Habitat Associations of Endangered Loach Minnow in Upper Blue River and its Tributaries, Greenlee Co., Arizona and Catron Co., New Mexico

Final Report

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March 12, 2015

Introduction

Blue River is tributary to San Francisco River in the greater Gila River basin. Its headwaters are in the physiographic setting of the Colorado River Plateau. The watershed is approximately 1602 square kilometers (km^2) and the river flows for approximately 85 km before flowing into San Francisco River. Blue River is divided into two Fifth Hydrologic Unit watersheds (1504000403 Upper Blue River and 1504000407 Lower Blue). Elevations range from 2865 m near the Mogollon Rim to 1177 m at its mouth. The river corridor varies from wide flood plains separated by narrow box canyons to wide and narrow sandy river bottoms to a relatively narrow canyon with towering canyon walls. Slumps and fault lines are visible in some areas.

Blue River contains one of the highest diversities of native fishes in Arizona. Among these, it contains federally endangered loach minnow (*Tiaroga cobitis*) and 106.5 km of the main stem Blue River and its tributaries are designated critical habitat (US Fish & Wildlife Service [USFWS] 2012). Several Forest Service sensitive species also are present including desert sucker (*Pantosteus clarkii*), Sonora sucker (*Catostomus insignis*), and longfin dace (*Agosia chrysogaster*). Speckled dace (*Rhinichthys osculus*), a non-sensitive native species also occurs in Blue River.

The Wallow Fire burned more than half a million acres in eastern Arizona and western New Mexico in May-July 2011, and shortly after fish kills were observed in portions of the Gila River and its affected tributaries. Previous studies in 2011 and 2012 were initiated to assess overall post-fire fish population status in Blue and Black rivers (Kesner et al. 2011; Patterson et al. 2012). At the request of the Forest Service, as follow up to these preliminary investigations, we now have completed a two-year study to examine habitat of loach minnow within the Blue River system. This investigation was designed to critically examine key habitat associations of this endangered species by comparing parameters among typical (i.e., turbulent, swift riffles with loose gravel substrate; Minckley and Marsh 2009) and atypical (i.e., pools, sandy bottom runs; Marsh et al. 2003) sites where this species may be found. Eight sites were sampled to represent the range of habitats occupied by loach minnow throughout the upper Blue River system in Greenlee Co., Arizona and Catron Co., New Mexico (Figure 1). Four sites were on Blue River, two on Campbell Blue Creek, and one each on Dry Blue and Pace creeks. Sites were sampled in early summer to target the nominal low-flow period (~0.5 cfs) before onset of monsoon rains (May to June). This report represents a summary of collection activities for 2014 and a complete analysis of the two-year dataset.

Methods

Collections were made June 17-20, 2013 and June 23-26, 2014. Two types of evaluations occurred within each site.[1] First was a whole site evaluation in which a 0.8 to 1.6 km section was evaluated for general conditions: water and air temperature, conductivity, water clarity, presence or absence of algae and northern crayfish (*Orconectes virilis*), general bank composition and condition, and aquatic and

[1] The locality at Grant Creek (Blue River) was sampled but a formal station was not established here because habitat (large beaver pond and shallow runs and riffles) was unsuitable for loach minnow.

riparian vegetation. Bank composition refers to a qualitative description of bank material (e.g., bedrock, cobble, soil, root masses, etc.). Bank condition is a qualitative description that includes cover (exposed, sparsely-to-densely vegetated, trampled, etc.) and repose (gently sloping, sloping, vertical, and undercut). Regional gradient for these sites was estimated from elevation profiles as provided in TOPO® mapping software.

Next was an in depth evaluation of a specific section (sample station) within the site. Each sample station was measured to be approximately 100 m long and contained all types of habitat evident within the site. A sketch map of each station was made that included GPS coordinates of upper and lower boundaries (Table 1) and salient features and relevant sidebars. Within each sample station discrete mesohabitat segments were defined and sampled separately. Mesohabitat distinctions were based on the general and easily recognized classifications of riffle, pool, and run (see Clarkson 2011). Local gradient was measured for each mesohabitat using a site level (tenths of ft) over the entire mesohabitat (m) when possible (within line of site), otherwise a 5-20 m segment was assessed. Local gradient was determined based on level of the substrate, and negative values were possible in pools where silt had increased elevation at the downstream terminus. Substrate composition as defined by Wentworth (1922; proportion of silt, sand, gravel, cobble, boulder, bedrock and organic matter) and embeddedness in riffles and runs as defined by Davis et al. (2001; loose, mostly loose, mostly embedded, and embedded) were estimated by visual and physical (tactile) inspection. Silt and ash were not differentiated. No specific guidelines were used other than to generally and qualitatively (and subjectively) assess the embeddedness of the stream substrate. Embeddedness was evaluated by attempting to move cobble or boulders within the mesohabitat. The general evaluation ranged from loose (all substrate freely moved) to embedded (no substrate moved freely). The areal coverage of the bottom with silt or other fine material was not assessed, and embeddedness was not assessed in pool habitats because substrate there was mostly silt, sand, or organic matter.

Stream width, depth, and water velocity were measured and discharge was estimated as the product of cross-sectional area and velocity. In 2013, water velocity was estimated from timing the passage of a buoyant float through a measured stream section. In 2014, water velocity was measured in feet per second using a SonTek FlowTracker® with an acoustic Doppler velocimeter probe. One to five measurements of stream width were taken using a 100 m tape, depending on the length of the mesohabitat (typically at start, middle and end of each mesohabitat). Stream depth was measured (up to five replicates) to the nearest cm using a collapsible ruler.

Fishes were sampled using a Smith-Root model 15-B battery powered backpack electrofisher, dip nets, and nylon straight seine (1.8 m x 1.4 m, 0.3 cm mesh). Mesohabitat sections were sampled by single pass backpack electrofishing. Loose substrate was disturbed during the pass to dislodge loach minnow. For each mesohabitat section sampled, electrofisher output voltage was adjusted between 300 and 400 VDC and current was maintained near 0.25 amps. After all habitats were sampled within a station, riffles were kick seined (2 to 5 replicates depending on size) to evaluate loach minnow occurrence in this "preferred" habitat. Effort for this supplemental effort (m^2; number of hauls) was also recorded. All sampling data were recorded separately for each mesohabitat.

Results and Discussion

Site Evaluation

Evaluations for eight sites (Figure 2) during June 2013 and June 2014 are described below.

The KP Creek site (Figure 3) is located on Blue River. Water temperature, air temperature, and conductivity respectively were 24.1° C, 29° C, and 436 µS in the evening of 17 June 2013 and 16.4° C, 24° C and 451 µS in the morning of 24 June 2014. Water was clear and algae were present in both years. Crayfish also were present in both years. Substrate of KP Creek was composed predominately of strewn bedrock, boulders, and cobble and included cliff sides. A percentage of the bank was shaded by an abundance of vegetation including trees. The bank was stable, not eroded, undercuts were not present, and there existed good vegetative stability. In addition to algae, no other aquatic vegetation was recorded either year. Riparian vegetation was less dense than other sites due to the large amount of bedrock on the bank and was dominated by grasses and horsetail (*Equisetum sp.*). Arizona Alder (*Alnus oblongifolia*), willow (*Salix*), sycamore (*Platanus wrightii*), and cottonwood (*Populus*) also were present. A large amount of willow was downed on the bank.

The Grant Creek site (Figure 4) is located on Blue River. Water temperature, air temperature, and conductivity respectively were 22.7° C, 28° C, and 501 µS in the afternoon of 20 June 2013 and 24.6° C, 32° C and 488 µS in the afternoon of 24 June 2014. Water was clear and algae were present in both years. Crayfish also were present in both years. Tadpoles were observed in 2014 in large numbers. Boulder and cobble were common while gravel and sand comprised substrate in pools. The bank was relatively unstable and eroded, and undercut banks were present. Vegetative stability was good. A large amount of algae was observed along with watercress (*Nasturtium*) and riparian vegetation was moderate in density and predominated by shrubs. Vegetation included grasses, horsetail, willow, alder, cottonwoods, and Arizona walnut (*Juglans major*).

The Jones Canyon site (Figure 5) is located on Blue River. Water temperature, air temperature, and conductivity respectively were 12.0° C, 15° C, and 429 µS in the morning of 20 June 2013 and 15.8° C, 24° C and 444 µS in the late afternoon of24 June 2014. Water was clear and algae were only recorded as present in 2013. Crayfish were present in both years. Stream substrate at Jones Canyon was composed mostly of incised sand and cobble with some boulders and trees. The bank of the Jones Canyon site ranged from steep to flat and had some local areas of erosion but was mostly stable. Vegetative stability was good. Riparian vegetation was predominately shrubs such as alder and willow, but also included grasses, horsetail, box elder (*Acer negundo*), cottonwood, and ponderosa pine (*Pinus ponderosa*). Approximately half the site was shaded in 2013, while in 2014 most of the trees were fallen and much of the boulder and cobble appeared freshly moved, indicating a recent flooding event. In 2013, the entire reach was wetted, but in 2014 the river flowed subsurface just downstream of the Jones Canyon site.

The Bobcat Flat site (Figure 6) is located on Blue River. Water temperature, air temperature, and conductivity respectively were 27.8° C, 34° C, and 365 µS in the afternoon of 20 June 2013 and 15.3° C,

24° C and 410 µS in the morning of 26 June 2014. Water was clear and algae were present in both years. Crayfish also were present in both years. The upstream section of the site exhibited an incised soil bank while the downstream section was composed more of bedrock. The bank was unstable and could easily erode although vegetative stability was good. Aquatic vegetation was not recorded in 2013, but watercress was present in 2014. Riparian vegetation was dominated by grasses and shrubs and included willow. Box elder and cottonwood also were observed. In 2014, there was a large beaver pool at the top of the site which required station mesohabitat measurements to be moved downstream. Stations in 2014 were therefore slightly less vegetated than stations in 2013.

The Turkey Creek site (Figure 7) is located on Campbell Blue Creek. Water temperature, air temperature, and conductivity respectively were 27.5° C, 25° C, and 288 µS in the afternoon of 18 June 2013 and 20.0° C, 28° C and 317 µS in the late afternoon of 23 June 2014. Water was clear and algae were present in both years. Crayfish also were present in both years. Turkey Creek habitat characteristics differed greatly from 2013 to 2014. In 2013 the bank was stable with only some local areas of erosion. There were few trees but there was an abundance of grasses and willows creating good vegetative stability. In 2014, there were indications of a recent scour. The bank was mostly lined with boulder and cobble and little vegetation was present, creating poor vegetative stability conditions. Undercuts were also observed. Watercress was present in 2013 while no aquatic vegetation was observed in 2014. Riparian vegetation in 2014 was predominated by grasses and trees. In 2013, vegetation included willow and alder but only young willow was observed in 2014, none of which was overhanging. Arizona walnut and pine were recorded in the upper half of the site. Fish and tadpoles were common throughout the site's cobbled riffles and runs.

The Luce Ranch site (Figure 8) is located on Campbell Blue Creek. Water temperature, air temperature, and conductivity respectively were 19.6° C, 26° C, and 269 µS in the morning of 18 June 2013 and 22.6° C, 31° C and 286 µS in the afternoon of 26 June 2014. Water was clear and algae were present in both years. Crayfish also were present in both years. The banks at Luce Ranch were flat and stable. In 2013 a large amount of woody vegetation was observed along the banks. Aquatic vegetation included filamentous algae, watercress, and water hyacinth (*Eichhornia crassipes*). Riparian vegetation was predominated by shrubs and consisted of grasses, poison ivy (*Toxicodendron radicans*), clover (*Trifoliu*), juvenile and adult willow, alder, a large amount of box elder, ponderosa pine, and sycamore. Additionally, several sparsely vegetated point bars split the channel along the site increasing habitat complexity.

The Dry Blue site (Figure 9) is located on Dry Blue Creek. Water temperature, air temperature, and conductivity respectively were 14.1° C, 21° C, and 417 µS in the morning of 19 June 2013 and 15.6° C, 25° C and 429 µS in the morning of 25 June 2014. Water was clear and algae were present in both years. Crayfish also were present in both years. Downstream, the bank was low, wide, and stable, composed of sand and gravel, supported by riparian grasses and shrubs, creating good vegetative stability. Upstream, the bank became sandy, eroded, and less stable. A large amount of undercut bank was present. Watercress and a large amount of algae were recorded in both years. Riparian vegetation was dominated by grasses and shrubs that included multiple age stands of willow and alder. Cottonwood and pine also were present. Tadpoles were observed in riffles in 2013. In 2013, the stream was

described to split at multiple locations (braided channel) and was dry for a quarter mile in the most upstream section of the site. Downstream stations appeared more channelized in 2014 than 2013, and with less water.

The Pace Creek site (Figure 10) is located on Pace Creek. Water temperature, air temperature, and conductivity respectively were 23.5° C, 33° C, and 494 µS in the afternoon of 25 June 2014. The site was mostly dry on 19 June 2013. Where water was present, it was clear though algae were observed. Crayfish were recorded in 2013 but not in 2014. The bank was composed of boulders and cobble; it was unstable, displayed signs of erosion, and had only fair vegetative stability. Riparian vegetation consisted predominately of pines and included some grasses. There was little water at this site. The water flows subsurface causing the upper half of the site to be dry. Water started near the lower site boundary in 2014. Sampling was not completed in 2013 because the majority of the site was dry or lightly wetted.

Station Evaluation

Five native fish species, loach minnow, desert sucker, Sonora sucker, speckled dace, and longfin dace, and one non-native fish, brown trout (*Salmo trutta*) were collected from Blue River, Campbell Blue Creek, Dry Blue Creek, and Pace Creek (Table 2). Blue River at Grant Creek was the most productive site in 2014 (598 individuals among five species), while Blue River at Jones Canyon was the most productive in 2013 (293 individuals among five species). Similar to 2013, speckled dace was the most abundant species overall in 2014 and distributed among all sites samples (1092 individuals; 35% of total catch; Table 2). All five native species were encountered at Blue River at Jones Canyon and Bobcat Flat in both 2013 and 2014. Native fish catch in Blue River was 2.5 times greater in 2014 than in 2013. This is greater than October 2011 and July 2012 surveys as well (Kesner et al. 2011, Patterson et al. 2012). Mean electrofishing catch per unit effort (CPUE, fish per 100 s) was 32 across all sites (Table 2) and varied among sites from 17 (Dry Blue Creek) to 45 (Jones Canyon). Variation in CPUE within Blue River mainstem sites was from 33 (KP Creek) to 45 (Jones Canyon).

Loach minnow catch increased to a total of 23 individuals in June 2014 compared to 11 in June 2013, four in July 2012, and five in October 2011. Loach minnow was present in Blue River at Bobcat Flat (2013, 2014), Jones Canyon (2013, 2014), and Grant Creek (2014), as well as in Campbell Blue Creek at Turkey Creek (2014). Turkey Creek, Bobcat Flat, and Jones Canyon all are within 7 km of each other (Figure 1). Proximity of these sites may have influenced the presence of loach minnow at Turkey Creek from 2013 to 2014. Grant Creek is the next downstream site after Jones Canyon but is more than 20 km away.

Only speckled dace and longfin dace were captured at Dry Blue Creek and Pace Creek in 2014, significant because longfin dace were not captured at Dry Blue Creek in 2013. Speckled dace and longfin dace were captured at all sites in 2014. Desert sucker was captured at six of eight sites, an increase from 2013, and Sonora sucker was captured at three of eight sites, a decrease from 2013. Longfin dace young-of-year were captured only at Blue River mainstem sites and speckled dace young-of-year were captured at all sites except those on Campbell Blue Creek. Juvenile suckers (undetermined but likely including both species) also were captured at all Blue River sites and Campbell Blue Creek at Turkey Creek (Table 2).

Non-native catch was restricted to brown trout, which was not encountered at Campbell Blue Creek at Turkey Creek in 2014 after small catches there in 2013. Though not captured in 2013, brown trout was present in 2014 in Blue River at Bobcat Flat and catch increased two orders of magnitude from 2013 to 2014 in Campbell Blue Creek at Luce Ranch. Non-native crayfish were present at all sites and in relatively high numbers. Green, filamentous algae was present at all sites in 2013 and all sites except Jones Canyon in 2014.

Substrate at Blue River mainstem sites (Bobcat Flat, Grant Creek, Jones Canyon, and KP Creek) tended toward sand, gravel, and cobble although Bobcat Flat had a higher percentage of silt (Table 3). Habitats alternated between low and high gradient riffles and runs with seven pool mesohabitats sampled in the mainstem in 2014 compared to only two in 2013 (Table 4). Campbell Blue Creek sites had similar substrate compositions with higher percentages of cobble while Dry Blue and Pace Creeks had no boulders present. Local gradients also were variable. Only one pool was sampled in non-mainstem sites, which was at Luce Ranch. Substrate embeddedness was generally high (Table 5) at all Blue River mainstem and tributary sites.

Typical loach minnow habitat has been identified as shallow (<20 cm) riffles of medium current (30-40 cm/s) over substrate of pebble-cobble or coarse gravel and small rubble (Barber and Minckley 1996, Turner and Tafanelli 1983, Rinne 1989, Propst and Bestgen 1991). Most sites sampled in 2013 had mean depths less than 20 cm while no sites sampled in 2014 had a mean depth of less than 20 cm (Table 6). Approximately half of the sites sampled in both 2013 and 2014 were riffles. Approximately one sixth of sites sampled in 2013, and one eighth of those sampled in 2014 had mean velocity measurements between 30 and 40 cm/s (Table 6). Most sites sampled in 2013 and approximately half of the sites sampled in 2014 had substrate composed predominately of gravel and cobble.

Of sites at which loach minnow was present, the species was distributed relatively equally across mesohabitat types (Table 7). Loach minnow were captured approximately 30% of the time in all pools, riffles, and runs sampled. These results conflict with previous studies that suggest loach minnow are more likely to be found in riffles (Turner and Tafanelli 1983, Rinne 1989, Propst and Bestgen 1991). The presence of loach minnow in runs and pools at Jones Canyon in 2013 and 2014 and Bobcat Flat in 2014 may be a product of a source of loach minnow already occurring in adjacent or nearby riffles at these sites. Half of the runs and pools where loach minnow were present occurred in direct proximity of a riffle where loach minnow were captured. However, this does not account for the three individual loach minnow caught in a run at Grant Creek in 2014 where loach minnow were found in no other mesohabitat types. Besides substrate of cobble and gravel, there was nothing significantly recorded about this site that would make it ideal loach minnow habitat.

There was little difference in stream width where loach minnow was found, as compared by means and ranges of physical characteristics of mesohabitats sampled. However, loach minnow were more commonly present in mesohabitats of comparatively greater depth and slower velocity (Table 7). Rinne (1989) and Barber and Minckley (1966) identified depths less than 20 cm as loach minnow habitat yet mean depth of mesohabitats with loach minnow present was more than four times that value (94.45

cm, [8.8-258.3 cm]). Rinne (1989) also described ideal velocities for loach minnow habitat to fall between 30 and 40 cm/s while Propst and Bestgen (1991) recorded velocities of 24-80 cm/s for adults. Mean velocities observed here were approximately half of these lower ranges (16.44 cm/s [4.8-33.3 cm/s]). Calculated gradient of sites where loach minnow were present (7.53 m/km [-27.4-51.8 m/km]) was slightly higher than the upper range reported by Propst and Bestgen (1991) (3-6 km/m) (Table 7).

Proportion of native suckers in samples was greater at mesohabitat sites where loach minnow was present compared to sites without loach minnow. (Table 8). The catch proportion of native longfin dace and speckled dace was less where loach minnow was present compared to where the species was absent. However, speckled dace was still present at 16 of 17 mesohabitat sites where loach minnow occurred. Minckley (1973) reported speckled dace was found in association with the loach minnow though it was generally at higher water levels. Loach minnow were not found at Luce Ranch where large numbers of brown trout were captured, but were present in relatively high numbers at Bobcat Flat where only one brown trout was captured. It is unknown if loach minnow may have been suppressed by brown trout as this site, as has been demonstrated for another native cyprinid, Little Colorado spinedace (*Lepidomeda vittata*) and non-native rainbow trout (*Oncorhynchus mykiss*; Blinn et al. 1993).

All mesohabitat sites in 2013 where loach minnow were present were described as having substrate consisting of cobble and gravel but ranged between a loose and embedded substrate disposition (Table 9). In 2014, while cobble and gravel was the most common substrate composition type, mesohabitat sites where loach minnow were present also included sites composed of predominately only cobble or only gravel, as well as sand and silt (Table 10). The majority of these 2014 mesohabitat sites were described as having embedded substrate though several did exhibit a loose substrate disposition. Embedded substrate disposition contrasts with those of “high-quality” loach minnow streams that typically are characterized by an abundance of loose, gravel substrates in riffles. Embeddedness in Blue River may have been associated with high levels of silt, low local gradient, and persistence of ash and sediment washed into the stream with post-Wallow Fire runoff. Overall, Jones Canyon had looser substrate in 2014 as compared to 2013. Looser substrate may be more typical for these sites and they may recover given time. Only mesohabitats of sites where loach minnow were present were compared.

Although sample sizes were smaller here compared to previous studies of loach minnow habitat preference, this study was able to establish loach minnow presence in atypical habitat types as previously defined. The species was found in pools and runs as well as riffles, and in deeper waters of slower current velocities. Loach minnow was present at sites in 2014 where it had not been recorded in 2013, and in greater numbers per unit effort. The increase in loach minnow presence does not appear to be due to an increase in preferred habitat type at Blue River. Rather, loach minnow may have a wider threshold (tolerance) for habitat type that suggested by previous studies. An important outcome of this observation is that loach minnow repatriation and transplantation into runs and pools may have better likelihood of success than previously predicted. This information allows for less stringent habitat requirements when determining stocking sites, which creates an increase in stocking opportunities.

Acknowledgements

We thank Stephanie Coleman (USFS) for field assistance and facilitating financial support, and Edyth Hermosillo (USGS) for field assistance. Appropriate collecting permits were issued by US Fish and Wildlife Service and Arizona Game and Fish Department.

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Table 1. Sample sites visited June 23-26, 2014 to assess loach minnow habitat within the upper Blue River drainage, Greenlee Co., Arizona and Catron Co., New Mexico. Regional gradient was the different in elevation between start and end UTM coordinates as determined from TOPO® maps.

General location	Site name	UTM at start	UTM at end	Gradient (m/km)
Blue River	KP Creek	666918E, 3711250N	666974E, 3711986N	10.5
	Grant Creek	669216E, 3716505N	669381E, 3716721N	20.0
	Jones Canyon	677259E, 3727424N	677615E, 3727976N	16.3
	Bobcat Flat	680631E, 3732016N	680662E, 3732423N	12.0
Campbell Blue Creek	Turkey Creek	679053E, 3734568N	678664E, 3734467N	15.7
	Luce Ranch	675136E, 3734618N	674801E, 3734599N	17.9
Dry Blue Creek	Dry Blue	681878E, 3733811N	682216E, 3734570N	17.6
Tributaries	Pace Creek	683126E, 3736798N	682379E, 3737220N	16.0

Table 2. Total combined catch (number of fish) for electrofishing, kick seining, and dip netting for seven sites sampled in the upper Blue River drainage, Greenlee Co., Arizona, June 23-26, 2014. Catch per unit effort (CPUE) was calculated as the number of fish captured for each 100 seconds of electrofishing.

General location	Site name	Loach minnow	Desert sucker	Sonora sucker	YOY sucker	Speckled dace	YOY speckled dace	Longfin dace	YOY longfin dace	YOY minnow	Brown trout	YOY brown trout	Total catch	Total E-fishing catch	E-fishing effort (sec)	CPUE
Blue River																
	KP Creek	0	32	0	26	61	25	285	106	0	0	0	535	485	1466	33
	Grant Creek	3	29	0	413	101	6	34	12	0	0	0	598	447	1299	34
	Jones Canyon	8	14	6	104	87	25	25	20	5	0	0	294	294	653	45
	Bobcat Flat	10	27	10	187	152	79	81	21	0	0	1	568	564	1348	42
Campbell Blue Creek																
	Turkey Creek	2	31	0	100	99	0	96	0	1	0	0	329	323	1208	27
	Luce Ranch	0	54	11	0	121	0	8	0	0	12	254	460	456	1576	29
Dry Blue Creek																
	Dry Blue	0	0	0	0	121	4	12	0	0	0	0	137	137	786	17
Tributaries																
	Pace Creek	0	0	0	0	208	3	5	0	0	0	0	216	216	703	31
Totals		23	187	27	830	950	142	546	159	6	12	255	3137	2922	9039	32

Table 3. Mesohabitat-specific substrate composition as percentage, Blue River and selected tributaries, Greenlee Co., Arizona, June 23-23, 2014.

Stream	Site	Mesohabitat	Silt	Sand	Gravel	Cobble	Boulder	Bedrock	Organic matter
Blue River	KP Creek	Pool	5	80	15	0	0	0	0
		Pool	0	50	40	10	0	0	0
		Riffle	0	10	10	70	10	0	0
		Riffle	0	5	5	70	20	0	0
		Riffle	0	10	10	70	10	0	0
		Run	0	10	0	80	10	0	0
		Run	0	10	20	70	0	0	0
Blue River	Grant Creek	Pool	0	80	20	0	0	0	0
		Riffle	0	10	30	60	0	0	0
		Riffle	0	20	0	20	40	0	0
		Riffle	0	40	10	50	10	0	0
		Run	0	30	70	0	0	0	0
		Run	0	20	40	40	0	0	0
		Run	0	70	30	0	0	0	0
Blue River	Jones Canyon	Pool	0	70	0	25	5	0	0
		Riffle	0	10	10	70	10	0	0
		Riffle	0	10	20	70	0	0	0
		Run	0	80	10	10	0	0	0
		Run	0	30	60	10	0	0	0
Blue River	Bobcat Flat	Pool	90	0	10	0	0	0	0
		Pool	90	0	5	5	0	0	0
		Riffle	0	0	0	0	0	0	0
		Riffle	10	10	30	40	10	0	0
		Riffle	10	0	60	30	0	0	0
		Riffle	10	0	40	50	0	0	0
		Riffle	20	0	40	40	0	0	0
		Run	60	30	10	0	0	0	0
		Run	10	10	40	40	0	0	0
Campbell Blue Creek	Turkey Creek	Riffle	0	10	15	70	5	0	0
		Riffle	0	10	5	70	15	0	0
		Run	0	30	45	10	5	0	0
		Run	0	90	0	10	0	0	0
Campbell Blue Creek	Luce Ranch	Riffle	0	5	10	80	5	0	0
		Riffle	0	10	10	50	30	0	0
		Riffle	5	5	20	50	20	0	0
		Run	0	0	80	20	0	0	0
		Run	20	10	10	50	10	0	0
Dry Blue Creek	Dry Blue	Riffle	0	40	40	20	0	0	0
		Run	0	90	10	0	0	0	0
		Run	0	30	40	30	0	0	0
Pace Creek	Pace Creek	Riffle	0	0	0	0	0	0	0
		Run	0	10	40	50	0	0	0

Table 4. Mesohabitat-specific (local) gradient, Blue River and selected tributaries, Greenlee Co., Arizona, June 23-26, 2014. Local gradient was converted to m/km for comparison with regional estimates from Table 1, field units are provided in methods.

Stream	Site	Mesohabitat	Gradient (m/km)
Blue River	KP Creek	Pool	12.57
		Pool	4.27
		Riffle	19.93
		Riffle	-41.05
		Riffle	46.74
		Run	4.00
		Run	-0.90
Blue River	Grant Creek	Pool	-0.32
		Riffle	1.22
		Riffle	28.14
		Riffle	30.78
		Run	15.41
		Run	0.61
		Run	-2.27
Blue River	Jones Canyon	Pool	1.89
		Riffle	13.55
		Riffle	9.40
		Run	0.91
		Run	7.33
Blue River	Bobcat Flat	Pool	-27.43
		Pool	-4.25
		Riffle	19.81
		Riffle	32.85
		Riffle	6.97
		Riffle	150.37
		Riffle	53.85
		Run	-0.11
		Run	2.68
Campbell Blue Creek	Turkey Creek	Riffle	17.78
		Riffle	29.19
		Run	-0.16
		Run	1.27
Campbell Blue Creek	Luce Ranch	Riffle	34.93
		Riffle	23.85
		Riffle	19.25
		Run	6.81
		Run	2.37
Dry Blue Creek	Dry Blue	Riffle	10.85
		Run	3.05
		Run	2.38
Pace Creek	Pace Creek	Riffle	19.88
		Run	1.37

Table 5. Mesohabitat-specific substrate embeddedness as percentage of each of four qualitative categories, Blue River and selected tributaries, Greenlee Co., Arizona, June 23-26, 2014.

Stream	Site	Mesohabitat	Sand + Silt (%)	Embedded	Mostly embedded	Mostly loose	Loose
Blue River	KP Creek	Pool	0	10	80	10	0
		Pool	0	90	10	0	0
		Riffle	0	80	20	0	0
		Riffle	85	0	10	70	20
		Riffle	0	0	90	10	0
		Run	0	0	60	40	0
		Run	0	10	80	10	0
Blue River	Grant Creek	Pool	0	0	5	5	90
		Riffle	0	0	10	70	20
		Riffle	0	0	80	20	0
		Riffle	0	0	60	40	0
		Run	0	0	70	30	0
		Run	0	0	80	20	0
		Run	0	0	80	20	0
Blue River	Jones Canyon	Pool	0	0	20	80	0
		Riffle	0	0	80	20	0
		Riffle	0	0	80	20	0
		Run	0	0	60	40	0
		Run	0	0	70	30	0
Blue River	Bobcat Flat	Pool	0	0	0	0	0
		Pool	90	0	0	0	0
		Riffle	20	60	30	10	0
		Riffle	20	10	20	50	20
		Riffle	0	0	20	70	10
		Riffle	0	0	0	0	0
		Riffle	0	0	10	60	30
		Run	0	0	0	0	0
		Run	0	0	0	40	40
Campbell Blue Creek	Turkey Creek	Riffle	0	0	90	0	10
		Riffle	0	5	20	70	5
		Run	0	10	40	40	10
		Run	0	0	10	0	90
Campbell Blue Creek	Luce Ranch	Riffle	0	20	30	40	10
		Riffle	0	60	30	10	0
		Riffle	0	0	20	60	20
		Run	30	10	40	40	10
		Run	10	10	40	40	10
Dry Blue Creek	Dry Blue	Riffle	0	0	10	10	80
		Run	0	0	10	20	70
		Run	0	10	20	40	30
Pace Creek	Pace Creek	Riffle	0	0	60	40	0
		Run	0	0	0	0	0

Table 6. Physical stream measurements and estimated current velocity and discharge, Blue River and selected tributaries, Greenlee Co., Arizona, June 23-26, 2014. Standard deviations of means are provided in parentheses. Estimates of discharge are based on mean width and depth measurements and estimated velocity.

Stream	Site	Mesohabitat	Total mesohabitat length (m)	Mean width (m)	Mean depth (cm)	Mean velocity (m/s)	Discharge (m3/s)	Discharge (cfs)
Blue River	KP Creek	Pool	16	7.1 (3.4)	125 (5)	0.16 (0.2)	1.40	49.37
		Pool	10	3.3 (0.9)	323.3 (266)	0.3 (0.3)	3.21	113.36
		Riffle	13	2.8 (0.5)	148.3 (40.1)	0.24 (0.2)	1.01	35.54
		Riffle	42	4.6 (0.8)	138.3 (10.4)	0.31 (0.2)	1.97	69.66
		Riffle	9	3.4 (2)	113.3 (40.4)	0.43 (0.1)	1.65	58.27
		Run	48	3.8 (0.1)	318 (101)	0.11 (0.1)	1.35	47.78
		Run	17	4.9 (2.1)	175 (143.1)	0.12 (0)	0.99	34.83
Blue River	Grant Creek	Pool	47	5.7 (1.3)	146.7 (63.3)	0.08 (0)	0.63	22.24
		Riffle	5	5.7 (0.8)	98.3 (17.6)	0.11 (0.1)	0.63	22.10
		Riffle	26	4 (1)	166.7 (55.1)	0.22 (0.2)	1.47	51.91
		Riffle	10	5 (0.6)	126.7 (40.4)	0.32 (0.2)	2.00	70.70
		Run	18	1.8 (1)	90 (43.6)	0.14 (0)	0.23	8.02
		Run	35	5.6 (1.4)	121.7 (33.3)	0.12 (0)	0.81	28.44
		Run	43	5.9 (3.7)	176.7 (67.9)	0.08 (0.1)	0.88	31.21
Blue River	Jones Canyon	Pool	29	4.2 (1.8)	120 (20)	0.1 (0.1)	0.51	18.03
		Riffle	9	2.7 (1)	90 (40)	0.11 (0.1)	0.28	9.75
		Riffle	12	4.3 (0.7)	111.7 (59.2)	0.09 (0)	0.45	15.78
		Run	20	2.8 (1)	130 (47.7)	0.05 (0)	0.17	6.06
		Run	37	2.5 (0.5)	118.3 (33.3)	0.2 (0.2)	0.57	19.96
Blue River	Bobcat Flat	Pool	7	2.4 (0.5)	258.3 (155.1)	0.12 (0.1)	0.71	24.99
		Pool	28	4.6 (1.8)	218.3 (98)	0.05 (0)	0.48	17.05
		Riffle	6	3.7 (1.9)	66.7 (12.6)	0.39 (0.2)	0.95	33.54
		Riffle	9	3.5 (0.8)	98.3 (10.4)	0.29 (0.1)	1.02	35.99
		Riffle	7	1.8 (0.1)	120 (22.9)	0.29 (0.1)	0.63	22.14
		Riffle	3	2.7 (0.6)	90 (10)	0.61 (0.3)	1.46	51.63
		Riffle	6	3.6 (1.2)	108.3 (71.8)	0.26 (0.2)	1.02	36.13
		Run	27	5.8 (3.6)	108.3 (51.1)	0.13 (0.1)	0.81	28.61
		Run	25	3 (0.6)	126.7 (23.1)	0.15 (0)	0.58	20.32
Campbell Blue Creek	Turkey Creek	Riffle	85	2.9 (0.7)	78.3 (62.5)	0.2 (0.2)	0.46	16.06
		Riffle	26	3.2 (0.5)	125.7 (57.3)	0.3 (0.2)	1.21	42.67
		Run	39	3.2 (1)	90 (8.7)	0.38 (0.2)	1.09	38.31
		Run	24	3.7 (0.5)	190 (78.6)	0.06 (0)	0.42	14.82
Campbell Blue Creek	Luce Ranch	Riffle	13	2.6 (0.8)	110 (50.7)	0.3 (0)	0.84	29.76
		Riffle	34	5.1 (1.5)	148.3 (32.1)	0.28 (0.1)	2.14	75.40
		Riffle	35	5 (1.6)	128.3 (43.1)	0.31 (0.2)	1.99	70.17
		Run	100	6 (2.1)	105 (109)	0.14 (0)	0.90	31.90
		Run	18	4.4 (0.8)	151.7 (11.5)	0.26 (0.1)	1.78	62.68
Dry Blue Creek	Dry Blue	Riffle	34	2.1 (0.2)	91.7 (27.5)	0.25 (0.1)	0.46	16.37
		Run	29	2 (0.2)	93.3 (20.8)	0.27 (0)	0.52	18.37
		Run	50	2.8 (0.5)	91.7 (28.4)	0.24 (0.1)	0.59	20.97
Pace Creek	Pace Creek	Riffle	65	1.8 (0.6)	48.3 (7.6)	0.02 (0)	0.02	0.73
		Run	40	1.8 (0.5)	86.7 (76.4)	0.05 (0)	0.09	3.02

Table 7. Number of mesohabitat types where loach minnow was present and mean physical characteristics where loach minnow was present, Blue River and selected tributaries, Greenlee Co., Arizona, June 17-21, 2013 and June 23-26, 2014. Only sites where loach minnow were present are included. Ranges are provided in parenthesis.

Loach minnow	Pool	Riffle	Run	Width (m)	Depth (cm)	Max depth (cm)	Velocity (cm/s)	Gradient (m/km)
present	2	9	6	3.15, (1.8-5.6)	94.45, (8.8-258.3)	205.07, (18.5-480)	16.44, (4.8-33.3)	7.53, (-27.4-51.8)
not present	5	21	13	3.7, (1.6-8.3)	71.73, (5.7-218.3)	156.02, (13-595)	20.76, (4.8-61)	14.23, (-42.7-150.4)

Table 8. Mean species composition among mesohabitats where loach minnow was present, Blue River and selected tributaries, Greenlee Co., Arizona, June 17-21, 2013 and June 23-26, 2014. Only sites where loach minnow were present are included. Ranges are provided in parenthesis.

		Mean percentages						
Loach minnow	**Sum of fish**	**AGCH**	**CAIN**	**FISH**	**PACL**	**RHOS**	**SATR**	**TICO**
present	1354 (2-261)	17.15 (0-33.3)	3.19 (0-26.6)	1.19 (0-10.5)	29.5 (0-68)	39.73 (0-71.4)	0 (0-0)	9.22 (0.8-100)
not present	1230 (0-151)	27.58 (0-75)	2.97 (0-41.7)	1.33 (0-25)	20.79 (0-100)	47.19 (0-100)	0.15 (0-3.7)	0 (0-0)

Table 9. Physical characteristics of each mesohabitat site in 2013. Sites where loach minnow were present are highlighted.

Stream	Site	Mesohabitat	Gear type	TICO count	Mean width (m)	Mean depth (cm)	Mean max depth (cm)	Mean velocity (cm/s)	Mean gradient (m/km)	Substrate > 60%	Substrate embeddedness
Blue River	KP Creek	Pool	backpack shocker	0	5.7	14.1	25	NA	NA	silt	NA
		Riffle	backpack shocker	0	3.1	14	23.9	23.8	NA	cobble-gravel-sand	embedded
		Riffle	kick seine	0	3.1	14	23.9	23.8	NA	cobble-gravel-sand	embedded
		Run	backpack shocker	0	4.4	18.2	30.5	4.8	NA	cobble-sand-silt	loose
	Grant Creek	Riffle	backpack shocker	0	8.3	6.4	13	18.5	7.9	cobble-gravel	embedded
		Riffle	kick seine	0	8.3	6.4	13	18.5	7.9	cobble-gravel	embedded
		Run	backpack shocker	0	6.7	11.3	30	9.4	-6.1	gravel-sand	embedded
	Jones Canyon	Pool	backpack shocker	0	2.3	23	39	7.7	-42.7	cobble-gravel	embedded
		Riffle	backpack shocker	1	1.9	12.3	18.5	33.3	27.4	cobble-gravel	embedded
		Riffle	kick seine	0	1.9	12.3	18.5	33.3	27.4	cobble-gravel	embedded
		Riffle	backpack shocker	5	3.9	8.8	19.5	14.3	51.8	cobble-gravel	NA
		Riffle	kick seine	0	3.9	8.8	19.5	14.3	51.8	cobble-gravel	NA
		Riffle	backpack shocker	0	1.6	12	15	37.5	89.4	cobble-gravel	embedded
		Riffle	kick seine	0	1.6	12	15	37.5	89.4	cobble-gravel	embedded
		Run	backpack shocker	0	3.1	16.7	25	13.9	-7.9	Cobble-sand-silt	embedded
		Run	backpack shocker	2	2.6	10.8	24	8.5	-5.2	cobble-gravel	embedded
		Run	backpack shocker	0	2	15	27	7	-4.3	cobble-gravel	embedded
	Bobcat Flat	Riffle	backpack shocker	2	3.1	11.5	24	18.2	9.1	cobble-gravel	loose
		Riffle	kick seine	1	3.1	11.5	24	18.2	9.1	cobble-gravel	loose
		Run	backpack shocker	0	3.1	20.3	48	8.2	-27.7	cobble-gravel	embedded
Campbell Blue Creek	Turkey Creek	Pool	backpack shocker	0	2.6	20.2	38.5	15.4	-39.6	cobble-gravel	embedded
		Riffle	backpack shocker	0	3.2	5.7	16	37.5	20.1	gravel	loose
		Riffle	kick seine	0	3.2	5.7	16	37.5	20.1	gravel	loose
		Riffle	backpack shocker	0	2.2	9.3	21	36.4	25	cobble-gravel	loose
		Riffle	kick seine	0	2.2	9.3	21	36.4	25	cobble-gravel	loose

		Riffle	backpack shocker	0	2.6	7.2	19	26.7	37.8	cobble	embedded
		Riffle	kick seine	0	2.6	7.2	19	26.7	37.8	cobble	embedded
		Run	backpack shocker	0	1.9	14.2	25	23.8	-29.3	cobble-gravel-silt	loose
		Run	backpack shocker	0	2.5	19	37	17.3	-10.2	silt-gravel	embedded & loose
		Run	backpack shocker	0	2.9	25.7	50	10.2	21.3	sand-silt-organic matter	loose
	Luce Ranch	Riffle	backpack shocker	0	2.4	18.3	21	50	9.8	gravel	loose
		Riffle	dip net	0	2.4	18.3	21	50	9.8	gravel	loose
		Riffle	kick seine	0	2.4	18.3	21	50	9.8	gravel	loose
		Riffle	backpack shocker	0	2.8	19	30	33.3	23.2	gravel	loose
		Riffle	kick seine	0	2.8	19	30	33.3	23.2	gravel	loose
		Riffle	backpack shocker	0	4.5	18	27	35.7	29.3	boulder-cobble	embedded
		Riffle	kick seine	0	4.5	18	27	35.7	29.3	boulder-cobble	embedded
		Riffle	backpack shocker	0	4.8	15.3	33	29.6	41.5	boulder-cobble	embedded
		Riffle	kick seine	0	4.8	15.3	33	29.6	41.5	boulder-cobble	embedded
		Run	backpack shocker	0	3.7	26.5	41	12.8	-12.2	gravel-sand	loose
		Run	backpack shocker	0	3.1	12.8	22	41.7	1.2	gravel	loose
		Run	dip net	0	3.1	12.8	22	41.7	1.2	gravel	loose
		Run	backpack shocker	0	4.7	17	25	33.2	3.7	cobble-gravel	embedded
Dry Blue Creek	Dry Blue	Pool	backpack shocker	0	2.4	18.3	34	6.2	-3	organic matter	loose
		Pool	dip net	0	2.4	18.3	34	6.2	-3	organic matter	loose
		Riffle	backpack shocker	0	3.6	5.8	9	NA	60.6	gravel-organic matter	embedded & loose
		Riffle	kick seine	0	3.6	5.8	9	NA	60.6	gravel-organic matter	embedded & loose
		Run	backpack shocker	0	2.9	6.3	22	38.5	14.6	cobble	loose
		Run	backpack shocker	0	2.2	11.7	20	34.8	33.5	gravel-organic matter	loose

Table 10. Physical characteristics of each mesohabitat site in 2014. Sites where loach minnow were present are highlighted.

Stream	Site	Mesohabitat	Gear type	TICO count	Mean width (m)	Mean depth (cm)	Mean max depth (cm)	Mean velocity (cm/s)	Mean gradient (m/km)	Substrate > 60%	Substrate embeddedness
Blue River	KP Creek	Pool	backpack shocker	0	3.3	323.3	860	29.7	4.3	sand-gravel	embedded
		Pool	backpack shocker	0	7.1	125	640	15.7	12.6	sand	loose
		Riffle	backpack shocker	0	4.6	138.3	280	31.3	-41	cobble	embedded
		Riffle	kick seine	0	4.6	138.3	280	31.3	-41	cobble	embedded
		Riffle	backpack shocker	0	2.8	148.3	245	24.1	19.9	cobble	embedded
		Riffle	kick seine	0	2.8	148.3	245	24.1	19.9	cobble	embedded
		Riffle	backpack shocker	0	3.4	113.3	210	43	46.7	cobble	embedded
		Riffle	kick seine	0	3.4	113.3	210	43	46.7	cobble	embedded
		Run	backpack shocker	0	4.9	175	400	11.6	-0.9	cobble	embedded
		Run	backpack shocker	0	3.8	318	540	11.2	4	cobble	embedded
	Grant Creek	Pool	backpack shocker	0	5.7	146.7	370	7.5	-0.3	sand	loose
		Pool	kick seine	0	5.7	146.7	370	7.5	-0.3	sand	loose
		Riffle	backpack shocker	0	5.7	98.3	260	11.2	1.2	cobble	embedded
		Riffle	backpack shocker	0	4	166.7	270	22.3	28.1	boulder-cobble-sand	embedded
		Riffle	backpack shocker	0	5	126.7	190	31.7	30.8	cobble-sand	embedded
		Run	backpack shocker	0	5.9	176.7	595	8.4	-2.3	sand	embedded
		Run	backpack shocker	3	5.6	121.7	470	11.8	0.6	cobble-gravel	embedded
		Run	backpack shocker	0	1.8	90	70	14	15.4	gravel	loose
	Jones Canyon	Pool	backpack shocker	1	4.2	120	260	10.1	1.9	sand	embedded
		Riffle	backpack shocker	1	4.3	111.7	230	9.3	9.4	cobble	embedded
		Riffle	backpack shocker	1	2.7	90	110	11.5	13.5	cobble	embedded
		Run	backpack shocker	2	2.8	130	270	4.8	0.9	sand	loose
		Run	backpack shocker	3	2.5	118.3	260	19.5	7.3	gravel	embedded
	Bobcat Flat	Pool	backpack shocker	1	2.4	258.3	480	11.6	-27.4	silt	NA
		Pool	backpack shocker	0	4.6	218.3	415	4.8	-4.2	silt	NA

		Riffle	backpack shocker	2	1.8	120	140	29.2	7	gravel-cobble	loose
		Riffle	kick seine	0	1.8	120	140	29.2	7	gravel-cobble	loose
		Riffle	backpack shocker	0	3.7	66.7	200	38.7	19.8	NA	NA
		Riffle	backpack shocker	2	3.5	98.3	180	29.5	32.9	cobble-gravel	embedded
		Riffle	backpack shocker	0	3.6	108.3	205	26	53.8	cobble-gravel	loose
		Riffle	backpack shocker	0	2.7	90	140	61	150.4	cobble-gravel	loose
		Run	backpack shocker	0	5.8	108.3	330	12.9	-0.1	silt	NA
		Run	backpack shocker	3	3	126.7	380	15.2	2.7	cobble-gravel	loose
		Run	backpack shocker	2	NA	NA	NA	NA	NA	NA	NA
Campbell Blue Creek	Turkey Creek	Riffle	backpack shocker	2	2.9	78.3	210	19.8	17.8	cobble	embedded
		Riffle	backpack shocker	0	3.2	125.7	250	29.7	29.2	cobble	embedded & loose
		Riffle	kick seine	0	3.2	125.7	250	29.7	29.2	cobble	embedded & loose
		Run	backpack shocker	0	3.2	90	260	37.7	-0.2	gravel-sand	loose
		Run	backpack shocker	0	3.7	190	410	6	1.3	sand	loose
		Run	kick seine	0	3.7	190	410	6	1.3	sand	loose
	Luce Ranch	Pool	backpack shocker	0	NA	NA	NA	NA	NA	NA	NA
		Riffle	backpack shocker	0	5	128.3	350	30.9	19.2	cobble-boulder-gravel	embedded & loose
		Riffle	kick seine	0	5	128.3	350	30.9	19.2	cobble-boulder-gravel	embedded & loose
		Riffle	backpack shocker	0	5.1	148.3	250	28.2	23.8	cobble-boulder	loose
		Riffle	kick seine	0	5.1	148.3	250	28.2	23.8	cobble-boulder	loose
		Riffle	backpack shocker	0	2.6	110	195	29.9	34.9	cobble	embedded & loose
		Riffle	kick seine	0	2.6	110	195	29.9	34.9	cobble	embedded & loose
		Run	backpack shocker	0	4.4	151.7	270	26.4	2.4	cobble-silt	embedded & loose
		Run	backpack shocker	0	6	105	290	14.4	6.8	gravel	embedded
Dry Blue Creek	Dry Blue	Run	backpack shocker	0	NA	NA	NA	NA	NA	NA	NA
		Riffle	backpack shocker	0	2.1	91.7	170	24.7	10.8	gravel-sand	loose
		Run	backpack shocker	0	2.8	91.7	130	23.6	2.4	gravel-cobble-sand	loose
		Run	backpack shocker	0	2	93.3	140	27.4	3	sand	loose
Pace Creek	Pace Creek	Riffle	backpack shocker	0	1.8	48.3	240	2.4	19.9	NA	NA
		Run	backpack shocker	0	1.8	86.7	205	5.4	1.4	cobble-gravel	embedded

Figure 1. Map of eight sites in the upper Blue River Basin, Greenlee Co., Arizona and Catron Co., New Mexico, sampled for leach minnow habitat assessment, June 23-26, 2014.

Figure 2. Bobcat Flat 2012 (A), Dry Blue 2014 (B), Grant Creek 2014 (C), Jones Canyon 2014 (D), KP Creek 2014 (E), Luce Ranch 2013 (F), Pace Creek 2013 (G), and Turkey Creek 2014 (H).

Figure 3. KP Creek in 2014 (A, B).

Figure 4. Electrofishing at Grant Creek in 2013 (A) and 2014 (B).

Figure 5. Electrofishing at Jones Canyon in 2013 (A), Jones Canyon site in 2013 (B) and 2014 (C), and downed vegetation at Jones Canyon in 2014 (D).

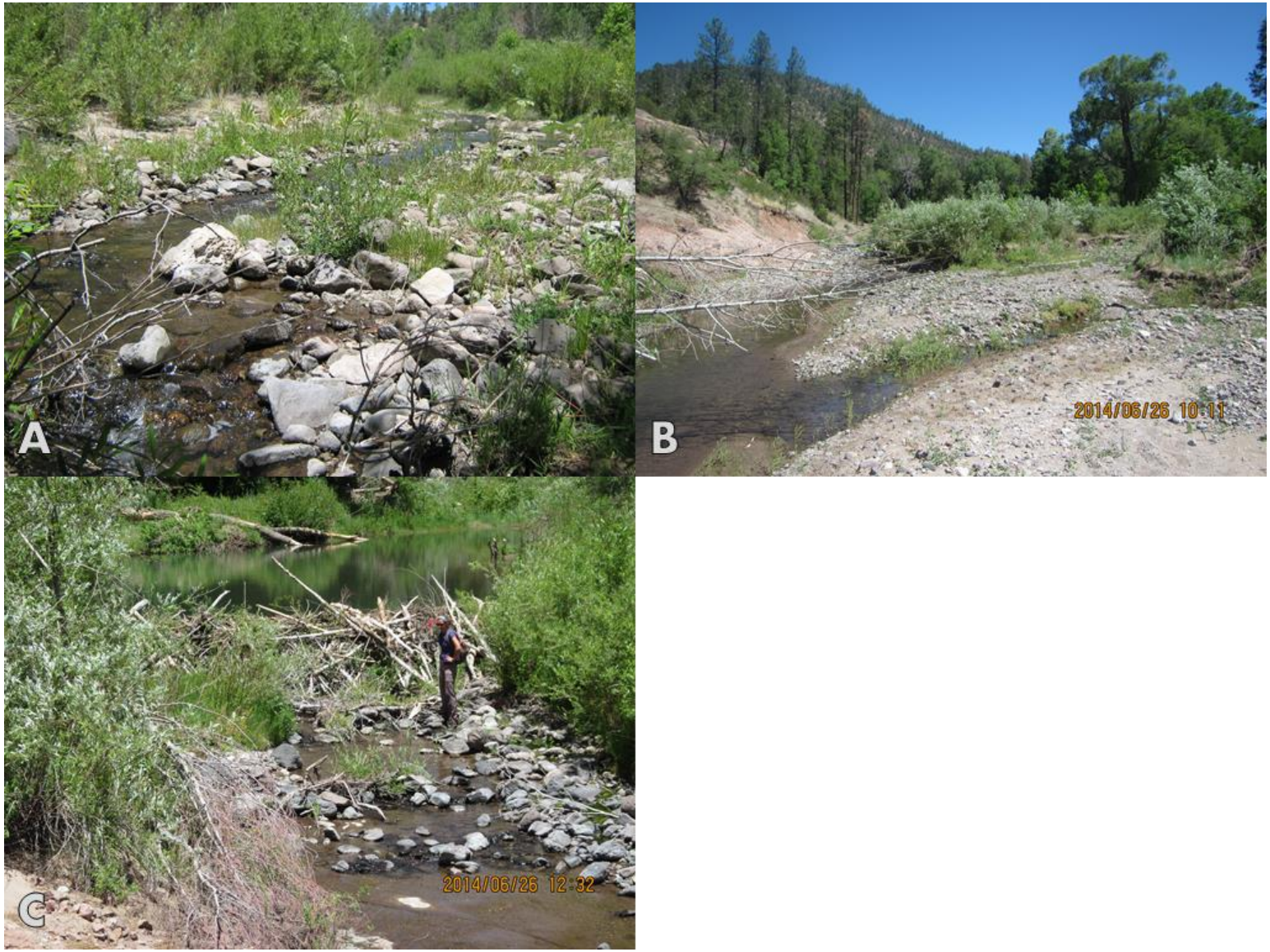

Figure 6. Bobcat Flat in 2013 (A) and 2014 (B). Beaver pond at Bobcat Flat in 2014 (C).

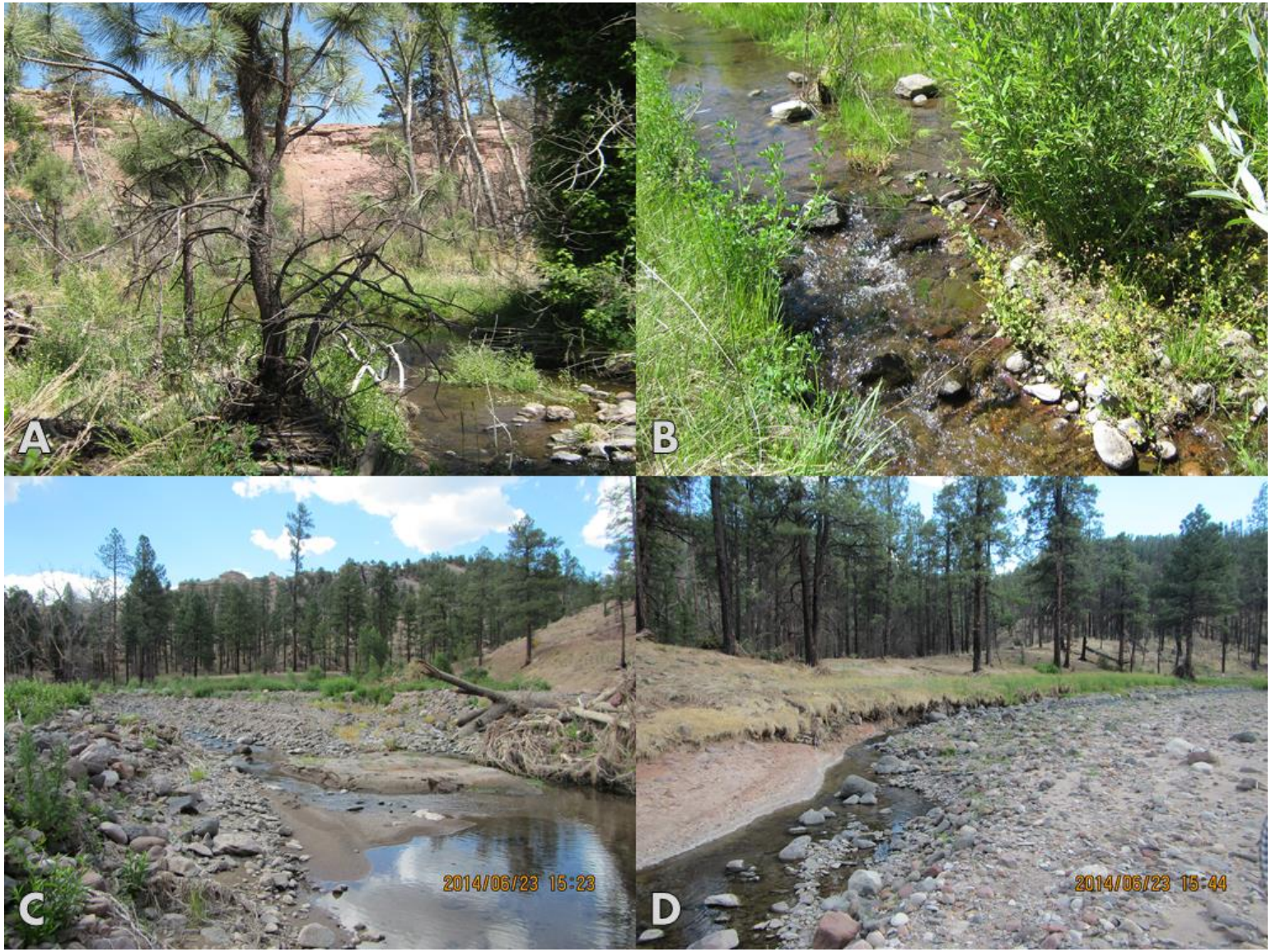

Figure 7. Comparison of vegetation at Turkey Creek in 2013 (A, B) and 2014 (C, D).

Figure 8. Luce Ranch in 2013 (A) and 2014 (B, C).

Figure 9. Dry Blue Creek in 2013 (A) and 2014 (B, C).

Figure 10. Pace Creek dry in 2013 (A, B), Pace Creek slightly wet in 2014 (C), stream measurements being conducted in the lower section of the Pace Creek site (D).