Muleshoe Cooperative Management Area Native Fish Restoration: Monitoring and Stocking During 2011

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INTRODUCTION

During 2007 through 2010 four listed-fish species were stocked into seven waters within the Muleshoe Cooperative Management Area (CMA), near the Galiuro Mountains of Arizona (Appendix 1, Figures 1 thru 3; Robinson 2008; Robinson et al. 2010). Spikedace *Meda fulfida* and loach minnow *Rhinichthys cobitis* were stocked into Redfield Canyon upstream of the confluence with Swamp Springs Canyon. Both species were stocked into Hot Springs Canyon, primarily within a 500-m reach just upstream of the confluence of Wildcat Canyon. Stock of both species originated from Aravaipa Creek, directly so in 2007, but in 2008 thru 2010 from fish propagated at Bubbling Ponds Native Fish Conservation Facility (BPNFCF). Gila topminnow *Poeciliopsis occidentalis* and desert pupfish *Cyprinodon macularius* were stocked into Swamp Springs Canyon, Cherry Spring Canyon, Secret Spring, and Headquarters Spring, and desert pupfish were stocked into Larry & Charlie Tank on the hillside above the Muleshoe Ranch headquarters. Gila topminnow were of Bylas Springs lineage, and originated from Arizona State University in 2007 and from The Nature Conservancy's (TNC) Lower San Pedro River Preserve (Dudleyville) ponds near Dudleyville during 2008. Desert pupfish stocked in 2007, 2008 and 2010 originated from TNC's Dudleyville ponds, whereas those stocked in 2009 were acquired from BPNFCF but originated from Dexter National Fish Hatchery.

The first post-stocking annual monitoring was conducted on September 15-16, 2008 (Robinson 2008). Gila topminnow were present in each of the three sites where they were stocked the previous year. Desert pupfish were present in Secret Springs and Swamp Springs Canyon, but none were found in Cherry Spring Canyon. Both loach minnow and spikedace were present in Redfield Canyon and Hot Springs Canyon. Additional fish of all species were stocked into the same waters on September 17, 2008, except that no additional Gila topminnow or desert pupfish were stocked into Secret Spring. Also, an additional site, Headquarters Spring, was stocked with desert pupfish and Gila topminnow.

The second post-annual monitoring was conducted on September 14-15, 2009 (Robinson et al. 2010). Gila topminnow were captured in all of the sites where they had been stocked. Desert pupfish were only captured in Secret Spring and Cherry Spring. Both loach minnow and spikedace were present in Redfield Canyon and Hot Springs Canyon. On October 28, 2009 more fish were stocked into some of the locations. Gila topminnow had reproduced and had increased in abundance in all of the locations where they had been stocked, so no additional topminnow were stocked in 2009. Source stocks of desert pupfish were low in abundance, so only one site, Larry & Charlie Tank, was stocked in 2009. Stocks of Aravaipa lineage spikedace and loach minnow at BPNFCF produced relatively few offspring, so all were stocked into Hot Springs Canyon, which was thought to have the best and most habitat for the two species.

The third post-annual monitoring was conducted during September 12-14, and October 7-8, 2010 (Robinson et al. 2011). Gila topminnow, of both size classes (≤10 and >10 mm TL) were captured in all of the locations where they had been stocked. Desert pupfish were captured in Larry & Charlie Tank, Secret Spring , and Cherry Spring Canyon (one fish), but none were captured in Swamp Springs Canyon or Headquarters Spring. Loach minnow and spikedace were captured in Hot Springs Canyon, but only one loach minnow and no spikedace were captured in Redfield Canyon.

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This report summarizes the results of the native fish monitoring during September 2011 and subsequent stockings during October 2011. The goal of the stocking program is to establish populations within the systems where the species are stocked (i.e., to repatriate the species to the systems). A population is considered to have established (a successful repatriation) when it is reproducing to the point where it is self-sustaining (Griffith et al. 1989, Bright and Smithson 2001, Armstrong and Seddon 2007). The objectives of monitoring were to: 1) verify persistence of fish species since stocking; 2) detect recruitment of young (and hence reproduction) into the population; 3) evaluate if relative abundance (measured as catch-per-unit effort) increases over time (i.e., from the starting point of zero); 4) determine if species have dispersed outside of the stocking area; 5) assess population viability per recovery plans; and 6) report any non-native fish species captured during monitoring. The objective of the supplemental stockings is to increase the number of individuals to help a population establish.

STUDY AREA

The Muleshoe CMA is located on the southwestern edge of the Galiuro Mountains and west of the Winchester Mountains in southern Arizona. The Muleshoe CMA is jointly managed by U. S. Bureau of Land Management (BLM), U. S. Forest Service, and TNC. The 57,500 acre CMA contains major portions of the Redfield Canyon, Cherry Springs Canyon, and Hot Springs Canyon watersheds, all of which are tributaries to the San Pedro River. The Nature Conservancy's Muleshoe Ranch CMA headquarters is located along Hot Springs Canyon at a location previously known as Hookers Hot Springs.

Before native fish stockings in 2007, fish species reported from Redfield Canyon included Sonora sucker *Catostomus insignis*, desert sucker *Catostomus clarki*, longfin dace *Agosia chrysogaster*, speckled dace *Rhinichthys osculus*, Gila chub *Gila intermedia*, and green sunfish *Lepomis cyanellus* (Griffith and Tiersch 1989, Bureau of Land Management 1998; AGFD Native Fish Database). Gila topminnow were stocked into Redfield Canyon in 1977 (Minckley and Brooks 1985) but did not persist. In Swamp Springs Canyon, longfin dace (SONFISHES and AGFD Native Fish databases) and speckled dace (Bob Rogers, The Nature Conservancy, personal communication) were present. Fish species reported from the Hot Springs Canyon drainage include the same five native fishes found in Redfield Canyon (SONFISHES and AGFD Native Fish databases; Bureau of Land Management 1998). No fish were present in Headquarters Spring, Secret Spring, or Larry & Charlie Tank before stockings in 2007-2009.

Fish monitoring and stockings described in this report occurred within the following waters: Redfield Canyon and its tributary Swamps Springs Canyon, Cherry Spring Canyon, Hot Springs Canyon, and three isolated and unnamed springs (referred to as Secret Spring, Headquarters Spring, and Larry & Charlie Tank) within the Hot Springs Canyon drainage. Length of perennial water in the streams was previously estimated to be 7.5 km in Redfield Canyon, 2.6 km in Swamp Springs Canyon, 5.1 km in Hot Springs Canyon, and 0.7 km in Cherry Spring Canyon, but during dry periods is likely much less and interrupted (Bureau of Land Management 1998). Secret Spring is an earthen pond below a hillside spring and is located about 600 m northwest of the Muleshoe Ranch headquarters. Headquarters Spring is a pooled area at the edge of but within the Hot Springs Canyon stream bed and is located about 25 m east of and down the hill from the Muleshoe Ranch headquarters dormitory building; springs originating near the dormitory drain downhill into the pooled area. During 2009, two small tanks (Larry and Charlie

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Tanks) about 1 m apart were dug below a spring located about 25 m west and on the hillside above the casitas at the Muleshoe Ranch headquarters; a shallow (~3 mm) film of water flowed over the ridge between the two tanks. During May 2010 a trench was dug to join the two tanks, which then became known as Larry & Charlie Tank.

Each of the major stream courses was divided into sections (reaches) to facilitate a stratified random sampling design or to encompass stocking locations (Appendix 1, Figures 1 thru 3). Reaches in Hot Springs Canyon were: Reach 1 = from Bass Canyon down 1.4 km to Wildcat Canyon, Reach 2 = from Wildcat Canyon down 1.7 km to the second unnamed tributary from the south, and Reach 3 = from the lower end of Reach 2 down 3.7 km to the first unnamed tributary from the south. Reaches in Redfield Canyon were: Reach 1 = from the Swamp Springs Canyon confluence upstream about 1.5 km in Redfield Canyon to the first tributary from the east (the approximate location of the waterfall at UTM coordinates 564212mE, 3590025mN; NAD 83), and Reach 2 = from Swamp Springs Canyon confluence downstream about 2.9 km to an unnamed tributary from the north (561433mE and 3589266mN; NAD 83). Most of Reach 2 is intermittent (Bob Rogers, The Nature Conservancy, personal communication). The two reaches designated in Swamp Springs Canyon were: Lower = from the mouth upstream 1.3 km, but only the uppermost 300 m has perennial water and is sampled, and Upper = an approximately 1.53 km section beginning at an unnamed tributary from the north at about 2.75 km upstream from the mouth, and extending upstream about 100 m past the unnamed tributary from the south that drains Cherry Peak (a small spring is located in this tributary near where it meets Swamp Springs Canyon). The one reach in Cherry Spring Canyon begins at the unnamed tributary containing Cherry Spring and extends upstream for about 2,100 m. The reach is dry except for a small, ~30 m long tinaja about 690 m upstream of the bottom of the reach, and the uppermost 100 m, the latter of which is where topminnow and pupfish were stocked.

METHODS

MONITORING

Spikedace and Loach Minnow

Annual monitoring of spikedace and loach minnow was completed on September 18 and 19, 2011. Fixed and randomly selected 100-m long sites (transects) were sampled in Redfield Canyon (Figure 1) and Hot Springs Canyon (Figure 3). The three fixed sites in Redfield Canyon and three fixed sites in Hot Springs Canyon were also sampled during 2008, (Robinson 2008), 2009 (Robinson et al. 2010), and 2010 (Robinson et al. 2011). A fourth fixed site in Redfield Canyon, located about 2.1 km downstream of the Swamp Springs confluence, was sampled in 2011, but not in previous years because it was dry. Four additional sites in Redfield Canyon and six in Hot Springs Canyon were randomly selected in the office by mapping the stream courses (National Geographic TOPO! software), dividing the lengths into 100-m-long segments, and using a random number table to select sites within an identified reach.

Fish were sampled within each 100-m transect using a backpack electrofisher (Smith Root model LR24) moving upstream in a single pass, and stunned fish were netted with 3 mm-mesh dip nets. At the end of each major mesohabitat (pool, run, riffle, cascade) within the 100-m transects, fish were processed and data were recorded.

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In addition to and outside of the 100-m transects, crews conducted targeted-habitat sampling within each reach if they determined they had time to do so. Runs, eddies and pools (presumed spikedace habitat) were sampled either by electrofishing or by seining. Seining was done in a downstream direction, moving faster than the current. Cobble-bottom riffles (presumed loach minnow habitat) were sampled with a combination of kick-seining and electrofishing as described above. Each seine haul or electrofishing-kick-seining was a separate event and was considered a separate site. Data were recorded after each seine haul or kick-seining event.

Captured fish were identified to species and counted. All spikedace and loach minnow were measured (mm total length, TL). Other species were counted within two size classes: 20-40 mm and > 40 mm for speckled dace and longfin dace, ≤20 and >20 mm for desert pupfish and Gila topminnow, and 20-100 mm and >100 mm for suckers and Gila chub. Except for topminnow and pupfish, we categorized fish <20 mm TL as larvae. After processing, fish were released alive just downstream from where they were captured. Data recorded for each sampling effort included: site name, site location (GPS coordinates), length of site, date, time, participants, gear type, gear settings, gear dimensions, effort (seconds shocked or length and width of seining or dip netting), species of fish captured, size class of fish, and counts of individuals within each species-size-class category. Habitat information was sometimes collected at the 100-m sites. Habitat data recorded included visual estimations of: percentage of site composed of each habitat type (cascade, riffle, run, pool), and percentage of site composed of each substrate type (clay, silt, sand, gravel, pebble, cobble, boulder). Additionally, because fish were processed at the end of each major mesohabitat type, the length of each mesohabitat type was also recorded. Water quality characteristics sometimes measured were: water temperature (°C), pH, and conductivity (µS) using an EXTECH Instruments Inc. ExStik EC500 meter, and dissolved oxygen (mg/L) using an ExStik II dissolved oxygen meter.

Gila Topminnow and Desert Pupfish

Monitoring for Gila topminnow and desert pupfish was conducted on September 16 within Secret Spring, Headquarters Spring, and Larry & Charlie Tanks (Figure 3) and on September 17 in Cherry Spring and in Swamp Springs Canyon (Figure 2). Sampling was completed throughout the Secret Spring pond, Larry & Charlie Tank, and Headquarters Spring pool. Within Cherry Spring Canyon and Swamp Springs Canyon the stocking locations and areas immediately upstream and downstream of the stocking locations were sampled. In upper Swamp Springs Canyon, sampling occurred in the reach beginning at the upper stocking site and extending downstream about 1,250 m. In lower Swamp Spring Canyon, sampling occurred in an approximately 300-m reach encompassing the stocking location. Fish were sampled using Promar® collapsible minnow traps (0.46 m long x 0.3 m wide, with 2 mm mesh), dip nets (3 mm mesh, 1.5 m long pole), and seines (3 mm mesh, and typically 2 m long by 1.5 m tall). Collapsible minnow traps were baited with dry dog food. Six to ten traps were set upon arrival at each site, and were pulled 2-3 h later. An attempt was made to conduct a minimum of 10 dip net sweeps or 10 seine hauls at each site.

After each seine haul, dip net sweep, or trap pull, captured fish were held in buckets or the nets in the water until they could be identified, counted and data recorded. After processing, fish were released alive back to the area from which they were captured. Data recorded for each sampling effort included: site name, site location (GPS coordinates), date, time, participants, gear

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type, gear dimensions, effort (length and width of seining or dip netting, and set and pull times for each trap set from which duration was calculated), species of fish captured, size class of fish (≤20 mm or >20 mm), and counts of individuals within each species-size-class category. Water quality characteristics sometimes measured were: water temperature (°C), pH, and conductivity (µS) using an EXTECH Instruments Inc. ExStik EC500 meter, and dissolved oxygen (mg/L) using an ExStik II dissolved oxygen meter.

Analysis

Numbers of fish in each size class captured in each water and catch-per-unit effort were calculated. We use catch-per-unit effort (catch rates) as an index of abundance, and not the absolute number of fish captured. Catch rates adjust the number of fish captured by the amount of effort, and so are more correlated with abundance than the total number of fish captured. Catch rates depend on the number of fish present, the number of fish captured, and the amount of and effectiveness of the sampling effort, among other things. Length frequency diagrams for spikedace and loach minnow and length category frequencies for Gila topminnow and desert pupfish were examined to determine if reproduction and recruitment had occurred. Distance between capture location and the stocking reach within Hot Springs Canyon and Redfield Canyon was used as a measure of dispersal distance for spikedace and loach minnow.

FISH STOCKINGS

Presence, abundance, and size class structure of repatriated populations as derived from monitoring in 2008, 2009 and 2010 were used to determine if augmentation stockings were needed. Availability of stock of the four species was also used to determine stocking priorities. For spikedace and loach minnow, the Aravaipa lineage stocks held at BPNFCF produced about 5,300 spikedace (about 2,500 were <25 mm TL) and about 1,035 loach minnow, and augmentations were originally planned for three streams (Hot Springs Canyon, Redfield Canyon, and Fossil Creek). Sampling during 2008 thru 2011 indicated that relatively little habitat for spikedace and loach minnow was available in Redfield Canyon. Therefore, a multi-agency team recommended that the fish be divided amongst Fossil Creek and Hot Springs Canyon, and that none be stocked into Redfield Canyon. For spikedace, the plan was to stock the smaller spikedace into Hot Springs Canyon, and the remaining 2,800 larger spikedace into Fossil Creek. For loach minnow the plan was to stock half into Hot Springs Canyon and half into Fossil Creek.

Based on monitoring information, Gila topminnow were present and abundant at each of the sites where they had been stocked. Therefore the multi-agency team recommended that no augmentation stockings of Gila topminnow were needed for 2011. Therefore, Gila topminnow were not stocked into any sites on the Muleshoe CMA during 2011. Since 2009, desert pupfish were not captured in Swamp Springs Canyon or Headquarters Spring, and were very rare in Cherry Spring Canyon so these three sites were likely unsuitable for desert pupfish. Desert pupfish were captured at Larry & Charlie Tank and Secret Spring and were considered established in these sites. Therefore, desert pupfish were not stocked into any sites during 2011.

Spikedace and loach minnow were the only species stocked in 2011, and they were only stocked into Hot Springs Canyon. Spikedace and loach minnow were transported in a two-compartment 200-gal fish transport tank in the bed of a truck from BPNFCF to The Muleshoe Ranch CMA headquarters in the morning of October 18, 2010. Water in the fish transport tank originated

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from the well at BPNFCF and was treated with salt and AMQUEL® and was aerated using oxygen tanks to minimize stress to the fish during transport.

After arriving at Hot Springs Canyon, fish were transferred to 5-gal buckets that had battery powered aerators attached to their lids and hand-carried to the stocking sites. To minimize stress to the fish, at the stocking sites water was tempered to stream conditions by exchanging approximately 25% of the bucket water with stream water every 10-15 minutes, making 2-4 exchanges until the water in the bucket was within 1.5˚C of the stream temperature. After the tempering process, the fish were removed from the bucket with a dip net, identified to species, counted and released to the stream. Fish were observed after release and stress behaviors (e.g., loss of equilibrium, rapid respiration, etc.) noted.

RESULTS AND DISCUSSION

MONITORING

Spikedace and Loach Minnow

Eight species of fish were captured in Redfield Canyon during September 2011 (Table 1). Gila chub was the most abundant species captured, followed by speckled dace, Sonora sucker, longfin dace, and one each of Gila topminnow, loach minnow, spikedace, and green sunfish (Table 2). Therefore, spikedace and loach minnow continue to persist in Redfield Canyon. The spikedace was greater than 50 mm TL and so was likely an adult, and thus could have been one of the individuals stocked in 2010. The loach minnow captured was 35 mm TL, and hence was likely a young-of-year (YOY) fish, and so is probably evidence of reproduction, although some fish stocked into Redfield Canyon during 2010 were <20 mm TL. Both the spikedace and loach minnow were captured in Reach 1, so there was no indication that they had dispersed outside of the stocking reach. About the same number of loach minnow and spikedace were captured in 2011 as in 2010, which was fewer individuals of both species than in 2008 or 2009 (Robinson 2008, Robinson et al. 2010). The decrease in catch may indicate that the populations, if they ever actually established, are decreasing in abundance. We surveyed about 40% of reach 1, so do not think that the decrease in catch was a result of insufficient sampling effort. Another possibility is that fish densities may have been lower because some fish may have been washed downstream during a flood event within the week before monitoring. A rainfall event a few days before monitoring caused flooding on September 14 in most of the streams on the Muleshoe CMA.

We captured one Gila topminnow in Redfield Canyon within reach 2 and many others were observed in isolated pools within that reach. Topminnow were also captured in 2009 and 2010, so now appear established in Redfield Canyon near the Swamp Springs confluence. Topminnow entered Redfield Canyon from Swamp Springs Canyon and will likely continue to during floods.

Similar to previous years, seven species of fish, all native, were captured in Hot Springs Canyon during September 2011 (Table 1). Speckled dace was the most abundant species followed by longfin dace, Gila chub, desert sucker, loach minnow, Sonora sucker, and spikedace (Table 1). Catch rates for each species are summarized in Table 2. Numbers of fish captured were lower than in previous years, despite more 100-m transects being sampled in 2011. It is possible that the flooding that occurred a few days before the monitoring in 2011 washed fish downstream and caused lower catch rates.

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Four spikedace and 26 loach minnow were captured in Hot Springs Canyon, which for spikedace is less than what was captured in 2010 (29; Robinson et al. 2011) or 2009 (24; Robinson et al. 2010), but equal to what was captured in 2008 (four; Robinson 2008). For loach minnow, catch was less than in 2010 (65; Robinson et al. 2011), but similar to 2009 (23; Robinson et al. 2010) and more than 2008 (12 loach minnow; Robinson 2008). The decrease from 2010 to 2011 may, as previously mentioned, have been a result of the flooding that occurred days before sampling occurred in 2011. It is also possible that fewer loach minnow were captured because the only sampling method used was backpack electrofishing, whereas in previous years, riffles had been sampled by a combination of kick seining and backpack electrofishing; the latter method is more efficient for capturing loach minnow.

All of the spikedace captured in Hot Springs Canyon were greater than 50 mm TL (56, 58, 61, and 63 mm TL), and all loach minnow were greater than 40 mm TL (Figure 4), providing no clear evidence that spikedace or loach minnow reproduced during 2011. Six of the loach minnow were between 40 and 50 mm TL, so it is possible that some of these could have originated from a spawn early in the year. It is possible, that flooding may have washed mostly small fish downstream, thus affecting the size of fish captured.

Our catch information indicates that both species have dispersed downstream of the stocking reach (Reach 1; Figure 3) in Hot Springs Canyon. Similar to 2010, spikedace were captured in Reach 3, although during 2011 the one captured was at the upper end of the reach, not further down as in 2010. Similar to previous years, loach minnow were captured in both Reach 1 and Reach 2 (Figure 3).

Gila Topminnow and Desert Pupfish

During September 2011, Gila topminnow were captured in most, and desert pupfish in some, of the sites where they had been stocked (Table 3). At Larry & Charlie Tank where only desert pupfish were stocked, 54 desert pupfish were captured; mean = 2.2 fish/hr±1.48 SE. One of the 54 pupfish captured was <20 mm TL. Therefore it can be concluded that desert pupfish are persisting and reproducing in Larry & Charlie Tank. Catch rates were about half of what they were in 2010 (mean = 5.4 fish/hr±1.65 SE); it is unclear if this is just natural variation in catch rates, or an actual decline in abundance.

At Secret Spring, nearly 3,700 Gila topminnow and 10 desert pupfish were captured (Table 3). Gila topminnow catch rates (105.7 fish/hr±19.8) were similar to previous annual monitoring: 133.5±38.14 in 2008, 78.7±11.82 in 2009, and 92.5±17.97 in 2010. Of 2,038 Gila topminnow that were categorized into length classes, 27% were <20 mm TL. Similar to what was concluded in 2010, based on abundance of Gila topminnow during the four years of annual monitoring and the evidence of reproduction, it can be concluded that Gila topminnow are established at Secret Spring. Similar to previous years, few desert pupfish were captured (0.30±0.16 fish/hr), and minnow trap catch rates remain low: 0.8±0.46 in 2008, 0.1±0.07 in 2009, and 0.3±0.23 in 2010. Two of the desert pupfish captured in 2011 were categorized as <20 mm TL. Therefore, based on the evidence reported, we conclude that desert pupfish have established a population in Secret Spring, although population size seems to be low, which was why more fish were stocked in October 2010.

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At Headquarters Spring, no fish were captured (Table 3). Absence of fish in the traps and dip net sweeps was likely a result of the September 14 flooding; water flowed through the pools where topminnow and pupfish were stocked, possibly washing fish downstream into ephemeral reaches. A month after the monitoring, a few Gila topminnow were observed at the Muleshoe Ranch Headquarters road crossing, so at least a few topminnow survived and persisted after the flood. This is the third year that no desert pupfish were captured, even with a second stocking in 2010. Because of the second stocking in 2010, we cannot yet conclude that desert pupfish are extirpated, based on the criteria of Weedman and Young (1995): three consecutive, intensive surveys with no fish captured.

In Cherry Spring Canyon, 15 Gila topminnow and no desert pupfish were captured (Table 3). Fewer topminnow were captured than in previous years and minnow trap catch rates (0.75±0.43 fish/hr) were also lower than previous years (1.5±1.13in 2010, and 5.5±3.46 in 2009) except for September 2008, when no topminnow were captured in traps (eight were captured by seining). About 13% of the Gila topminnow captured in September 2011 were <20 mm TL. Gila topminnow and desert pupfish were stocked into Cherry Spring Canyon in October 2007 and again in September 2008. Therefore, based on the monitoring evidence, we conclude that Gila topminnow have established a population in Cherry Spring Canyon. In addition, topminnow were observed in a large tinaja about 0.5 km downstream of the stocking site, and were likely transported there during the September 2011 flooding. We can conclude little regarding desert pupfish, because none were captured in 2011, and few were captured in previous years: one in 2010, five in 2009, but zero in 2008.

In Swamp Springs Canyon, Gila topminnow, but no desert pupfish were captured (Table 3). In the upper reach, trap catch rates (15.1±4.82 fish/hr) were greater than in 2010 (3.6±1.30), but were similar to 2009 (16.8±3.26). About 52% of the 204 Gila topminnow categorized to size class were < 20 TL. We seined from the stocking site downstream about 1,250 m to determine the extent of distribution of Gila topminnow, and found Gila topminnow as far as 930 m below the stocking site. Therefore, based on the monitoring evidence and the fact that Gila topminnow were only stocked once (September 2008), we conclude that they have established a population in upper Swamp Springs Canyon. Desert pupfish have not been captured in upper Swamp Springs Canyon in three consecutive annual surveys, and thus can be considered extirpated.

In lower Swamp Springs Canyon, more Gila topminnow (715) were captured than in previous years (113 in 2010, 83 in 2009, 63 in 2008), but different gear types were used in the four years: minnow traps in 2011, minnow traps and dip nets in 2010, seines and dip nets in 2009, and minnow traps, seines and dip nets in 2008. Minnow trap catch rates (24.0±14.04 fish/hr) were greater than they were in 2010 (3.3±1.51) or 2008 (1.5±1.36). About 25% of the Gila topminnow that were categorized to length class in 2011 were <20 mm TL. Based on the monitoring evidence from 2008 thru 2011, Gila topminnow are considered to have established a population in lower Swamp Springs Canyon. Desert pupfish have not been captured in the lower reach since 2008 and are therefore considered extirpated from lower Swamp Springs Canyon.

Physical Environment

During September 2011, habitat in Hot Springs Canyon was mostly riffles and runs whereas that in Redfield Canyon was comprised mostly of pools and runs (Figure 5). In Redfield Canyon, the

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pools and runs were often bounded by small cascades, but the cascades were so short a distance (e.g., 1-m long or less) that they often were not recorded, and probably comprised on average less than 0.5% of the total habitat. Gradient over 5 km (determined from National Geographic TOPO) is about 1.5% in Hot Springs Canyon and about 1.9% in Redfield Canyon. Substrate types were reflective of the habitat types and gradients in the two streams, as Hot Springs Canyon was dominated by gravels then cobble and pebble, whereas Redfield Canyon was dominated by cobble then pebble then gravel substrates. Water quality characteristics, for the sites where they were measured, were unremarkable (Table 4), and were similar to what was reported in 2008 (Robinson 2008).

FISH STOCKINGS

Spikedace and loach minnow were stocked into Hot Springs Canyon on October 18, 2011 (Appendix 1). In an attempt to facilitate their dispersal within the stream, fish were stocked into two general locations: 1) a few hundred meters upstream from Wildcat Canyon, and 2) at the lower end of Reach 2, about 1.3 km downstream from Wildcat Canyon near the confluence with the tributary from the north and the road access point. At the upper location, 864 spikedace were divided amongst four sites from about 270 to 400 m upstream of Wildcat Canyon; no mortalities occurred. Also at the upper location, 99 loach minnow were stocked into a riffle about 180 m upstream from Wildcat Canyon; no mortalities occurred. Fish behaved normally upon release.

At the lower location, 656 spikedace were stocked at a site about 40 m upstream of the tributary and 485 at a site about 130 m downstream of the tributary; an additional 13 spikedace died during the transport process. Also at the lower location, 162 loach minnow were stocked into a riffle at the mouth of the tributary; two loach minnow died during transport. Site water temperature and bucket water temperature were both 22°C, but two water exchanges were still performed to acclimate fish to local conditions. Fish behaved normally upon release.

RECOMMENDATIONS

The environmental assessment for the establishment of aquatic vertebrate species into Muleshoe CMA waters (Bureau of Land Management 2004) indicated that stockings of the federally threatened and endangered fish species would occur every year for five years, at which time success (establishment of self-sustaining populations) would be evaluated. The assessment also indicated that monitoring of the populations would occur during the five years of augmentation to determine the success of the stockings, and continue for at least five years after stocking ceased. The T&E fish species were stocked and monitored during 2007 thru 2011, and so if the plan outlined in the environmental assessment is followed, stockings should cease but monitoring should continue until at least 2016. However, for a variety of reasons, not all waters were stocked every year with each species planned for that water. Reasons included the unavailability of stock of some species, the likely extirpation of a species from sites, and the likely establishment of a species at sites. Partners (AZGFD, BLM, BOR, FWS, and TNC) that comprise the Muleshoe Native Fishes Team should meet to discuss results so far and decide if any more stocking should occur in the immediate future. The team should consider that it will be easier to determine if populations have successfully established if stockings cease for several years, because then any recruitment will be a result of natural reproduction and not stockings.

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The native fish repatriations have so far resulted in the successful establishment of at least two species in Muleshoe CMA waters. Stockings resulted in the establishment of Gila topminnow in Secret Spring, Cherry Spring Canyon, Swamp Springs Canyon, Redfield Canyon (dispersed from Swamp Springs Canyon), and Headquarters Spring. With the exception of Headquarters Spring, where the population was nearly decimated by a flood, further stockings of Gila topminnow at these locations are not necessary, except to occasionally introduce fresh genetic material.

The attempted establishment of desert pupfish in the same waters was much less successful. Desert pupfish established a population in Secret Spring, and have likely established a population in Larry & Charlie Tank, where they were the only species stocked (in 2009), but the latter repatriation is still being evaluated. However, desert pupfish are extirpated from Swamp Springs Canyon, Cherry Spring Canyon, and Headquarters Spring. It is unknown why desert pupfish failed to establish in these locations, but it could have been a result of negative interactions with Gila topminnow (Robinson and Ward *in press*). Habitat, or some aspect of it, may have been unsuitable for desert pupfish. Water quality seems unlikely to be the cause of desert pupfish extirpation because water quality characteristics are within the range of other sites where desert pupfish persist (USFWS 1993). It may be that the stream environment was unsuitable, because an examination of stocking data revealed that pupfish have not persisted in any stream setting where they have been reintroduced in Arizona (Voeltz and Bettaso 2003, USFWS 2010). It may be that flood events in some of these streams resulted in the extirpation of pupfish.

Spikedace and loach minnow may have established populations in Hot Springs Canyon. Both species have been captured during monitoring each year (2008 thru 2011) and putative YOY spikedace were captured in 2010 and putative YOY loach minnow in 2008 and 2010, indicating reproduction had occurred. However, the two species have been stocked each year from 2007 thru 2011, which has undoubtedly contributed to recruitment. It is unclear whether natural recruitment is sufficient to allow the species to establish and persist. We recommend that stockings be ceased for a period of at least three years (approximate life span of the two species). If multiple size classes of the two species continue to be detected during monitoring thru 2014 then the species can be considered established in Hot Springs Canyon.

It is less likely that spikedace and loach minnow have established populations in Redfield Canyon. Loach minnow have been detected during monitoring each year from 2008 thru 2011, but only one was captured in three of the years; 12 were captured in 2009. Putative YOY loach minnow were detected in 2010 and 2011, indicating that reproduction had occurred, although some of the fish stocked during 2010 were small (<20 mm TL), so the one loach minnow captured in 2011 may have been an individual that was stocked the previous year. Spikedace have been detected in three of the four years of monitoring, but putative YOY individuals only during 2008. No spikedace were captured in 2010 and only one was captured in 2011. It is unclear whether natural recruitment is sufficient for the two species to establish populations in Redfield Canyon. In addition, suitable habitat for the two species is limited in Redfield Canyon. The perennial reach where the two species were stocked is only about 1.5 km long, and mesohabitat is mostly pools or runs (Robinson 2008; current report) in that reach. Therefore, similar to Hot Springs Canyon, we recommend that stockings be ceased for at least two more years (none were stocked in 2011). If multiple size classes of the two species continue to be

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detected during monitoring thru 2013 then the species can be considered established in Redfield Canyon.

The study design and methods appear to be sufficient to address objectives 1 (verifying persistence), 2 (detecting recruitment), and 4 (detecting dispersal) for all species, and also appeared sufficient to address objective 3 (change in abundance) for Gila topminnow and possibly desert pupfish. Techniques used to sample for Gila topminnow and desert pupfish have been pretty consistent, and the catch rates for the trapping data can be validly compared among years. The study design and methods to assess spikedace and loach minnow varied, depending on the stream, from 2008 thru 2010, but were finally standardized early in 2011 when the monitoring plan was revised. Single pass electrofishing is now the only method used to sample within the 100-m transects. Restricting fish collection to just one method will allow for valid comparisons in catch rates among years.

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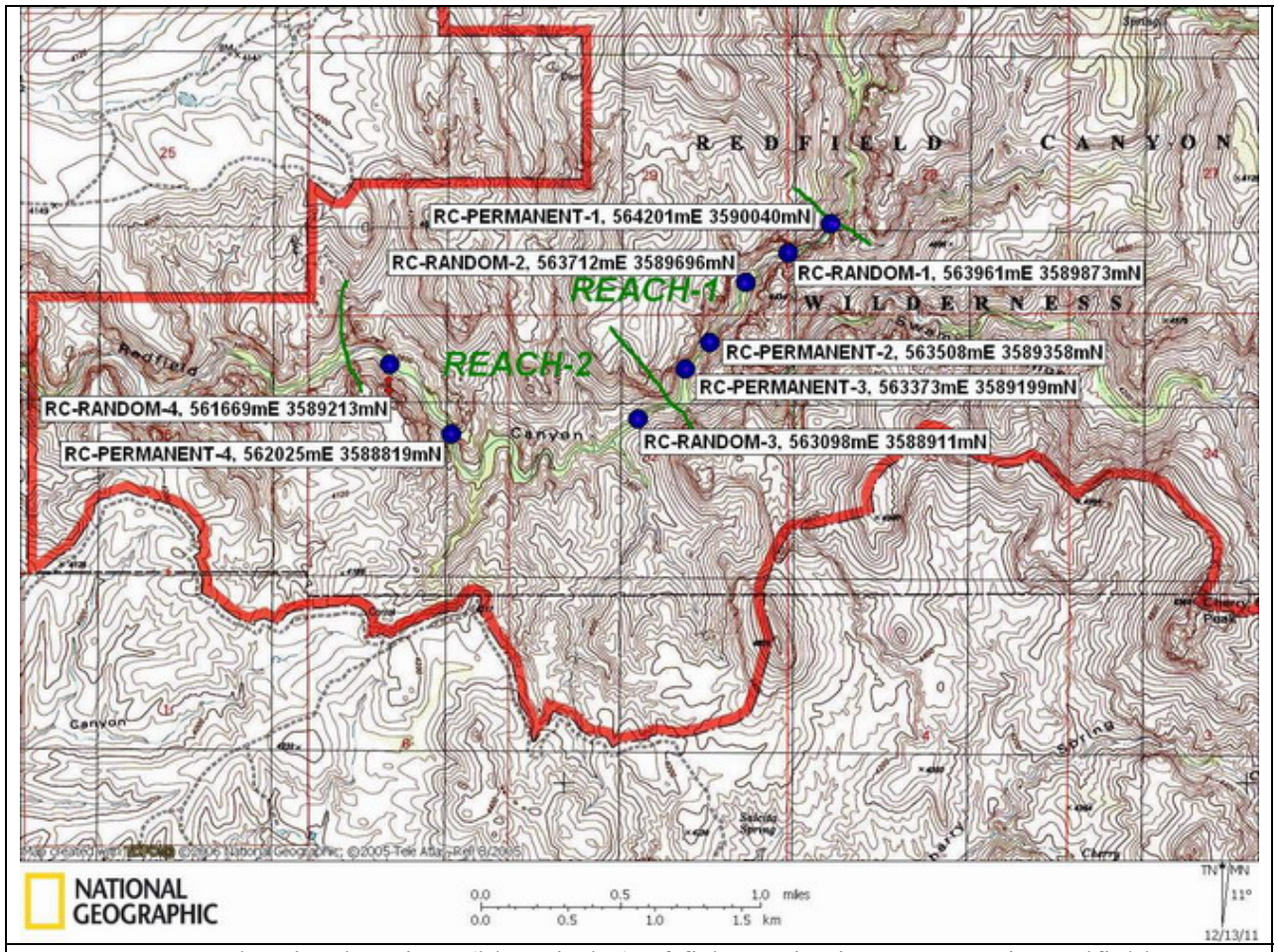

Figure 1. Map showing locations (blue circles) of fish monitoring transects in Redfield Canyon within the Muleshoe Cooperative Management Area, southwest of the Galiuro Mountains, Arizona during 2011. The map shows the locations of permanent and randomly selected 100-m long transects within two reaches (delineated with green lines); spikedace and loach minnow were stocked into Reach 1 during 2007, 2008, and 2010. The thick red line is the boundary of Redfield Canyon Wilderness.

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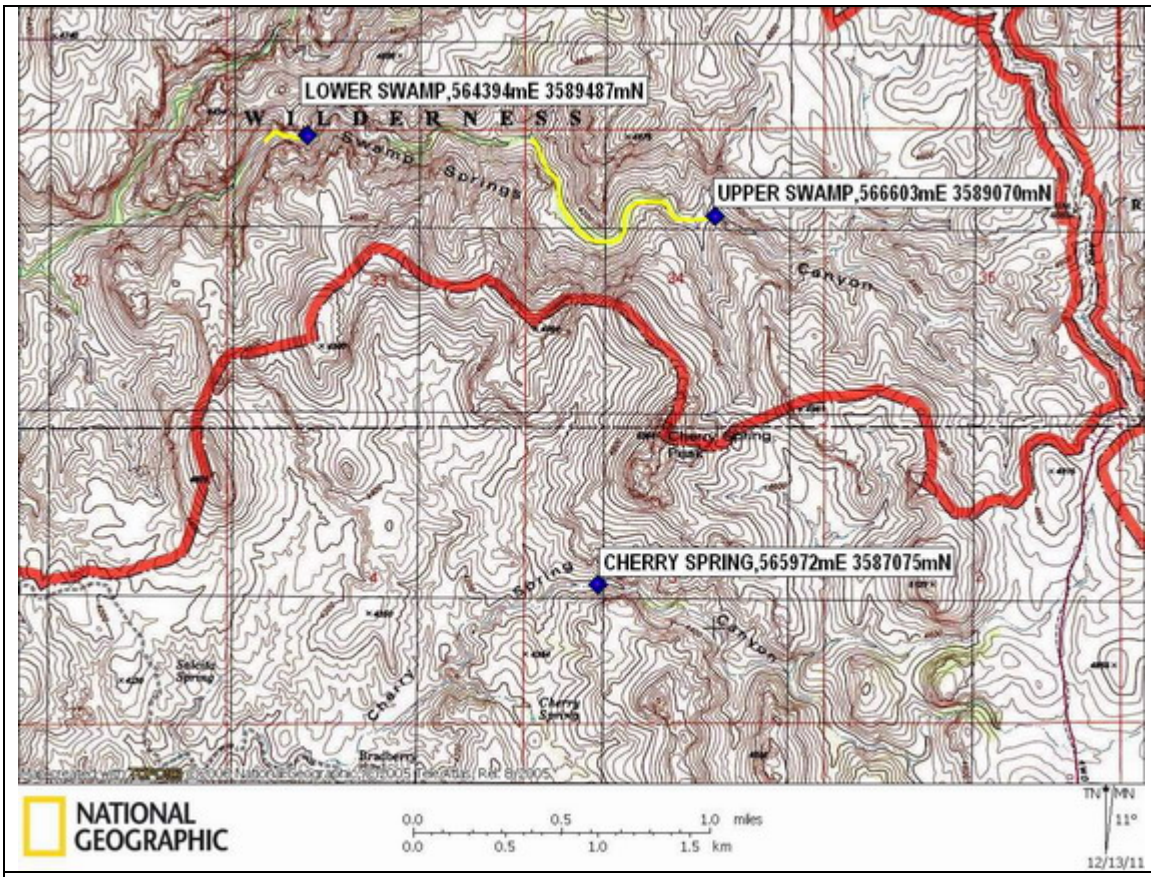

Figure 2. Map showing locations (blue diamonds) of fish monitoring sites in Swamp Springs Canyon and Cherry Spring Canyon within the Muleshoe Cooperative Management Area, southwest of the Galiuro Mountains, Arizona during 2011. In Swamp Springs Canyon desert pupfish and Gila topminnow were stocked into the lower monitoring site in 2007 and the upper site during 2008. The yellow lines are the approximate reaches surveyed in Swamp Springs Canyon. The monitoring location shown in Cherry Spring Canyon was stocked with Gila topminnow and desert pupfish during 2007 and 2008. The thick red line is the boundary of Redfield Canyon Wilderness.

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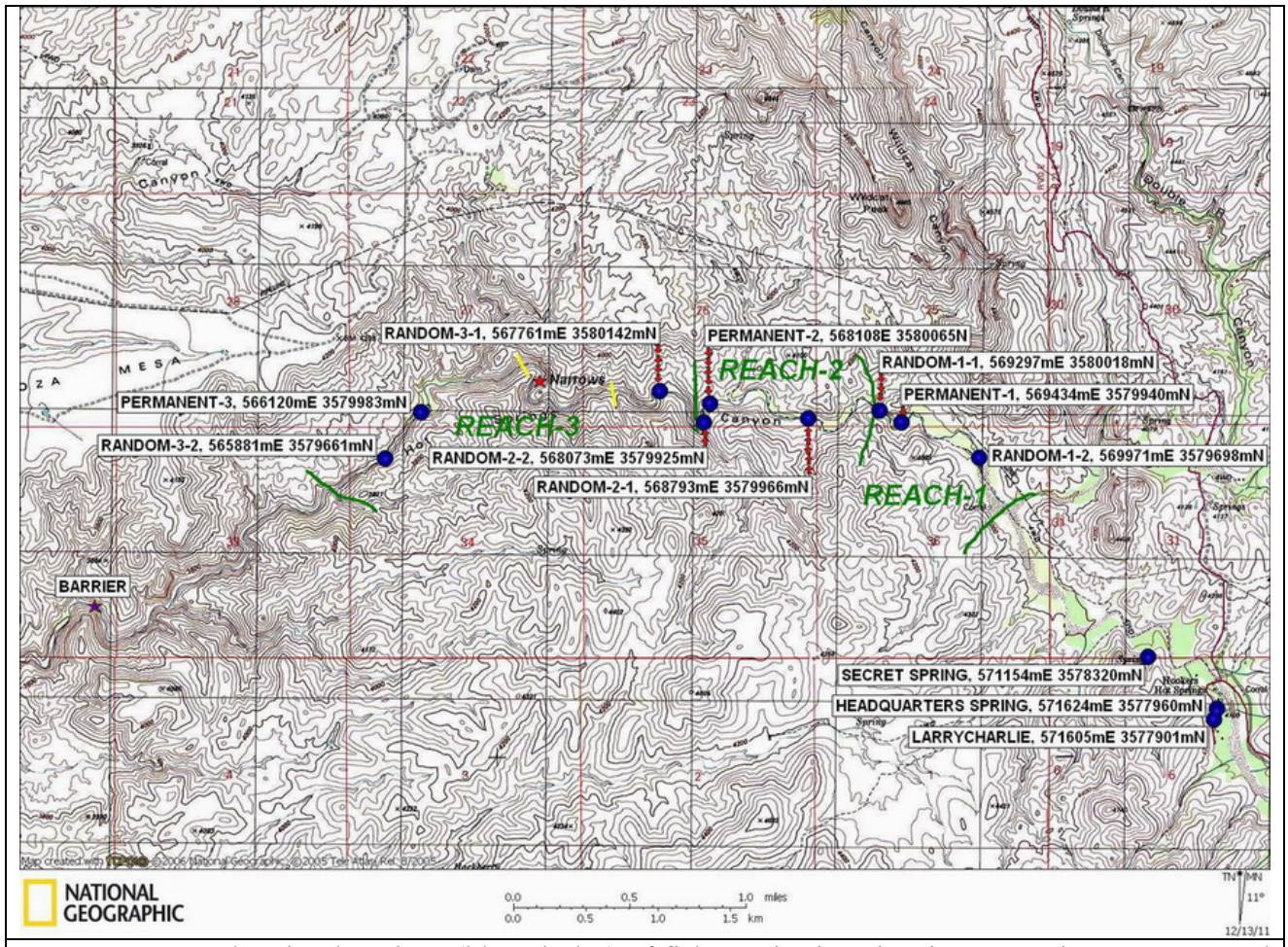

Figure 3. Map showing locations (blue circles) of fish monitoring sites in Hot Springs Canyon and near the Muleshoe Ranch Headquarters (Hookers Hot Springs) within the Muleshoe Cooperative Management Area, west of the Winchester Mountains, Arizona during 2011. In Hot Springs Canyon downstream (north and west) of Bass Canyon, the map shows the locations of permanent and randomly selected 100-m long transects within three reaches (delineated with green lines); spikedace and loach minnow were stocked into Reach 1 during 2007, 2008, 2009, and 2010. Also shown are Secret Spring where Gila topminnow and desert pupfish were stocked during 2007 and desert pupfish in 2010, Headquarters Spring where the same two species were stocked in 2008 and desert pupfish in 2010, and Larry & Charlie Tank where desert pupfish were stocked in 2009.

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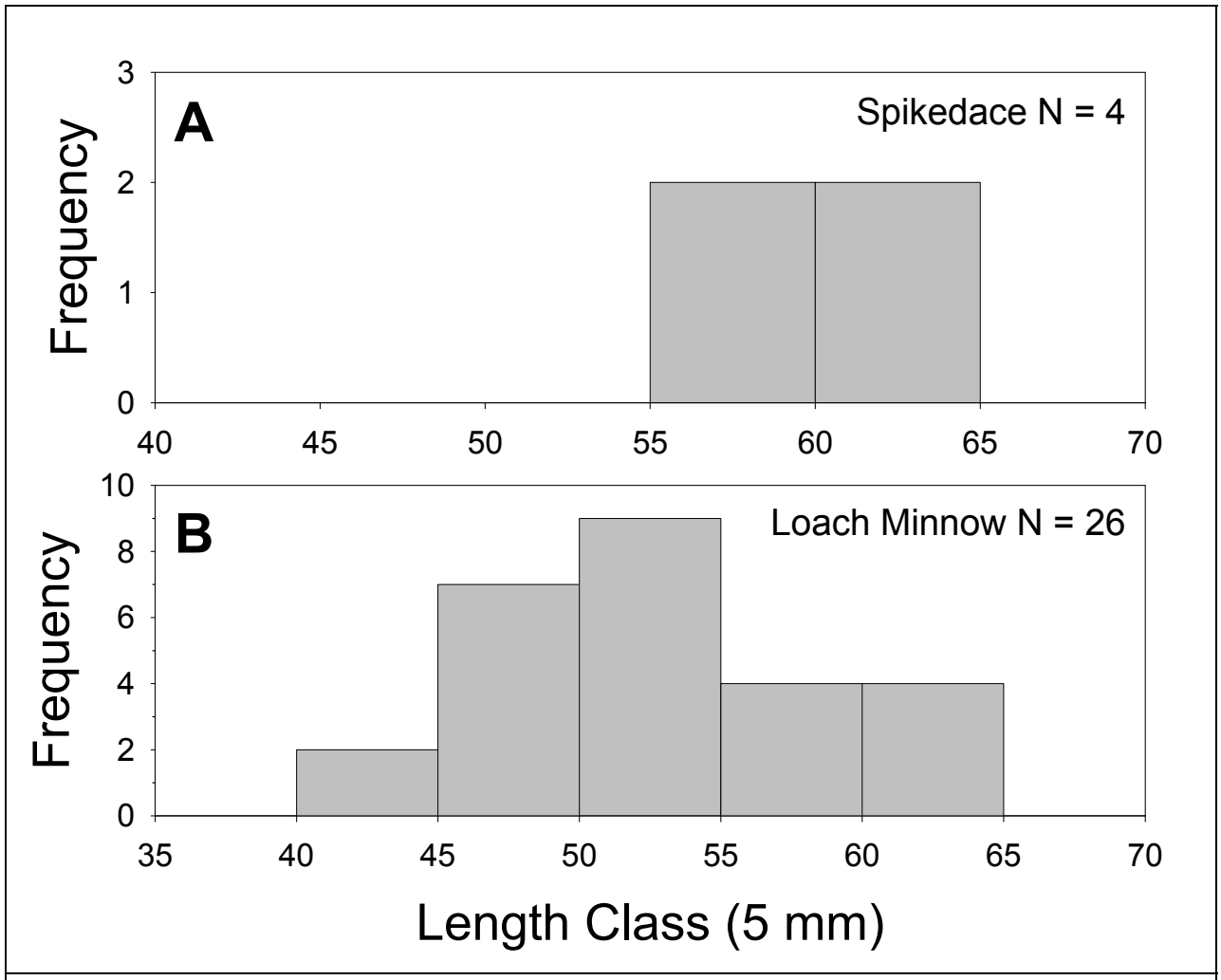

Figure 4. Length frequency distributions in 5-mm length classes for spikedace (A) and loach minnow (B) in Hot Springs Canyon on September 19, 2011.

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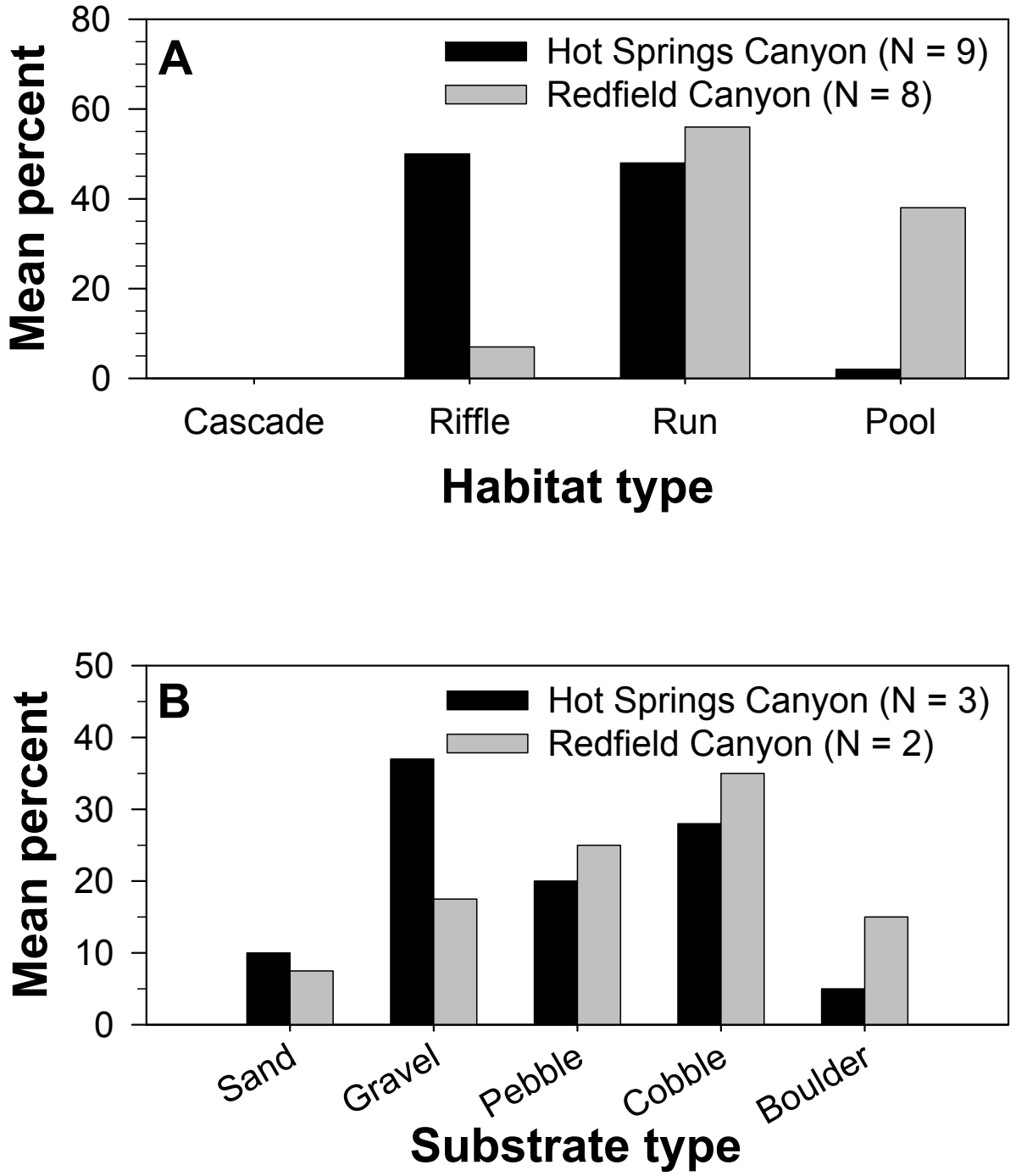

Figure 5. Percent mesohabitat types (A) and substrate types (B) in 100-m transects in Hot Springs Canyon and Redfield Canyon, Muleshoe CMA, Arizona on September 18-19, 2011.

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Table 1. Numbers of fish of each species captured (all gear types) within 100-m transects in Hot Springs Canyon and Redfield Canyon, Muleshoe Cooperative Management Area, Arizona during September 2011. Reach descriptions are presented in the Study Area section.

Stream	Reach	Transect	Spikedace	Loach minnow	Speckled dace	Longfin dace	Gila chub	Desert sucker	Sonora sucker	Gila topminnow	Green sunfish	Total
Hot Springs Canyon	1	Permanent 1	0	0	17	7	0	4	0	0	0	28
		Random 1-1	3	12	56	19	9	19	2	0	0	120
		Random 1-2	0	0	5	0	0	0	0	0	0	5
		Reach total	3	12	78	26	9	23	2	0	0	153
	2	Permanent 2	0	5	24	4	5	2	0	0	0	40
		Random 2-1	0	7	42	13	5	6	2	0	0	75
		Random 2-2	0	2	36	6	6	1	0	0	0	51
		Reach total	0	14	102	23	16	9	2	0	0	166
	3	Permanent 3	0	0	3	8	0	0	0	0	0	11
		Random 3-1	1	0	15	30	20	3	5	0	0	74
		Random 3-2	0	0	13	15	0	0	0	0	0	28
		Reach total	1	0	31	53	20	3	5	0	0	113
		Stream total	4	26	211	102	45	35	9	0	0	432
Redfield Canyon	1	Permanent-1	0	0	19	0	19	0	5	0	0	43
		Permanent-2	0	0	3	0	5	0	8	0	0	16
		Permanent-3	1	0	1	0	18	0	9	1	0	30
		Random-1	0	0	38	0	57	0	56	0	0	151
		Random-2	0	1	29	0	20	0	5	0	0	55
		Reach total	1	1	90	0	119	0	83	1	0	295
	2	Permanent-4	0	0	0	0	1	0	0	0	0	1
		Random-3	0	0	0	6	13	0	1	0	0	20
		Random-4	0	0	0	0	0	0	0	0	1	1
		Reach total	0	0	0	6	14	0	1	0	1	22
		Stream total	1	1	90	6	133	0	84	1	1	317

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Table 2. Number of fish captured (#) and mean and standard error (SE) catch rates for backpack electrofishing (#/min) by reach and by stream for Hot Springs Canyon and Redfield Canyon, September, 2011. Reach definitions are presented in the Study Area section.

Stream	Reach	Statistic	Spikedace	Loach minnow	Speckled dace	Longfin dace	Gila chub	Desert sucker	Sonora sucker	Gila topminnow	Green sunfish	Total
Hot Springs Canyon	1 (N = 5)	#	3	12	78	26	9	23	2	0	0	153
		Mean #/min	0.06	0.73	1.77	0.49	0.17	0.67	0.04			3.92
		SE	(0.06)	(0.52)	(0.88)	(0.36)	(0.17)	(0.35)	(0.04)			(1.77)
	2 (N = 6)	#	0	14	102	23	16	9	2	0	0	166
		Mean #/min		0.16	1.26	0.40	0.30	0.11	0.03			2.25
		SE		(0.06)	(0.31)	(0.15)	(0.12)	(0.06)	(0.03)			(0.27)
	3 (N = 12)	#	1	0	31	53	20	3	5	0	0	113
		Mean #/min	0.02		0.59	1.09	0.56	0.06	0.13			2.47
		SE	(0.02)		(0.18)	(0.39)	(0.50)	(0.04)	(0.07)			(0.77)
	Total (N = 23)	#	4	26	211	102	45	35	9	0	0	432
		Mean #/min	0.02	0.20	1.02	0.78	0.41	0.21	0.08			2.73
		SE	(0.02)	(0.12)	(0.24)	(0.23)	(0.26)	(0.09)	(0.04)			(0.55)
Redfield Canyon	1 (N = 16)	#	1	1	90	0	119	0	83	1	0	295
		Mean #/min	0.01	0.02	1.80		2.28		1.73	0.05		5.89
		SE	(0.01)	(0.02)	(0.57)		(0.66)		(0.64)	(0.05)		(1.43)
	2 (N = 7)	#	0	0	0	6	14	0	1	0	1	22
		Mean #/min				0.21	0.25		0.02		0.02	0.50
		SE				(0.14)	(0.17)		(0.02)		(0.02)	(0.22)
	Total (N= 23)	#	1	1	90	6	133	0	84	1	1	317
		Mean #/min	0.01	0.01	1.25	0.06	1.66		1.21	0.04	0.01	4.25
		SE	(0.01)	(0.01)	(0.43)	(0.04)	(0.50)		(0.47)	(0.04)	(0.01)	(1.12)

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Table 3. Number of individuals captured (#), mean catch-per-unit effort (#/h for traps and #/m^2 for seines), and standard error (SE) of the mean for three different gear types used to survey for Gila topminnow and desert pupfish during September 2011 in five waters within the Muleshoe Cooperative Management Area, Arizona. Sample size (N) is the number of collapsible minnow traps set, dip-net sweeps, or seine hauls.

Water	Gear	Statistic	Gila topminnow	Desert pupfish	Longfin dace	Total
Cherry Spring Canyon	Minnow trap (N = 10)	#	15	0	0	15
		Mean #/hr	0.75	0.00	0.00	0.75
		SE	(.43)	(.00)	(.00)	(.43)
Headquarters Spring	Minnow trap (N = 10)	#	0	0	0	0
		Mean #/hr	0	0	0	0
		SE	(.00)	(.00)	(.00)	(.00)
	Dip net (N = 15)	#	0	0	0	0
Larry & Charlie Tank	Minnow trap (N = 10)	#	0	54	0	54
		Mean #/hr	0.00	2.20	0.00	2.20
		SE	(.00)	(1.48)	(.00)	(1.48)
Secret Spring	Minnow trap (N = 10)	#	3694	10	0	3704
		Mean #/hr	105.66	0.30	0.00	105.95
		SE	(19.76)	(.16)	(.00)	(19.89)
Lower Swamp Springs Canyon	Minnow trap (N = 12)	#	715	0	584	1299
		Mean #/hr	23.97	0.00	22.58	46.54
		SE	(14.04)	(.00)	(7.59)	(14.88)
Upper Swamp Springs Canyon	Minnow trap (N = 10)	#	431	0	827	1258
		Mean #/hr	15.05	0.00	29.24	44.29
		SE	(4.82)	(.00)	(6.44)	(9.82)
	Seine (N = 11)	#	102	0	59	161
		Mean #/m2	1.51		1.03	2.54
		SE	(.77)		(.32)	(.76)

2ASLDRedfield000108

Table 4. Water quality characteristics measured at some of the Muleshoe CMA waters during annual monitoring on September 16-19, 2011.

Water Quality Characteristic	Headquarters Spring	Cherry Spring Canyon	Swamp Springs Canyon	Hot Springs Canyon
Time (military; hh:mm)	09:02	13:12	11:30	09:05
Water temperature (ºC)	23.2	20.2	23.4	18.8
Dissolved oxygen (mg/L)		6.7		
Ph	8.25	8.00	8.05	8.55
Conductivity (µS)	837	715	382	451
Total dissolved solids (mg/L)	363		268	315
Salinity (ppm)			191	219

2ASLDRedfield000109

Appendix 1. Summary of species stocked and stocking location information for seven waters within the Muleshoe Cooperative Management Area, Arizona during 2007-2011. Reach definitions are given in the Study Area section.

Water	Reach	Species	Date	Site name	Meters from bottom of reach	Easting (NAD 83)	Northing (NAD 83)	Number Stocked
Redfield Canyon	1	Loach minnow	10/4/2007		613	563625	3589507	77
			10/4/2007		904	563760	3589433	44
			10/4/2007		1134	563932	3589858	92
			9/17/2008		1212	564011	3589842	200
			9/17/2008		1258	564013	3589918	200
			9/17/2008		924	563768	3589918	120
			9/17/2008		881	563732	3589744	120
			9/17/2008		813	563688	3589683	120
			9/17/2008		746	563674	3589617	120
			9/17/2008		501	563674	3589414	120
			10/28/2010		825	563707	3589690	273
		Loach minnow or spikedace	10/28/2010		825	563707	3589690	279
		Spikedace	10/4/2007		1180	564027	3589881	192
			9/17/2008		924	563768	3589918	100
			9/17/2008		881	563732	3589744	100
			9/17/2008		813	563688	3589683	100
			9/17/2008		746	563674	3589617	100
			9/17/2008		134	563354	3589126	100
			10/28/2010		960	563803	3589781	346
			10/28/2010		930	563793	3589743	261
			10/28/2010		915	563784	3589737	123
Hot Springs Canyon	1	Loach minnow	10/4/2007		160	569319	3579964	205
			9/17/2008		717	569706	3579826	250
			9/17/2008		609	569620	3579844	249
			9/17/2008		476	569592	3579986	250
			9/17/2008		255	569422	3579933	250

2ASLDRedfield000110

Water	Reach	Species	Date	Site name	Meters from bottom of reach	Easting (NAD 83)	Northing (NAD 83)	Number Stocked
			10/28/2009		160	569334	3579986	87
			10/28/2009		609	569624	3579847	69
			10/28/2010		465	569590	3579935	130
			10/28/2010		420	569580	3579983	45
			10/28/2010		350	569501	3579998	88
			10/28/2010		215	569378	3579948	63
			10/28/2010		200	569366	3579961	130
			10/28/2010		195	569359	3579961	58
			10/18/2011		180	569384	3579951	99
	2		10/18/2011		323	568224	3580084	162
		Spikedace	10/4/2007		68	569265	3580026	105
			10/4/2007		255	569424	3579941	105
			9/17/2008		717	569706	3579826	125
			9/17/2008		609	569620	3579844	125
			9/17/2008		476	569592	3579986	125
			9/17/2008		255	569422	3579933	125
			10/28/2009		68	569277	3580018	212
			10/28/2009		609	569624	3579847	174
			10/28/2010		465	569590	3579935	73
			10/28/2010		420	569580	3579983	171
			10/28/2010		350	569501	3579998	91
			10/28/2010		215	569378	3579948	197
			10/28/2010		200	569366	3579961	114
			10/28/2010		195	569359	3579961	104
			10/18/2011		225	569413	3579938	176
			10/18/2011		246	569420	3579939	162
			10/18/2011		360	569513	3580017	496
			10/18/2011		314	569458	3579980	30
	2		10/18/2011		381	568282	3580056	656

2ASLDRedfield000111

Water	Reach	Species	Date	Site name	Meters from bottom of reach	Easting (NAD 83)	Northing (NAD 83)	Number Stocked
	2		10/18/2011		178	568078	3580060	485
Swamp Springs Canyon	Lower	Gila topminnow	10/4/2007		1275	564394	3589487	249
		Desert pupfish	10/4/2007		1275	564394	3589487	248
	Upper	Gila topminnow	9/17/2008		4245	566576	3589070	225
			9/17/2008		4267	566603	3589070	50
		Desert pupfish	9/17/2008		4245	566576	3589070	225
			9/17/2008		4267	566603	3589070	48
Cherry Spring Canyon	1	Gila topminnow	10/4/2007	Lower pool	1310	565977	3587082	130
			10/4/2007	Upper pool	1320	565981	3587090	134
			9/17/2008	Lower pool	1310	565977	3587082	275
		Desert pupfish	10/4/2007	Lower pool	1310	565977	3587082	148
			10/4/2007	Upper pool	1320	565981	3587090	98
			9/17/2008	Lower pool	1310	565977	3587082	275
Secret Spring		Gila topminnow	10/4/2007			571100	3578303	499
		Desert pupfish	10/4/2007			571100	3578303	496
			10/28/2010			571100	3578303	311
Headquarters Spring		Gila topminnow	9/17/2008			571624	3577960	275
		Desert pupfish	9/17/2008			571624	3577960	290
			10/28/2010			571624	3577960	374
Larry & Charlie Tank		Desert pupfish	10/28/2009			571603	3577909	196

2ASLDRedfield000112