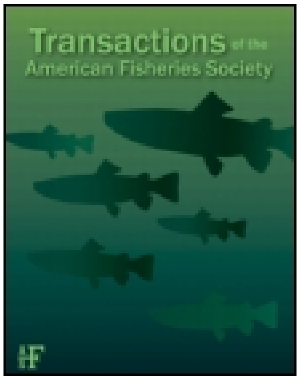

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ARTICLE

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Abstract
In the Blackfoot basin of western Montana, the recovery of migratory Westslope Cutthroat Trout *Oncorhynchus clarkii lewisi* requires landscape conservation as well as restoration of spawning tributaries. Westslope Cutthroat Trout are now increasing in the Blackfoot River and several streams, including Nevada Spring Creek, where natural channel, flow, and temperature regimes have reestablished aquatic habitat and migration corridors. To examine whether restoration has improved corridors for migration, we tracked the movements of 14 adult Westslope Cutthroat Trout from wintering areas in lower Nevada Creek (downstream of Nevada Spring Creek) to spawning and summering areas. Ten fish moved through Nevada Spring Creek upstream a median distance of 7.7 km (range, 7.6–16.9) to spawning sites at the headwaters of Wasson Creek through stream reaches where channels were reconstructed, instream flows enhanced, and grazing practices improved. Eight of the 10 fish that entered Wasson Creek spawned in a concentrated area upstream of two experimental diversion–fish screen structures located in the main channel of Wasson Creek. Prespawning movements of the remaining four radio-tagged fish were much farther than those of Wasson Creek spawners (median, 51.8 km; range, 44.9–63.1). These four fish moved downstream through Nevada Creek into the Blackfoot River and then ascended upper Blackfoot River before entering two separate spawning tributaries. This telemetry study indicates that restoration can improve migration corridors which, in turn, promote the recovery of migratory Westslope Cutthroat Trout, and that spring-influenced tributaries like Nevada Spring Creek provide important overwinter habitat for Westslope Cutthroat Trout that spawn and summer elsewhere in the basin.

Native salmonids were once abundant and widespread across the western United States, but as natural landscapes were modified many native salmonids declined to an imperiled state (Nehlsen et al. 1991; Behnke 1992; Thurow et al. 1997). Declines were largely associated with mining activities, timber extraction, stream channelization, irrigation practices, dams, riparian grazing, overfishing, and the adverse influence of nonnative species (e.g., Meehan 1991; Behnke 1992; Thurow et al. 1997). As a result of these human-induced threats, all 14 subspecies of native Cutthroat Trout *Oncorhynchus clarkii* are either imperiled ($n = 12$) or extinct ($n = 2$; Behnke 1992, 2002). In Montana, the Westslope Cutthroat Trout *O. c. lewisi,* a species of special concern (Shepard et al. 1997, 2005), is especially imperiled east of the Continental Divide (i.e., upper Missouri basin), where

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most populations are isolated above barriers in small (<10-km) habitat fragments (Shepard et al. 1997). In Montana west of the Continental Divide, Westslope Cutthroat Trout populations have also declined; however, populations are more widely distributed (Shepard et al. 2005; Fausch et al. 2009), present in greater abundance, and possess higher levels of life history and genetic diversity (Shepard et al. 2005; Fausch et al. 2009; Drinan et al. 2011).

Westslope Cutthroat Trout have migratory and stream-resident life histories, both of which are often represented in the same population (Rieman and Dunham 2000). Stream-resident fish occupy small tributaries their entire lives and can persist in isolated segments of stream. Conversely, migratory fish move downstream to larger rivers (or lakes) at age 2–4, where they mature at much larger sizes before returning to natal tributaries as adults to spawn. Migratory Westslope Cutthroat Trout thereby require much larger stream networks to fulfill their life history requirements than resident fish (Behnke 1992, 2002). In the Blackfoot River basin of western Montana, spawners often migrate > 50 river kilometers (rkm) upriver in May during the rising limb of the hydrograph, enter small streams where they spawn near the peak of the hydrograph (May and June), and then move downstream to larger waters as flows decline (Schmetterling 2001; Pierce et al. 2007).

Diverse life histories of native trout allow for dispersal and genetic exchange among subpopulations (Rieman and Dunham 2000; Fausch et al. 2009), which provides resiliency to natural stressors such as wildfire and debris flows (Fausch et al. 2009; Sestrich et al. 2011). Because migratory native trout require wide-ranging and often complex movements across a river network (Swanberg 1997; Schmetterling 2001; Petty et al. 2012), their recovery often requires multiscale conservation (Pierce et al. 2005, 2013; USFWS 2010), along with site-specific restoration techniques such as instream habitat restoration and balancing water needed for irrigation with the needs of migratory stocks (Pierce et al. 2007, 2013; Gale et al. 2008).

Although restoration is often conducted to conserve migratory native trout, few studies have examined metapopulation and life history dynamics of native trout from a restoration perspective (Rieman and Dunham 2000; Roni 2005; but see Petty et al. 2012). Likewise, the efficacy of restoration to mediate irrigation effects, such as managing for more natural flow regimes and using new technologies (e.g., Coanda-effect fish screens; Wahl 2001, 2003) to reconnect seasonally occupied habitats and limit entrainment of fish in irrigation systems, are rarely evaluated and poorly understood (Moyle and Israel 2005; Gale et al. 2008; Simpson and Ostrand 2012). Multiscale studies that document effects of restoration techniques on migratory trout are critical because migratory trout have experienced more severe declines than resident forms due to, in part, greater impacts from irrigation practices (McIntyre and Rieman 1995; Gale et al. 2008; Simpson and Ostrand 2012).

In the Blackfoot basin of western Montana, declines of migratory Westslope Cutthroat Trout and Bull Trout *Salvelinus confluentus* in the Blackfoot River during the 1980s triggered basinwide no-harvest (i.e., catch-and-release) regulations in 1990, combined with a program to restore degraded spawning tributaries on private ranch and timberlands from 1990 to the present (Aitken 1997; Schmetterling 2001; Pierce et al. 2005, 2007, 2013). Following these actions, the Westslope Cutthroat Trout have increased in abundance during the last 20 years in the Blackfoot River, where they now provide a valuable sport fishery for western Montana (MFWP 2012; Pierce and Podner 2013).

Within a context of these management strategies, restored tributaries of the Blackfoot River offer an ideal opportunity to examine the effects of multiscale efforts to conserve migratory Westslope Cutthroat Trout. This study expands on a prior study showing that Westslope Cutthroat Trout increased in abundance, while documenting a community-level shift from Brown Trout *Salmo trutta* to Westslope Cutthroat Trout following restoration of Nevada Spring Creek and Wasson Creek, a small adjoining tributary (Pierce et al. 2013). In this study, we examine the posttreatment spawning behavior of migratory Westslope Cutthroat Trout associated with this local expansion within a context of irrigation system and multiscale restoration activities. Specific study objectives are to (1) examine migration behaviors of Westslope Cutthroat Trout from their wintering areas into summer and to identify spawning sites for fish inhabiting the Nevada Creek complex, and (2) document the efficacy of irrigation-based restoration techniques involving an experimental Coanda fish screen and diversion for passing migratory spawners in Wasson Creek. Our broader goal is to help improve management of migratory trout and to guide habitat restoration on private lands where native trout conservation often requires balancing irrigation and other land uses with the life history and habitat needs of migratory fish.

STUDY AREA

The Blackfoot River, a fifth-order tributary (Strahler 1957) of the upper Columbia River, lies in west-central Montana and flows west 212 rkm from the Continental Divide to its confluence with the Clark Fork River in Bonner, Montana (Figure 1). The Blackfoot basin is regionally variable with subalpine forests in the high mountains, montane woodlands at the mid-elevations, and semiarid glacial topography on the valley floor. Land ownership in the Blackfoot basin is approximately 44% private land and 46% public land. Public lands occupy the mountainous areas, while private lands occupy the foothills and bottomlands where traditional uses of the land include mining, timber harvest, and agriculture. These activities have degraded habitat or led to the loss of habitat connectivity for Westslope Cutthroat Trout in most tributaries of the Blackfoot River (Peters and Spoon 1989; Schmetterling 2001; Pierce et al. 2005, 2007).

Our study involves the Nevada Spring Creek complex (i.e., Wasson Creek, Nevada Spring Creek, and lower Nevada Creek) located in the Nevada Creek drainage (Figure 1). Nevada Creek has been intensively managed for irrigation livestock production, which led to flow alterations, impaired water quality, and

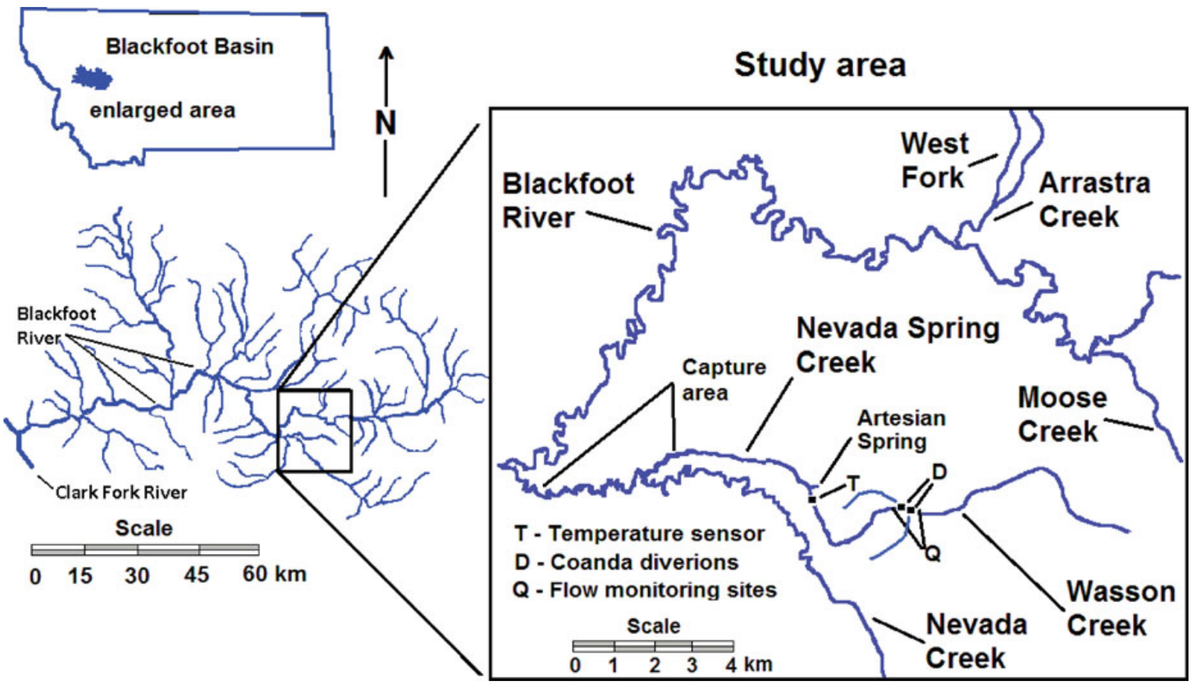

FIGURE 1. Location map showing the Blackfoot basin and the study area. Also shown are the capture locations of fish, flow and temperature monitoring sites, and locations of the two Coanda diversions.

depleted fisheries (DEQ 2007; Pierce et al. 2007). Nevada Spring Creek, located in the lower Nevada Creek drainage, originates from an artesian spring (Figure 1) that discharges 0.2–0.4 m^3/s of water with a nearly constant annual temperature ranging from 6.7°C to 7.8°C (Pierce et al. 2002). From this spring source, Nevada Spring Creek flows 7.1 rkm and enters Nevada Creek 10.1 rkm above its mouth. Prior to 2005, Nevada Spring Creek was overwidened and heavily degraded with high summer temperatures near 25°C at its junction with Nevada Creek (Pierce and Peters 1990). Likewise, the lower 3.8 rkm of Wasson Creek, a tributary to upper Nevada Spring Creek, was dewatered and damaged by intensive agricultural practices. Electrofishing surveys found Westslope Cutthroat Trout were incidental or absent from sampled segments of lower Wasson Creek, lower Nevada Spring Creek, and lower Nevada Creek (Montana Fish, Wildlife, and Parks, unpublished data; Pierce et al. 2013). Indeed, an intensive 6.1-rkm electrofishing survey of Nevada Creek downstream of the Nevada Spring Creek confluence captured only a single Brown Trout (and no Westslope Cutthroat Trout) in April 1990 (Montana Fish, Wildlife, and Parks, unpublished data).

Both Nevada Spring Creek and Wasson Creek were restored over a 10-year period (Pierce et al. 2013). Nevada Spring Creek was completely restored by forming a deep narrow channel, restricting livestock grazing in riparian areas, enhancing instream flows, and placing a protective conservation easement along the entire stream (Table 1). Restoration actions on Wasson Creek were similar but also include the addition of two experimental Coanda-effect fish screens at two diversion points (Figure 2 [top] and described below) in order to eliminate entrainment and facilitate movements of fish during the irrigation season. These combined treatments were intended to recreate more

TABLE 1. Summary of stream metrics before and after restoration; nd = no data, na = not applicable (modified from Pierce et al. 2013).

	Width-to-depth ratio		Sinuosity		Percent pool area		Maximum summer temperature (°C)		Minimum summer flow (m^3/s)		Ditch entrainment (number of age-1+ trout/30 m)	
Stream name	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Nevada Spring Creek	22	3.2	1.4	1.7	51	71	25	18	0.17	0.28	na	na
Wasson Creek	3	0.7	1.0	1.5	nd	nd	22	18	0	0.02	1.3	0

FIGURE 2. Picture of a Coanda diversion and fish screen on Wasson Creek. The photo shows two fish screens as well as a sediment sluice gate (middle slot with boards). The smaller photo (top) shows an adult Westslope Cutthroat Trout ascending the Coanda. (Photo by Jamie Nesbit.)

natural channels and flow regimes, reduce temperatures in Nevada Spring Creek, and restore habitat connectivity (Table 1). Following these activities, fisheries monitoring not only documented the down-valley expansion of Westslope Cutthroat Trout (Pierce et al. 2013) but also the increasing presence of larger adult Westslope Cutthroat Trout (fish > 300-mm TL) in Nevada Creek downstream of the Nevada Spring Creek confluence (Pierce and Podner 2013).

Irrigation improvements: instream flow and the Coanda fish screens.—Upgrades to irrigation systems in Wasson Creek enhanced instream flows and placed a pair of site-designed Coanda-effect (hereafter, "Coanda") diversion–fish screens in the main stem of Wasson Creek at two diversion points (Figures 1, 2). Instream flow enhancement was intended to mimic natural flow regimes including high and low flows, while maintaining a minimum base flow (>0.02 m^3/s) downstream of the diversion points in order to reestablish spawning, rearing, and movement corridors for Westslope Cutthroat Trout in areas of restored habitat. The Coanda in this study is an experimental structure intended to allow the uninhibited movement of fish and eliminate ditch entrainment, while also allowing diversion of water from the main channel of Wasson Creek into an irrigation ditch (Figure 2 [top]). To accomplish these functions, the structure is slightly elevated above the bed of the channel, which allows water to flow over the screen and wash debris from the screen in a manner that provides for the upstream movement of fish, while preventing fish from entering the ditches. The Coanda-effect fish screen itself is a slightly tilted, angular "wedge wire" design (Wahl 2001, 2003) with closely spaced bars (gap = 0.5 mm), which shears water from surface of the screen and routes water into a buried pipe that then discharges into irrigation ditches.

METHODS

Radiotelemetry.—Consistent with previous studies (Schmetterling 2001; Pierce et al. 2007), we captured adult Westslope Cutthroat Trout in Nevada Creek and lower Nevada Spring Creek by electrofishing suspected wintering areas prior to spawning migrations. We implanted 14 fish at capture locations with continuous radio transmitters (Model MST-930 miniature sensor tag; Lotek Wireless, Newmarket, Ontario) between 18 and 21 April 2011 ($n = 6$) and 9 and 10 April 2012 ($n = 8$), and tracked these fish to their spawning sites and summering areas. At the time of capture, these fish ranged from 292- to 377-mm TL (mean, 333-mm TL) and from 299 to 590 g in weight (mean, 438 g). We selected larger fish in this study to increase the likelihood that radio-tagged fish were sexually mature. To confirm visual identification of individuals as Westslope Cutthroat Trout, all 14 fish were tested for genetic purity by removing a small portion of fin and assessing eight microsatellite loci diagnostic between Westslope Cutthroat Trout and Rainbow Trout *O. mykiss* as described by Muhlfeld et al. (2009a).

Transmitters were distributed in fish captured over 8.7 rkm of stream, which included the lower 1.3 rkm of Nevada Spring Creek ($n = 3$) and an adjoining 7.4-rkm section of Nevada Creek downstream of the Nevada Spring Creek confluence (Figure 1). Individually coded transmitters weighed 4.0 g, had an estimated life of 278 d, emitted an individual coded signal, did not exceed 2% of fish weight (Winter 1996), and were implanted following standard surgical methods (Swanberg et al. 1999). Technicians use an omnidirectional whip antenna mounted on a truck, all-terrain vehicle, or canoe when identifying general fish locations and then identified specific locations on foot using a handheld, three-element Yagi antenna. Technicians located fish weekly prior to migrations, 3–4 times/week during migrations and spawning, once per week following spawning, and generally twice per month thereafter. All river locations and movements of Westslope Cutthroat Trout were referenced by river kilometer.

Fish were assumed to have spawned at their uppermost detected location if they ascended a stream with suitable spawning habitats during the spring (May–June) spawning period (Schmetterling 2001). Suitable spawning habitats were identified by observations of spawning, presence of redds, age-0 Westslope Cutthroat Trout, or a combination thereof. We estimated the timing of migration and spawning events as the median date between two contacts for a given event, and the peak of spawning for the entire group was identified as the median spawning date (Pierce et al. 2007, 2009). We used Mann–Whitney rank-sum test to analyze prespawning movement distances to spawning tributaries and migration distances up spawning tributaries for Wasson Creek versus other tributaries where tagged fish spawned (Arrastra Creek and Moose Creek). These tests were performed using R software (R Development Core Team 2012) and evaluated at the $\alpha = 0.05$ level of significance.

Water temperature and flows.—Mean daily water temperatures and daily stream flows were also measured in Wasson Creek to explore potential relationships with Westslope Cutthroat Trout movements and spawning events, including movements through the experimental (Coanda) diversion structures and stream reaches downstream of the diversions where instream flows were enhanced (Figure 3). Streamflow and temperature measurements were taken between 1 April and

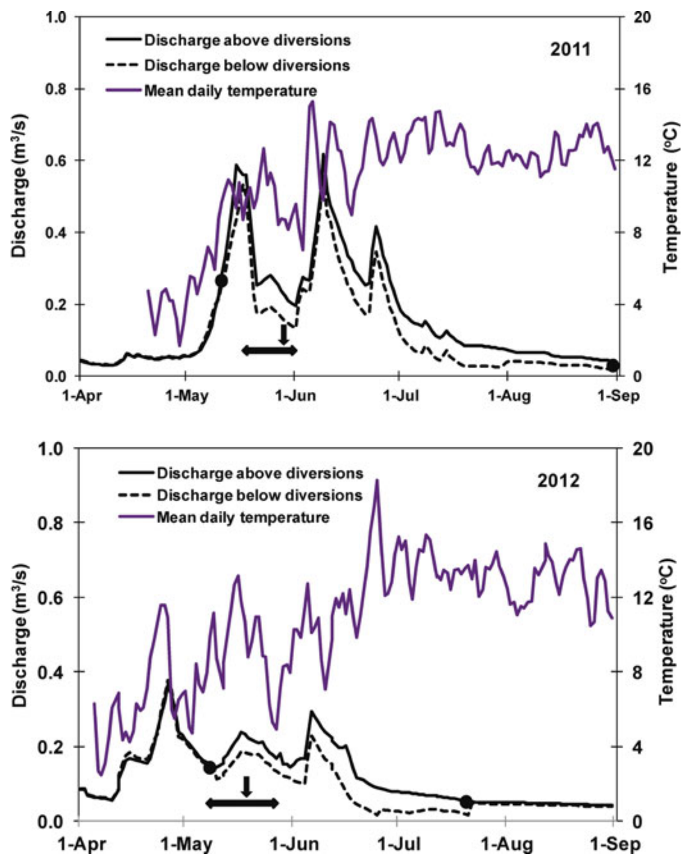

FIGURE 3. Relationship of migration and spawning to discharge and water temperatures in Wasson Creek for 2011 and 2012. The horizontal (arrowed) bar shows the migration period through the diversions ($n = 3$ in 2011, $n = 5$ in 2012). The vertical arrow represents the peak (median) spawning period for all Wasson Creek fish ($n = 10$). The dark circles show the dates irrigation was turned on and off.

1 September in both 2011 and 2012, and began prior to irrigation use and prior to movements of radioed fish. To measure water temperatures, we used a continuous (50-min interval) digital thermograph (Onset Computer, Pocasset, Massachusetts) located at rkm 0.2 on Wasson Creek (Figure 1). To calculate flows, we measured discharge and developed stage discharge rating tables for staff gauges immediately upstream (rkm = 3.7) and downstream (rkm = 4.3) of the two diversions (Figure 1). Estimates of mean daily discharge were then made from weekly staff gauge readings and correlations with daily flows from the USGS streamflow gauge on Nevada Creek (USGS 2013).

RESULTS

Telemetry.—We tracked 14 adult Westslope Cutthroat Trout to spawning sites in this study by making a total of 374 contacts with an average of 27 contacts (range, 13–37) per fish. All individuals were successfully tracked to spawning tributaries from 24 April to 7 June (Table 2). Thirteen of the 14 fish tested as genetically unaltered Westslope Cutthroat Trout across eight microsatellites. One fish that entered the West Fork of Arrastra Creek in 2012 tested as 6% introgressed with Rainbow Trout across the eight loci examined. With the exception of the West Fork fish, these genetic tests support our visual observations of Westslope Cutthroat Trout in this study.

As measured in lower Wasson Creek, water temperatures incrementally increased in the spring during the 2011–2012 Cutthroat Trout prespawning migrations. In these years, migrations began between 2 and 13 May during spring runoff. Ten Westslope Cutthroat Trout moved upstream through Nevada Spring Creek and into Wasson Creek, and four moved down Nevada Creek before ascending the Blackfoot River and moving up into two upper river tributaries (Arrastra and Moose creeks). Over an average of 14 d (range, 3–27), migratory Westslope Cutthroat Trout traveled a median of 14 rkm (range, 7.6–63.1) to their respective spawning site. Westslope Cutthroat Trout that spawned in Wasson Creek entered the stream at 5–6°C as flows increased and spawned at temperature between 8°C and 12°C as measured in lower Wasson Creek (Figure 3). Of these 10 fish, 8 spawned in a concentrated area upstream of the diversions (Figure 4).

Spawners spent an average of 18 d (range, 1–74) in spawning tributaries and ascended a median of 3.1 rkm (range, 0.2–6.4) to their spawning sites in low-order streams, where they held for an average of 7 d (range 1–16) before returning to the Blackfoot River (n = 4) or Nevada Creek (n = 3; Table 2). Based on the distance between location at the start of migration and spawning sites, fish moved a (median) distance of 14.1 rkm for the total group, and a median of 7.7 rkm (range, 7.6–16.9) for Wasson Creek fish versus 51.8 rkm (range, 44.9–63.1) for upper river spawners. The total migration distances to the mouths of Arrastra and Moose creeks were further than to Wasson Creek

TABLE 2. Summary of Cutthroat Trout spawning migrations for 14 migratory adults. The table includes the duration, dates, and distances of spawning events as well as summering locations. These summaries relate to spawning locations in Figure 4.

		Prespawning migration			Tributary spawning			Postspawning		
Fish ID	Capture location	Date migration started	Total kilometers	Total days	Tributary	Estimated spawning date	Date exited	Last live location	Last live contact date	Fate
1	Nevada Spring Creek	16 May 2011	7.6	16	Wasson Creek	2 Jun	4 Jun	Nevada Spring Creek	19 Jul	Unknown
2	Nevada Creek	15 May 2012	10.8	2	Wasson Creek	24 May	10 Jun	Nevada Spring Creek	8 Jun	Unknown
3	Nevada Creek	26 Apr 2012	11.3	11	Wasson Creek	17 May	27 May	Nevada Creek	29 May	Heron Predation
4	Nevada Spring Creek	12 May 2011	14.5	7	Wasson Creek	28 May	1 Jun	Wasson Creek	27 Jun	Mortality
5	Nevada Creek	10 May 2012	11.6	1	Wasson Creek	15 May	22 May	Blackfoot River	27 Aug	Alive
6	Nevada Creek	12 May 2011	12.1	10	Wasson Creek	29 May	1 Jun	Wasson Creek	16 Jun	Mortality
7	Nevada Creek	5 May 2012	14.6	4	Wasson Creek	15 May	24 May	Nevada Creek	27 Aug	Alive
8	Nevada Creek	7 May 2012	13.4	2	Wasson Creek	14 May	10 Jun	Nevada Creek	27 Aug	Alive
9	Nevada Creek	26 Apr 2012	12.7	19	Wasson Creek	23 May	27 May	Nevada Creek	29 May	Heron Predation
10	Nevada Spring Creek	11 May 2011	16.9	6.5	Wasson Creek	26 May	1 Jun	Wasson Creek	25 Jul	Alive
11	Nevada Creek	13 May 2011	63.1	25	Arrastra Creek	7 Jun	10 Jun	Blackfoot River	25 Jul	Alive
12	Nevada Creek	24 Apr 2012	44.9	11	West Arrastra Creek	1 May	7 Jul	Blackfoot River	23 Aug	Alive
13	Nevada Creek	24 Apr 2011	49.9	27	Moose Creek	30 May	2 Jun	Blackfoot River	12 Jun	Unknown
14	Nevada Creek	9 May 2012	53.8	14	Moose Creek	30 May	19 Jul	Blackfoot River	23 Aug	Alive

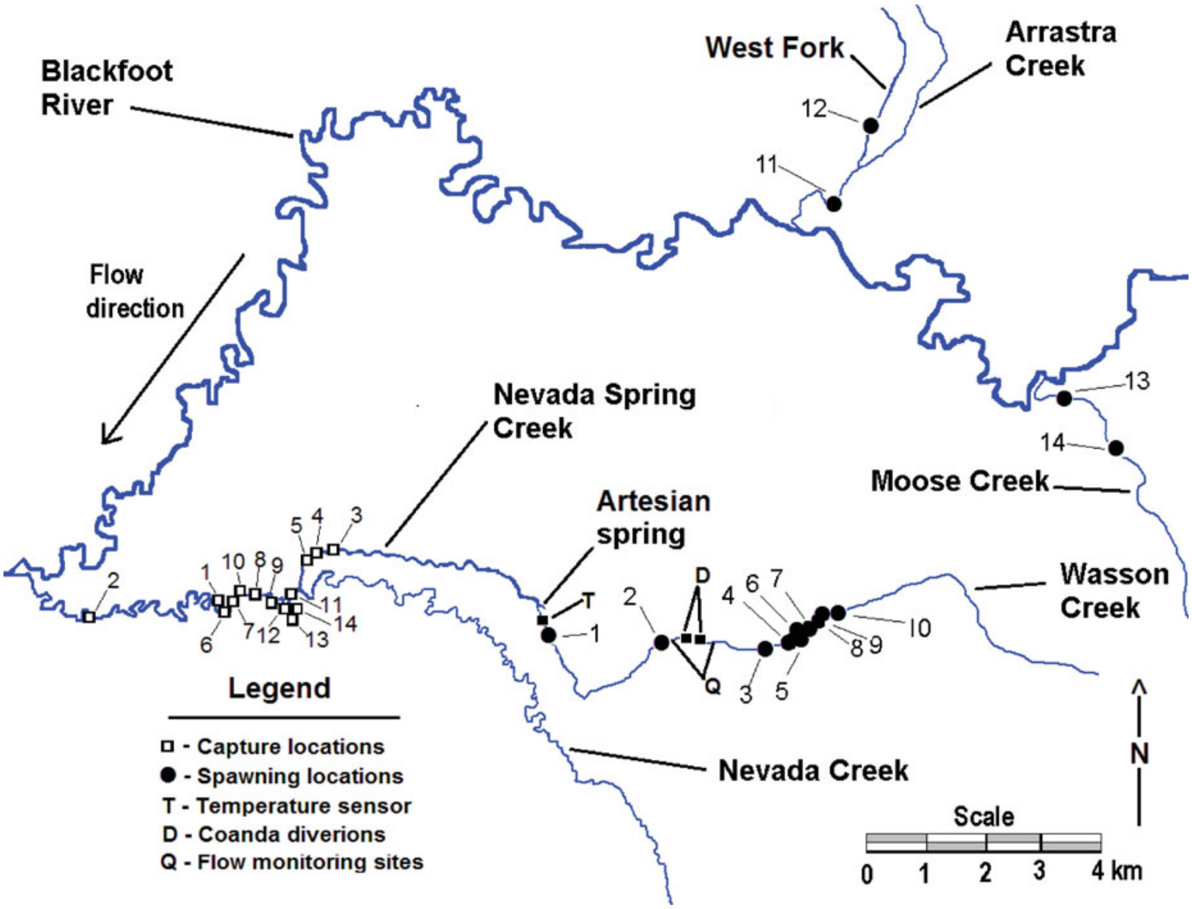

FIGURE 4. Capture locations (squares) and spawning locations (black circles) for 14 migratory Westslope Cutthroat Trout. The numbers for spawning locations relate to summaries of individual fish movements on Table 2.

(P = 0.002). However, Wasson Creek fish spawned higher in their respective spawning stream than fish that spawned in Arrastra and Moose creeks (median, 5.3 versus 1.6 rkm; $P = 0.02$).

When last contacted (Table 2), two postspawning Wasson Creek fish died in Wasson Creek (numbers 4 and 6), two (numbers 3 and 9) were killed by great blue heron *Ardea herodias* based on tags traced to a rookery, one (number 10) remained in Wasson Creek, two exited to Nevada Spring Creek (numbers 1 and 2), two exited to Nevada Creek (numbers 7 and 8), and one moved into the Blackfoot River 4.3 rkm downstream of the Nevada Creek confluence. After spawning, all Arrastra Creek ($n = 2$) and Moose Creek ($n = 2$) spawners returned to the Blackfoot River and moved downriver from the confluences of their spawning tributaries distances ranging from 6.0 to 81.4 rkm when last contacted. The Moose Creek spawner (number 14) that showed the longest prespawning movement (53.8 rkm) also showed the longest postspawning downriver movement (81.4 rkm). We ended the tracking in July when migratory trout exited spawning tributaries and entered summering areas of the larger streams.

Migrations at the Coanda diversions.—Of the 10 spawners that entered Wasson Creek, eight spawners migrated upstream of the Coanda diversion structures between 10 May and 1 June (Figure 3). Three spawners ascended the Coandas between 21 and 25 May 2011 at flows ranging from 0.25 to 0.28 m^3/s. Five spawners ascended the diversions between 10 and 19 May 2012 at flows ranging from 0.14 to 0.24 m^3/s. The remaining two fish that spawned in Wasson Creek fish spawned in lower Wasson Creek downstream of the Coanda diversions (Figure 4). Of the eight fish that moved over the Coanda fish screens, seven migrated back downstream through the diversion structures without becoming entrained in the ditch, and one fish died after spawning about 2 rkm upstream of the upper diversion. Water was diverted into irrigation ditches during these migration periods, but instream flows were managed to emulate natural flow conditions (Figure 3). Under these conditions, the Coanda fish screens showed no observed effect on upstream or downstream movements of adult fish.

DISCUSSION

Though human activities are broadly implicated in the loss of native salmonids, few studies evaluate the long-term efficacy of restoration for fisheries response (Bernhardt et al. 2005;

Roni 2005; Baldigo et al. 2008), and very few, if any, published studies document the response of migratory native trout to multiscale restoration. For this study, we chose a small sample size because we expected only local movements within the Nevada Creek complex. As expected, our small sample of spawners confirmed (1) the migratory behavior associated with the local expansion of resident Cutthroat Trout following restoration actions, and (2) the efficacy of experimental Coandas for passing adult migratory Westslope Cutthroat Trout. Interestingly, tagged fish also revealed unexpected large-scale movements to streams outside of the Nevada Creek basin. Though sample sizes were especially small for these spawners, these results were compelling because these individuals link the restoration area with increases of the broader metapopulation (Rieman ad Dunham 2000; Pierce and Podner 2013).

Restoration, migration, and spawning.—Restoration and habitat connectivity are both crucial to the long-term conservation of migratory salmonids (e.g., Rieman and Dunham 2000; Schrank and Rahel 2004; Petty et al. 2012; this study). Compared with resident trout, migratory forms appear to have experienced large and disproportionate reductions in numbers (Gale et al. 2008). In many areas, population reductions have been broadly implicated with instream dams, diversions, and dewatering that prevent or restrict the movements of fish (Pierce et al. 2007, 2013; Gale et al. 2008; Roberts and Rahel 2008). Indeed, age-1 and older Westslope Cutthroat Trout in Wasson Creek were abundant immediately upstream of the diversions (i.e., abundance = 22 trout/30 m) but absent immediately downstream of the diversions prior to restoration and irrigation upgrades when surveyed in 2003 (Montana Fish, Wildlife, and Parks, unpublished data). Following restoration (Table 1), the abundance of age-1 and older Cutthroat Trout increased from zero to an average 11 fish/30 m (range, 4.3–21) downstream of the diversions between 2004 and 2012.

In our study, spawners captured in lower Nevada Creek migrated in some cases long distances (>50 rkm) at high water through a complex range of large and small stream networks and spawned near the peak of the hydrograph in small headwater streams as temperatures increased, before returning to larger water bodies as flows declined. This behavior conforms to the known spawning life histories of migratory Westslope Cutthroat Trout from the Blackfoot River (Schmetterling 2001; Pierce et al. 2007) and is similar to migratory Cutthroat Trout behavior in other areas (Brown and Mackay 1995; Rosenfeld et al. 2002; Muhlfeld et al. 2009b).

In this study, 10 of 14 spawners ascended upper Wasson Creek after the restoration and installation of the Coandas. These movements were expected given the relatively high abundance of Westslope Cutthroat Trout above the upper diversion prior to restoration (Pierce and Podner 2013), increases in the abundance of Westslope Cutthroat Trout into Nevada Spring Creek following restoration (Pierce et al. 2013), and assignment tests demonstrating genetic similarity between the fish in this study and the population in Wasson Creek (K. Carim, unpublished data). Though irrigation was occurring during these movements, flows were managed to emulate natural conditions, and the Coandas passed all fish with no observed disruption. One adult Westslope Cutthroat Trout was actually observed successfully ascending the Coanda diversion (Figure 2 [bottom]). In addition to passing migratory fish at the irrigation diversions, we electrofished the ditches and found no entrained fish, which further indicate the Coanda fish screens are an effective screening device.

Telemetry not only revealed concentrated spawning in the headwaters of Wasson Creek but also identified long-distance migrations from Nevada Creek to spawning habitats outside of the focal stream network. Though small sample sizes limit our ability to fully interpret these results, varied movement of fish in this study suggest some recovery of metapopulation function. Specifically, the seasonal use of multiple stocks from distant natal streams using Nevada Creek where none were detected pretreatment demonstrate the added benefits of restoration beyond the local population. Conversely, we identified no spawning movements to other tributaries within the Nevada Creek drainage, although resident Westslope Cutthroat Trout are distributed widely in the headwaters of nearby streams. This was expected given pervasive human alterations of aquatic habitat in lower stream reaches and very little, if any, habitat connectivity between low-elevation stream and headwater populations (Pierce et al. 2007). In the case of Wasson Creek, spawning was concentrated near the mountain–valley interface upstream of a low-gradient meadow stream, which seems to generally lack the gravel bedforms that migratory Westslope Cutthroat Trout typically require for spawning (Schmetterling 2000). This concentrated spawning shows the patchy nature of spawning sites common to migratory native trout (Rieman and Dunham 2000) and underscores the importance of small streams for Cutthroat Trout, as shown in other regions (Rosenfeld et al. 2002)

Following spawning, most Cutthroat Trout from Wasson Creek returned to Nevada Creek to oversummer. Conversely, spawners from both Arrastra and Moose creeks entered the Blackfoot River, though they were originally captured, and presumably wintered in Nevada Creek. Although this study was not intended to examine overwintering habitat, our findings of migrant fish from outside of the Nevada Creek basin suggest Nevada Creek may provide important habitat for Westslope Cutthroat Trout that spawn and summer elsewhere. The Blackfoot River near the mouth of Nevada Creek is prone to severe winter conditions (i.e., super-cooled [<0°C] water and anchor ice; Peters and Spoon 1989; Pierce et al. 2012), which can trigger movements of native trout to areas of groundwater upwelling where temperatures are moderated (Cunjak 1996; Jakober et al. 1998; Brown et al. 2011). In the case of Nevada Spring Creek, the artesian spring at the head of this creek flows at a constant annual temperature of 6.7–7.8°C, cooling the main stem of Nevada Creek during the summer while also warming the stream during the winter.

CONCLUSIONS

Westslope Cutthroat Trout conservation west of the Continental Divide involves managing for diverse life histories, including both stream resident and migratory populations (Schmetterling 2001; Shepard et al. 2005; Fausch et al. 2009). Unlike resident fish that can persist in isolation (Shepard et al. 1997; Cook et al. 2010), the recovery of migratory native trout requires large and highly connected systems. In the case of the upper Blackfoot basin, stream systems are complex and private lands provide most of the spawning sites, migration corridors, and wintering areas for migratory Cutthroat Trout as well as having the most opportunity for meaningful restoration (Pierce et al. 2007, 2013). Here, managing for migratory Westslope Cutthroat Trout involves basin-scale conservation strategies, which integrate site-specific techniques that provide for the habitat and benefit the life history diversity of individual stocks. In the Nevada Spring Creek complex, reach-scale restoration has improved the general habitat necessary for migratory salmonids, while Coanda fish screens provide the mechanism to improve habitat connectivity in areas of suitable habitat by passing fish and reducing losses of fish to irrigations ditches even during active irrigation. This study shows that the integration of restoration techniques can not only improve specific habitat needed for migratory trout at a local scale but can also promote the recovery of migratory fish across larger stream networks.

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