988, Northcote 1997). Fluvial fish reside and move within a single stream or river segment throughout life, whereas fluvial-adfluvial fish reside in a mainstream river and migrate seasonally into tributaries. Hayden (1968) and Kiefling (1978, 1997) described fluvial-adfluvial migratory patterns of finespotted Snake River cutthroat trout in the Snake River. It is believed that finespotted Snake River cutthroat trout evolved fluvial-adfluvial migration because high spring flows and sediment movement in the Snake River limit spawning success (Kiefling 1978). In contrast, spring streams provide relatively stable flows with little sediment movement during the spring.

The finespotted Snake River cutthroat trout is the only native trout in the Salt River watershed (Isaak 2001), the most downstream Snake River tributary where the fish occurred naturally. Cutthroat trout are declining throughout their natural range for several reasons (Behnke 1992, Duff 1996, Kruse et al. 2000), many of which may be affecting finespotted Snake River cutthroat trout in the Salt River watershed. Rainbow trout (*Oncorhynchus mykiss*), which can hybridize with cutthroat trout, and brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis;* both are competitors of cutthroat trout) have become naturalized in the valley (Hudelson 1995). Habitat has been affected by numerous anthropogenic activities,

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particularly (1) by water diversion, causing periodic dewatering of long segments of tributaries and the Salt River headwater (Covington and Hubert 2003), and (2) by bank erosion, contributing sediment to streams throughout the watershed (Gelwicks et al. 2003).

A need exists for better understanding of the ecology of finespotted Snake River cutthroat trout in order to preserve and manage this native fish for future benefit. We studied the spawning ecology of finespotted Snake river cutthroat trout in spring streams because of the hypothesized value of spring streams for fluvial-adfluvial fish. Our objectives were to assess (1) relative numbers of upstream-migrant and resident adults during the spawning period in spring streams, (2) influence of habitat modification on use of spring streams for spawning, and (3) habitat features used for spawning in spring streams.

STUDY AREA

The Salt River watershed encompasses 2150 km^2 in western Wyoming and eastern Idaho (Fig. 1). A 6th-order stream at its mouth, it has a mean annual discharge of 22.5 m$^3 \cdot$ s^{-1}. River channel elevations range from 1750 m to 2150 m. The lower 72 km of the Salt River is perennial due to spring stream input, but upstream the river is dewatered annually to support irrigated agriculture. Finespotted Snake River cutthroat trout occur throughout the perennial reach, but little spawning habitat is available due to low channel slope and extensive silt deposition (Isaak 2001, Gelwicks et al. 2002).

Spring streams adjacent to the Salt River flow short distances (Fig. 1; Isaak 2001), and most have wide, shallow channels dominated by sand and silt substrates with few patches of clean gravels suitable as cutthroat trout spawning substrate. To enhance trout habitat, private landowners have modified segments of a small number of streams by constructing pools for adult habitat and cobble-gravel riffles that provide potential spawning sites (Kiefling 1997).

We studied 4 spring streams in the Salt River valley (Fig. 1). Preliminary surveys identified that Christensen Creek and Perk Creek had, respectively, 45 and 32 constructed pool-riffle pairs over the length of study reaches; Anderson Creek had 6 contructed pool-riffle pairs all in the upstream portion of the study reach; Bee Creek had no constructed pool-riffle pairs. Near the mouth of the spring streams, mean daily discharge from March through July 2000 was 0.51 m$^3 \cdot$ s^{-1} (range, 0.51–0.62 m$^3 \cdot$ s^{-1}) in Christensen Creek, 0.33 m$^3 \cdot$ s^{-1} (range, 0.28–0.38 m$^3 \cdot$ s^{-1}) in Perk Creek, 1.11 m$^3 \cdot$ s^{-1} (range, 0.89–1.88 m$^3 \cdot$ s^{-1}) in Anderson Creek, and 0.15 m$^3 \cdot$ s^{-1} (no measurable variation) in Bee Creek (Joyce 2001). Mean daily water temperatures in the 4 spring streams were similar, ranging from 5°C in early March to 15°C in late July 2000 (Joyce 2001).

METHODS

A weir was placed at the downstream end of the study reaches in Christensen and Anderson Creeks to capture fish moving upstream (Fig. 2). Weirs were aluminum rods placed 13 mm apart and fitted into racks. The Christensen Creek weir was 1800 m upstream from the Salt River, and the Anderson Creek weir was 1600 m upstream. No potential spawning habitat was observed downstream of the weirs. Cutthroat trout caught in the weirs were measured for total length (TL, mm) and observed for fungal growth. Adults (≥30 cm TL) free of fungus were tagged (Floy T-bar FD-94) behind the dorsal fin, their adipose fin was clipped, and these fish were released upstream of the weir. Two trap nets (20-mm bar mesh) were placed upstream of each weir to capture fish moving downstream. Cutthroat trout caught in these traps were checked for tags and fin clips, measured, and released downstream of the weir. We installed weirs and trap nets 7 March 2000 and removed them 14 June 2000.

We snorkeled to assess adult cutthroat trout abundance. Riffle, pool, glide, and culvert locations were recorded for each stream. Streams were stratified into reaches between culverts because these conduits could impede upstream movement (Fig. 2). Reaches where water was dammed and ponded were omitted, along with reaches with no pool or glide habitat greater than 30 cm deep; 20% of the pools and glides in each reach were randomly selected for sampling (14 in Anderson Creek, 13 in Christensen Creek, 9 in Perk Creek, and 6 in Bee Creek). Pools and glides were snorkeled 5 times in Christensen and Anderson Creeks, 3 times in Perk Creek, and twice in Bee Creek between 30 March and 14 June 2000.

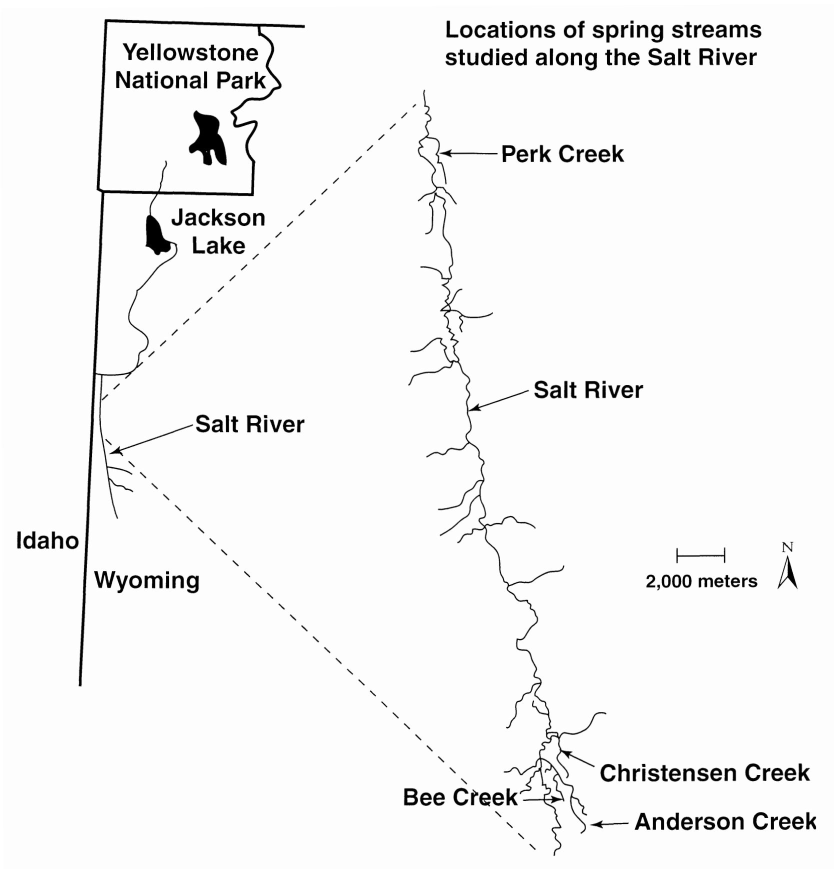

Fig. 1. Location of study streams in the Salt River valley, Wyoming.

Snorkel counts were expanded to estimate adult cutthroat trout abundance using the equation,

$$SRC_E = 1.04 + 1.07\ SRC_S,$$

where SRC_S = number of fish observed and SRC_E = estimated abundance from depletion electrofishing. We developed the regression equation ($r^2 = 0.95$) using estimates from 24 pools and glides sampled by snorkeling and 3- or 4-pass depletion electrofishing during spring 2000 in Christensen and Anderson Creeks (see Joyce 2001, Joyce and Hubert 2003). Snorkel counts of fish observed without tags or fin clips were used to estimate SRC_E. SRC_E estimates for each pool or glide in a reach were summed ($\Sigma\ SRC_E$), total area of all pools and glides (A) and total area snorkeled (a) in the reach were determined, and fish abundance (N_i) in the reach was estimated as $N_i = \Sigma\ SRC_E$ (A/a). We calculated abundance of unmarked fish by summing abundance estimates for each reach. Number of immigrants in each stream at the time of snorkeling was estimated by totaling the number of fish captured in the weir and released upstream and then subtracting the number captured in the trap nets and released downstream to that date.

Habitat in the spring streams was measured in each pool, riffle, and glide habitat unit (Bisson et al. 1981). To estimate water surface area, we measured length across 2 representative transects and wetted width following the thalweg. Water depth was measured at several points, and proportions (nearest 5%) of 5 substrate classes were visually estimated: (1) clay, silt, or sand, <2 mm in diameter; (2) small gravel, 2–20 mm; (3) large gravel, 21–64 mm; (4) cobble, 65–256 mm; or (5) boulder, >256 mm (Bain et al. 1985). In riffles, an upstream transect was established near the riffle edge,

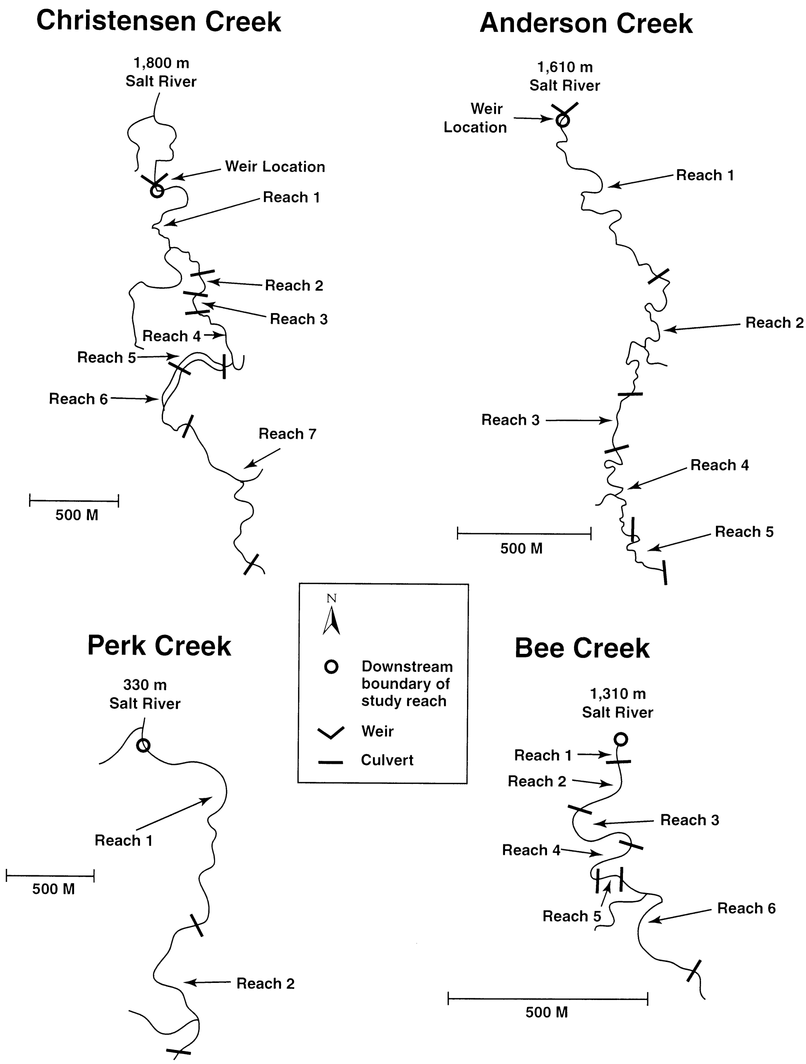

Fig. 2. Maps of the Christensen, Anderson, Perk, and Bee Creeks study areas showing the locations of culverts and reaches in each stream, and locations of weirs in 2 sampled streams.

and a 2nd transect was located at half the riffle length. Water depth and velocity (0.6 of depth) were measured at 1/4, 1/2, and 3/4 of the width across both transects.

We surveyed each stream for redds at least 6 times from March through mid-July 2000 by walking along the bank and observing redds in riffles. Redds were identified by a patch of gravel that was clean of periphyton and by the presence of a pit and tailspill (Crisp and Carling 1989). Locations of new redds were recorded during each survey. Redd features were measured except when the configuration could not be distinguished (usually the tailspill), or when the redd was under woody riparian vegetation or overhanging bank. We determined that fish were continuing to spawn if gravels were clean because periphyton quickly developed on undisturbed gravel. Depth, velocity (0.6 of depth), and substrate at redds were measured at the pit front, pit bottom, tailspill front, tailspill crest, and tailspill end (Grost et al. 1991). We visually identified dominant (covering the most surface area) and subdominant (covering the 2nd most surface area) substrates of the pit and tailspill.

TABLE 1. Total surface area of pools and glides in the study area, total surface area of pools and glides in which snorkeling counts were made, estimated abundance of unmarked adult (≥30 cm total length) finespotted Snake River cutthroat trout in the study areas on each sampling date, and number of marked fish present in the stream on each sampling date in Christensen and Anderson Creeks during spring 2000.

Location	Surface area (m^2)	Surface area (m^2) in snorkeling counts	Estimated unmarked fish and number of marked fish (in parentheses) by date				
Christensen Creek	27,806	16,350	16 April	27 April	5 May	23 May	10 June
			499 (36)	710 (46)	687 (65)	624 (83)	535 (117)
Anderson Creek	38,775	35,120	17 April	2 May	10 May	24 May	6 June
			184 (1)	170 (7)	216 (8)	154 (11)	207 (12)

RESULTS

Movements

More adult cutthroat trout were captured moving upstream into Christensen Creek than into Anderson Creek. In Christensen Creek, 151 fish were captured by the weir, but in Anderson Creek only 15 fish were captured by the weir. Capture of fish by weirs began in early April and peaked in late May and early June. Temporal pattern was similar in both streams.

More adult cutthroat trout were captured moving downstream in Christensen Creek than in Anderson Creek. Of 131 fish captured moving downstream in Christensen Creek, 33 were marked. Peak downstream movement in Christensen Creek occurred during the week of 17–23 May 2000. In Anderson Creek, 5 fish were captured moving downstream and 3 were marked.

Abundance

We identified 7 reaches in Christensen Creek (Fig. 2) with total pool and glide habitat comprising 27,806 m^2 of the study area, and we made snorkeling counts in 59% of this habitat. Estimated abundances of unmarked adult cutthroat trout ranged from 499 to 710 fish during the 5 sampling dates (Table 1). Marked fish were observed over the entire study area.

Five reaches were identified in Anderson Creek (Fig. 2) with pool and glide habitat comprising 38,775 m^2 of the study area, and snorkeling counts were made in 91% of this habitat. Estimated abundances of unmarked adult fish ranged from 154 to 216 fish during 5 sampling dates (Table 1). Marked fish were observed over the entire study area.

Two reaches were identified in Perk Creek (Fig. 2) with 12,117 m^2 of pool and glide habitat, all of which were included in the snorkeling counts. Estimated abundance of adult trout ranged from 110 to 203 fish during 3 sampling dates from 20 April to 11 June 2000. However, adult cutthroat trout, rainbow trout, and cutthroat trout × rainbow trout hybrids were observed while snorkeling and electrofishing. The snorkeler could not accurately determine if observed fish were cutthroat trout, rainbow trout, or cutthroat trout × rainbow trout hybrids, so abundance estimates of cutthroat trout could not be made in Perk Creek.

Six reaches were identified in Bee Creek (Fig. 2) with 19,000 m^2 of pool and glide habitat. Snorkeling counts were made over the entire study area twice during the spawning period, and no adult trout were observed in Bee Creek.

Proportions of Immigrants

Cutthroat trout that had moved upstream and were captured by the weirs comprised a small proportion of adult fish in both Christensen and Anderson Creeks (Table 1). Fish captured, tagged, and released upstream from the weir comprised 6%–18% of the estimated total number of adult fish in Christensen Creek and 1%–7% in Anderson Creek during the 5 snorkeling dates.

Distributions of Redds

Large numbers of redds were observed over the length of the study areas in Christensen and Perk Creeks where substantial habitat modifications had occurred. There were 49 riffles in Christensen Creek: 22 in reach 1, 5 in reach 2, 0 in reach 3, 5 in reach 4, 0 in reach 5, 2 in reach 6, and 15 in reach 7 (Fig. 2); 64 redds were found on 24 of 49 riffles. Reach 7 had the greatest number of redds (39) and reach 1 had the 2nd highest number (14). Most redds were on constructed riffles. Clean gravels indicating active spawning were observed in Christensen

Creek from early April through late June; peak spawning activity occurred around 1 May 2000.

In Perk Creek, 36 riffles were identified, 22 in reach 1 and 9 in reach 2 (Fig. 2); 72 redds were found on 27 riffles. Again, most redds were on constructed riffles. However, we could not determine if redds were the result of spawning by cutthroat trout, rainbow trout, or their hybrids.

Four redds were observed in Anderson Creek and none in Bee Creek where there was little or no habitat modification. In Anderson Creek we identified 52 riffles: 8 in reach 1, 22 in reach 2, 3 in reach 3, 15 in reach 4, and 4 in reach 5. One redd was found on each of 4 riffles in Anderson Creek. In Bee Creek, only 2 riffles were identified and no redds were observed.

Features of Redds

We measured features of 57 redds. In Christensen Creek, where the cutthroat trout was the only *Oncorhynchus* observed during spring 2000 (Table 2), relatively narrow confidence intervals suggested substantial similarity among redds. Small gravel most frequently dominanted substrate, and large gravel was the most frequent subdominant substrate in the pit of redds. Small gravel was the most frequent dominant substrate and sand the most frequent subdominant substrate in the tailspill of redds.

Cutthroat trout constructed redds in portions of riffles with smaller gravel, shallower water depths, and greater water velocities than that which was generally available among riffles in Christensen Creek. Median water depth in riffles was 28 cm, whereas median depth at the front of redd pits was 23 cm. Median water velocity in riffles was 0.40 m $\cdot$ s^{-1}, but median water velocity at the front of redd pits was 0.44 m $\cdot$ s^{-1}. Riffles in Christensen Creek averaged 56% small gravel, but small gravel was the dominant substrate in 74% of the redd pits and in 84% of the redd tailspills.

DISCUSSION

We captured cutthroat trout moving upstream and downstream in 2 spring streams during the spawning season, suggesting that a fluvial-adfluvial migratory pattern may occur among at least some adults in the Salt River (Varley and Gresswell 1988, Northcote 1997). However, the number of adult cutthroat trout that migrated into 2 spring streams during the spawning season was a small portion of the total number of adult fish in each stream, suggesting that most spawning in spring streams was by fish with a fluvial life history. Varley and Gresswell (1988) found fluvial, fluvial-adfluvial, lacustrine-adfluvial (i.e., adults spend most of their life in lakes and ascend tributaries to spawn), and allacustrine (i.e., adults spend most of their life in lakes and move into lake outlets to spawn) migratory patterns among Yellowstone cutthroat trout in the Yellowstone Lake drainage. It is likely that a wide range of movement patterns commonly exists among Yellowstone cutthroat trout populations across their natural range.

Christensen and Perk Creeks had more substantial pool and riffle habitat enhancement, more adult fish, and more redds than Anderson and Bee Creeks, which had little or no habitat modification, few pools, few or no adult fish, and few or no redds. Only cutthroat trout were observed in Christensen and Anderson Creeks, so numbers of adult fish and redds were indicative of use by this species. However, we could not determine numbers of adult cutthroat trout or redds constructed by them in Perk Creek because of the occurrence of both rainbow trout and cutthroat trout × rainbow trout hybrids in the stream. Habitat modifications in Christensen and Perk Creeks converted long, shallow glides to pool and riffle complexes. Spawning habitat was improved by placement of gravel in riffles between pools, and habitat for adults was created in constructed pools adjacent to riffles. A substantial increase in immigrant spawners and an estimated spawning population increase of almost sixfold occurred where spawning habitat was improved in spring streams tributary to the Snake River (Kiefling 1981). Similarly, cutthroat trout redd

TABLE 2. Mean water depths (cm) and water velocities (cm per second) at 0.6 water depth with 95% confidence intervals (in parentheses) at 5 locations in redds measured among 57 redds in Christensen Creek during spring 2000.

Location	Depth	Velocity
Pit front	23 (22–25)	47 (43–51)
Pit bottom	30 (29–32)	43 (39–47)
Tailspill front	23 (22–25)	47 (22–72)
Tailspill crest	15 (14–16)	65 (61–69)
Tailspill end	26 (24–30)	41 (35–47)

densities were related to abundance of spawning gravels in Montana streams, but no other measured habitat features appeared to affect redd densities (Magee et al. 1996).

Timing of upstream movements of adult cutthroat trout into Christensen and Anderson Creeks was similar, with peak movements in late May and early June. In upstream Snake River tributaries, spawning migrations by cutthroat trout have been observed as early as late February and as late as early August, but peak spawning occurs in April (Hayden 1968).

Although only narrow ranges of variability in features of cutthroat trout redds were observed in Christensen Creek, features of redds vary among streams. For example, measurement of Yellowstone cutthroat trout redds in Idaho indicated that mean water depth at the front of the pit (Thurow and King 1994) was similar to that observed in Christensen Creek, whereas mean water depth used by Westslope cutthroat trout in the Blackfoot River, Montana, was less (Schmetterling 2000). Mean water velocity at the front of redds in Christensen Creek was slower than for Westslope cutthroat trout in Blackfoot River, Montana tributaries (Schmetterling 2000). It is likely that the size of spawning adults and the amount of available habitat contribute to variation in redd features of cutthroat trout among stream systems.

In Christensen Creek small gravel (2–20 mm) was the most frequent substrate observed in both riffles and redds. Hayden (1968) reported that cutthroat trout in Snake River spring streams preferred gravels of 25–64 mm but did not comment on availability of different substrate sizes. Spawning substrates used by cutthroat trout in Christensen Creek were similar to those for Yellowstone cutthroat trout (Thurow and King 1994) and Westslope cutthroat trout (Magee et al. 1996, Schmetterling 2000) in other systems.

Our observations suggest that the construction of pools and cobble-gravel riffles in spring streams is likely to benefit both fluvial-adfluvial and fluvial finespotted Snake River cutthroat trout in the Salt River valley. However, we observed adult cutthroat trout, rainbow trout, and cutthroat trout × rainbow trout hybrids during the spawning season in Perk Creek, 1 of the 2 study streams with substantial habitat modification. Age-0 cutthroat trout, rainbow trout, and cutthroat trout × rainbow trout hybrids were also found in Perk Creek in 2000 (Evans and Shiozawa 2001, Joyce 2001). These observations suggest that habitat modifications to enhance trout habitat may be beneficial to cutthroat trout, but their preservation in the Salt River system must also involve efforts to halt (1) invasion by rainbow trout, (2) hybridization of native cutthroat trout with rainbow trout, and (3) development of hybrid swarms, as has been observed in other watershed (Kruse et al. 2000).

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