A FIVE-YEAR NARROW-HEADED GARTERSNAKE (*THAMNOPHIS RUFIPUNCTATUS*) SURVEY SUMMARY FROM CANYON CREEK, ARIZONA-REVISED

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TABLE OF CONTENTS

ABSTRACT

Canyon Creek, within the Tonto National Forest near Payson, Arizona, supports a population of the federally Threatened Narrow-headed Gartersnake (*Thamnophis rufipunctatus*). A combination of trapping and visual encounter surveys have been used to monitor this population annually since 2015 to assess the relative status of this population. Herein we present the survey results from 2018 and summarize the six surveys done from 2015–2018 to assess relative abundance, habitat use, survey techniques, and age class structure of the Narrow-headed Gartersnake. In addition, we summarize fish densities and biomass along the stream reach occupied by the gartersnake. We found evidence of a stable population and reproduction in all years, and distinct habitat segregation between the Narrow-headed Gartersnake and Terrestrial Gartersnake (*T. elegans*) along the 2.5 km study stream reach. Furthermore, VES captured more Narrow-headed Gartersnakes than minnow traps, and future monitoring of Canyon Creek should, at a minimum, include VES supplemented with minnow traps. Because of the ease of site access, ongoing fish studies, and relative ease of capturing snakes, the Canyon Creek population should be considered for an intensive mark-recapture study to estimate population size, demographic parameters, and ecological interactions (i.e., fish prey dynamics) for robust trend monitoring and factors that regulate population fluctuations.

INTRODUCTION

The Narrow-headed Gartersnake (*Thamnophis rufipunctatus*, THRU hereafter) has precipitously declined throughout its U.S. range prompting its listing as Threatened under the Endangered Species Act (USFWS 2014). In Arizona the species has a limited distribution restricted to headwater streams and drainages of the Mogollon Rim from 800–1900 m (Holycross et al. 2006). Recent work suggests that there have been declines or extirpations in approximately 60% of THRU's Arizona range, and many remaining populations occur at low densities (Holycross et al. 2006; Rosen et al. 2012). The primary drivers of the declines are stream habitat alteration, invasive crayfish, and spiny-rayed sportfish (Rosen et al. 2012; USFWS 2014).

In 2015, Arizona Game and Fish Department (AZGFD) detected THRU in Canyon Creek, a tributary of the Salt River, 25 years after the last verified record (Burger et al. 2015). Canyon Creek, in the Pleasant Valley Ranger District, Tonto National Forest (TNF), is one of the few streams draining the Mogollon Rim that has not been colonized by crayfish, and it supports a fish community composed of native and nonnative species. The first ca. 9 km of Canyon Creek, including its spring-fed headwaters, occur on USFS land before the majority of the creek flows through White Mountain Apache tribal lands (Warnecke et al. 2008). The first THRU records were in 1986: two just below OW Ranch (USNM Herp Images 2800-801) and one along lower Canyon Creek, approximately 2.25 miles above the Salt River on the Fort Apache Indian Reservation (Rosen and Schwalbe 1988). An unverified record, from 1990, came from upper Canyon Creek on TNF, just upstream of the Reservation (Carrothers and Koppinger, HDMS). In 2004 and 2005 Holycross et al. (2006) surveyed Canyon Creek but failed to detect THRU on the TNF portion of the creek (Table A1), but did note that *Thamnophis elegans* (THEL, Terrestrial Gartersnake) was common. Since 2004 AZGFD has been conducting annual May-June fish monitoring surveys at Canyon Creek without detecting THRU, until the 2015 detections.

Since 2015 AZGFD has done five THRU surveys at Canyon Creek to assess the species' distribution, collect tissues for molecular studies, measure relative abundance, and learn basic aspects of their biology. These surveys have made valuable contributions to the species' conservation propagation and molecular ecology (Wood et al. 2011; Wood et al. 2018), but more is to be learned about this population's ecology and dynamics.

In August 2018 we conducted a collaborative multi-partner, interagency (Table A2), week long THRU survey at Canyon Creek. Herein we present these results and a summary of the previous five surveys conducted from 2015–2018. The goal of this synthesis is to assess temporal trends in snake relative abundance, habitat use, and capture technique efficiency over time at Canyon Creek. Our aim, or long-term use of this synthesis is to determine if the Canyon Creek THRU population is suitable for a long-term mark-recapture monitoring study for use as a reference, baseline population to measure temporal population trends, life history, and micro-scale habitat-use.

METHODS

Our 2018 surveys used the same survey techniques as the 2015–2017, distance constrained visual encounter surveys (VES) (Crump and Scott 1994; Guyer and Donnelly 2012) and trapping with Gee Minnow© (3.175 mm; 1/8") mesh, along a 2.5 km stream stretch. All surveys from 2015–2018 were performed from May through August during the snake active season (Table 1). During all VES (i.e., 2015–2018) a group of surveyors (ranging from 4–12 people/survey; Table 1) spread out within the riparian zone, i.e., stream channel and up to 25 m on both sides of the stream banks, and searched for snakes. All available macro-habitats: wetted-stream, flat and terraced banks, and boulders; and micro-habitats: under rocks and logs, rock crevices, and dense vegetation, were searched to locate snakes. All flipped rocks and logs were returned to their original spot. If any snakes, lizards, frogs, or large invertebrates were found under an object they were removed and placed next to the object before returning the object.

Since 2015 we have conducted four multiday trap surveys (Table 1), all following the same trap set and check methods. Minnow traps were placed approximately 10–20 m apart in riffles, runs, and pools within the wetted-width, as well as side pools and backwaters. Traps were tethered to the banks and partially submerged so that one-third to one-half of the trap was out of water to prevent snakes from drowning. Traps were set so that the trap opening was below the water line to allow snakes and fishes to enter. Trapped fish were left in the traps as bait for snakes. Because of fluctuations in stream flow, weight of captured animals, or other factors, trap levels may shift and daily adjustments were made as needed. If a trap was found with the opening above the water we noted this and it was excluded from future effort-capture analyses.

In August 2018 we conducted VES on 13–16 August and trapped on 13–15 August along the previously surveyed 2.5 km stream stretch transect (e.g., Burger 2015). During the daily surveys we checked traps while conducting the VES. We had a range of 6–10 observers per day searching for snakes using the same techniques described above. During the morning surveys on 14 and 16 August the VES ended before completion, but more than halfway through the transect, because of impending thunder storms. On these days we completed the surveys in the afternoon.

On afternoon of 13 August 2018 we set 102 minnow traps, placed approximately 20 m apart. A subset of 10 traps, at the terminus of the upper section, were baited with sardines and anchovies as part of a baiting experiment to see if this attracted snakes. We set traps in riffle, run, pool, and backwater habitats. There was a 220 m gap between traps 50 and 51, but the transect midpoint was at Trap 44, and we used the midpoint for habitat analysis (see below). We checked traps in the morning starting at 0900 hr on all days and at 1600 hr on the 14^{th} and 15^{th}. We pulled traps on the afternoon of the 15^{th} after they were checked.

During daily trap checks we recorded presence/absence of snakes, fish, and giant water bugs (Belostomatidae). We did not count or identify fish, but we did count and assign a size class (large or small) for belostomatids. Because belostomatids are predatory and known to feed on snakes (Schwendiman 2004; Ohba 2018), including neonate *Thamnophis cyrtopsis* (Black-necked Gartersnake) and *T. sirtalis* (Common Gartersnake) (Jayne and Bennett 1990), large individuals were removed from traps. Fish and other invertebrates were left in traps.

We recorded the following data on all herpetofauna observed or captured during each survey: species, time of capture, generalized size category (hatchling/neonate, juvenile, or adult), coordinates (UTM, WGS84), and substrate; for THRU and THEL we also recorded mode of capture (trap or hand). All captured THRU, and a subset of THEL, were placed in cloth bags and brought to camp for additional processing where we checked snakes for previous marks or PIT tags, measured SVL (mm), and recorded sex. Newly captured snakes were given a cohort brand (branded scale immediately anterior to anal scale) with an Aaron Medical Change-A-Tip medical cautery unit (Winne et al. 2006; Durso et al. 2013). After processing, we placed individually bagged snakes in a locked cooler with ice, and with a towel placed between the ice and snake bags to avoid contact and prevent injury. Snakes were held in this manner for no more than 20 hours before they were released at the point of capture.

We pooled and compared the capture and effort data for all 2015–2018 THRU Canyon Creek surveys (Table 1) to explore temporal variation in THRU and THEL counts (e.g., captures) and compared whether counts differed between trap and VES effort. We log transformed VES and trap hours to account for the large difference in cumulative effort between the two methods. We used generalized Poisson regression to explore if snake counts differed by method (VES and trap) and year; we could not do a comparison among months because there were too few monthly sampling sessions. We then used a logistic regression to determine if stream reach, upper and lower, had higher counts of THRU and THEL.

We obtained annual (2015–2018) fish survey data collected in May from AZGFD Region 6 (Mesa Office) trip reports from. Two of the fish survey sites occurred within our survey transect, one in the upper section and one in the lower. We calculated mean density (m^2) and mean mass (g) for *Salmo trutta* (SATR, Brown Trout), *Catostomus clarkii* (CACL, Desert Sucker), and *Rhinichthys osculus* (RHOS, Speckled Dace) for each stream section. We compared annual fish density and mean mass by stream stretch using nominal logistic regression. We then tested whether number of THRU was associated with fish density by stream stretch using a General Linear Model (GLM). We pooled data for all years because there were too few data to include year as a variable.

Table 1. Canyon Creek THRU survey effort and capture summaries for 2015–2018 surveys. Number of people per VES in parentheses. *Did not report THEL captures.

Survey Start & End Dates	Trap hrs	THRU Obs VES:trap	THEL Obs VES:trap	VES hrs	# Traps	Source
16–19 Jun 2015	9600	8:7	9:6	135 (4)	100	Burger 2015
4–6 Aug 2015	8600	7:0	19:12	81 (7)	100	Holycross et al. 2015
13–14 Jun 2016	4584	7:1	NA*	57.4 (3)	75	Cotten 2017
16 May 2017	0	4 (–)	12 (–)	46 (6)	0	Lashway, pers. comm.
25 Jul 2017	0	6 (–)	12 (–)	76 (12)	0	Ryan et al. 2017
14–16 Aug 2018	4848	8:2	33:1	94 (10)	101	This Report

All analyses were done in JMP Pro. Means are presented ± 1 Standard Deviation (SD), and subscript values are degrees of freedom and sample sizes. We follow the scientific and standard names and formats of Crother (2017) for amphibians and reptiles and Page et al. (2013) for fishes.

RESULTS

We set and checked traps for two full days, 14–15 August 2018, for a total of 202 trap days (4,848 trap hours), and we spent 94.04 person hours conducting VES surveys from 14–16 August (Table 2). Due to inclement weather we pulled traps on the afternoon of Wednesday, 15 August. In total, we detected 12 herpetofauna species: three anurans, five lizards, and four snakes during the August 2018 trap and VES efforts (see Table A3 for a list of all species observed during VES and trapping). We found belostomatids in 23% of our traps (32 large and 18 small). In addition, one adult *Anaxyrus microscaphus* (ANMI, Arizona Toad) and one adult *Rana chiricahuensis* (RACH, Chiricahua Leopard Frog), were captured in traps. Fish colonized traps quickly and 67% of traps had fish by the first trap check day (14 August) and 71% had fish by the second day (15 August). Trap success was low for gartersnakes with 2 adult THRU (0.006% traps occupied) and 1 adult THEL (0.003% traps occupied) captures.

We detected eight THRU: three adults and five neonates (<210 mm SVL) and 33 THEL: four adults, two juveniles, 27 neonates (< 210 mm SVL) in 2018 (Table 3). Mean THRU neonate SVL was 191.8 ± 21.8 mm and 176.0 ± 13.0 mm for THEL. Adults were detected in all survey years, 2015–2018, and juveniles and neonates were detected during every survey except July 2017 (Fig 1). Four THRU were brought to the Phoenix Zoo to bolster their managed breeding program.

Table 2. August 2018 daily THRU trap and VES survey effort at Canyon Creek. Note, we subtracted break time and VES duration does not equal total VES person hours. Number of surveyors in parentheses.

Date	Trap Hours	VES Start & End Time	VES Hours	VES Person Hours
13 Aug 2018	Traps set	–	–	–
14 Aug 2018	2,424	0904–1302	3.47 (12)	41.64
15 Aug 2018	2,424	0918–1311	3.70 (8)	29.6
16 Aug 2018	Traps removed	0932–1126	3.8* (6)	22.8
Total Hours	**4,848**	**–**	**15.72**	**94.04**

*We split into two groups, one surveyed from upper end and one from lower end of the transect.

For all years data combined, there was no difference in the THRU counts by year ($P = 0.4618$, $\chi^2_{5,16} = 2.57$), but significantly more snakes were captured by VES over traps ($P = 0.0073$, $\chi^2_{1,16} = 7.19$); THEL counts significantly differed by year ($P = 0.0089$, $\chi^2_{5,16} = 11.59$) and more VES captures than by traps ($P = 0.0041$, $\chi^2_{1,16} = 8.23$).

Table 3. Body sizes, sex, and disposition for the seven THRU captured in 2018.

Date Captured	Sex	SVL (mm)	Capture Method	Notes
14 Aug 2018	Female	210	Trap	Released
14 Aug 2018	Female	154	VES	Released
14 Aug 2018	Male	475	Trap	Released

14 Aug 2018	Female	200	VES	To Phoenix Zoo
14 Aug 2018	Male	400	VES	To Phoenix Zoo
14 Aug 2018	Male	210	VES	To Phoenix Zoo
15 Aug 2018	Male	200	VES	To Phoenix Zoo
15 Aug 2018	unknown	Adult	VES, escaped	Not captured

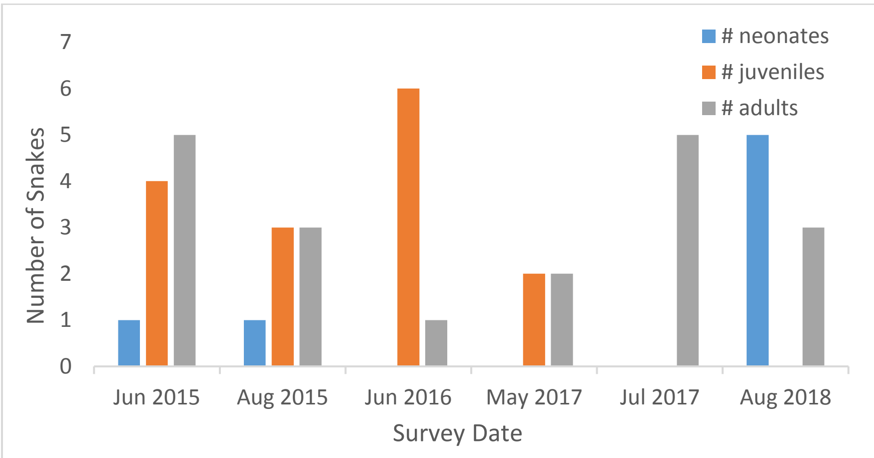

Figure 1. THRU 2015–2018 Canyon Creek size (assay of age) class distribution. Despite differences in survey effort multiple snake size classes have been consistently captured among years.

Pooled (all surveys from 2015–2018) fish density (m^2) between stream sections did not differ for SATR ($P = 0.2448$, $\chi^2_{6,8} = 1.35$) or RHOS ($P = 0.9259$, $\chi^2_{6,8} = 0.00$), but was greater in the lower reach for CACL ($P = 0.0009$, $\chi^2_{6,8} = 11.09$; Fig 2A); but RHOS was most abundant, and CACL and SATR were roughly equal overall throughout the study stream reach (Fig 2B). Mean fish mass did not differ between stream sections for SATR ($P = 0.1354$, $\chi^2_{6,8} = 2.22$), RHOS ($P = 0.8031$, $\chi^2_{6,8} = 0.06$), or CACL ($P = 0.1905$, $\chi^2_{6,8} = 1.71$). We found a positive relationship with the number of THRU captures and density of CACL, but no association with SATR and RHOS (Table 4).

In 2018, the two *Thamnophis* species appeared to segregate along the 2.5 km study stream transect, with a transition at the transect midpoint near Trap 44 (Fig 3A). We found significantly more THRU in the lower stream stretch than the upper stream stretch ($P = 0.0103$, $\chi^2_{4,36} = 6.57$) and significantly more THEL were found in the upper stream stretch than the lower stretch ($P = 0.0001$, $\chi^2_{4,37} = 29.75$). A single THRU occurred 71 m upstream of the transect midpoint, and seven were downstream of the midpoint. Conversely, 77% (25/31) of the THEL occurred upstream of the transect midpoint, and the farthest downstream observation was 164 m downstream of the midpoint. The pattern of segregation between the upper and lower reaches is further supported when all THEL and THRU observations from 2015–2018 are plotted (Fig 3B).

A. B.

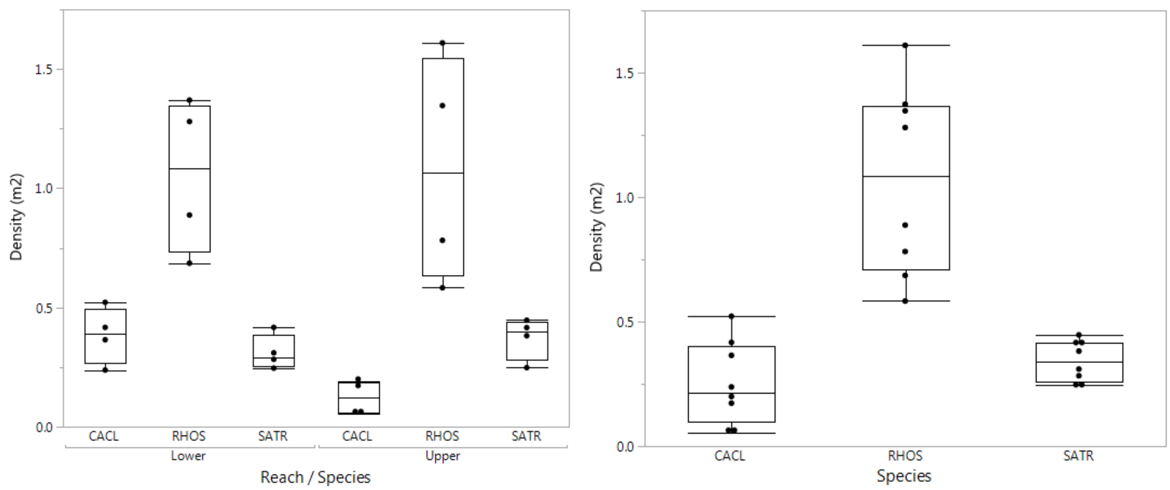

Figure 2. (A) Cumulative Canyon Creek fish densities collected annually (2015–2018) in May by species for upper and lower stream reaches; and (B) fish density for entire 2.5 km study stream reach from surveys.

Table 4. Generalized liner regression results of THRU captures by fish density and total fish densities along the stream reach and by upper and lower stream reaches. Whole model *P* = 0.0001, χ^2 = 27.16, DF = 4.

Species	P	χ^2	Estimate	Total Mean Density ± SD	Upper Mean Density ± SD	Lower Mean Density ± SD
CACL	0.0001	20.43	4.48	0.25 ± 0.16	0.12 ± 0.06	0.38 ± 0.11
RHOS	0.7015	0.52	-0.28	1.06 ± 0.37	1.08 ± 0.47	1.05 ± 0.32
SATR	0.4689	0.14	-2.27	0.34 ± 0.08	0.37 ± 0.37	0.31 ± 0.07

Discussion

Canyon Creek above the Fort Apache Indian Reservation is unique among Arizona's Mogollon Rim streams because it supports an apparently stable THRU population, a combination of native and non-native fish species, and lacks invasive crayfish (Jaeger 2016). There were no snake-specific trap surveys on Canyon Creek until 2004–2005 (Holycross et al. 2006), and during that work they noted the recent 2002 Rodeo-Chedeski Fire may have negatively affected their surveys. For instance, immediately following the fire there were increased silt and nutrient inputs, and depressed dissolved oxygen levels, which caused widespread fish mortality (Robinson et al. 2004; Ffolliot et al. 2011). The fire severity was greatest in the upper Canyon Creek watershed (e.g., Mule Creek, Valentine Canyon) and most of the Ponderosa pine overstory of the adjacent uplands and riparian willow-cottonwood trees in the burned area were lost. Due to this loss of riparian vegetation, monsoon flooding that followed the fire was severe and caused higher than normal magnitude floods (Warnecke et al. 2008). By 2005, the Canyon Creek fish community was recovering but densities were still below pre-fire levels (Warnecke and Wiggens 2005), which may have affected the 2004–2005 Holycross et al. (2006) surveys. But, it is also important to consider that their surveys did not have sufficient sampling effort for THRU detection (90 trap hours among the three surveys, and 20 hours or less of VES during each survey), therefore their lack of detection at that time was a false-negative; it wasn't until effort increased that snakes were finally observed.

Our 2018 effort is the sixth THRU survey since 2015, and like previous efforts we used VES and trapping along the same approximate stream reach for consistency. Both techniques reliably detect THRU, but VES has consistently produced more THRU captures than trapping at Canyon Creek, despite differences in survey hours between methods among years (e.g., Table 1). We had an 8:2 VES:trap snake capture ratio in 2018, and a 3:1 ratio for 2015–2018, even though trap hours were 56 times greater than VES hours. The increased efficacy of VES over trapping has also been noted for THRU surveys in Oak Creek, Arizona (Nowak and Santana-Bendix 2002), but trapping was more effective in New Mexico along the San Francisco River (Hibbitts et al. 2009) and Tularosa River (Jennings and Christman 2011). The difference in survey method success is unclear, but may be related to stream and streamside habitat structure, and warrants further study. What is clear is that detection success is stream dependent and both methods, VES and trapping, should be done together during any THRU survey to increase the likelihood of detection.

We cannot make strong inferences on the Canyon Creek THRU population size, which requires long-term mark-recapture, but the raw counts do provide insights on their relative abundance. The number of snakes encountered in the six surveys from 2015–2018 did not differ statistically, and suggests the population is relatively stable. Further supporting the relative stability at Canyon Creek is that multiple size classes (i.e., neonates, subadults, and adults) were regularly observed during all years, providing evidence of reproduction (Fig 1). This result is somewhat surprising because sampling effort and surveyor experience, two variables known to effect snake capture rates (Rodda 2012), varied among years and *a priori* we would expect relative abundance to differ from effort and experience alone. We have no evidence of population recruitment, which again requires long-term mark-recapture, but the presence of multiple age classes among years is encouraging.

Sixteen years post- Rodeo-Chedeski Fire, the study area fish community appears healthy and consists primarily of three species, non-native SATR, and native CACL, and RHOS (Jaeger 2016). Overall fish density by reach section did not vary, but the native species were numerically dominant in the entire stream reach and in both lower and upper reaches individually (Fig 4), while our study reach has consistently supported lower SATR densities and smaller sized fish than more upstream reaches (Gill 2011; Jaeger 2014, 2015). Water temperatures and a lack of large pool habitat in our study reach are likely factors for the low numbers of the non-native SATR (Curtis Gill, AZGFD, pers. comm). It is unclear if the presence of THRU here is related to the dominance of native fish, is associated with physical traits of the stream and valley bottom, or a combination of biotic and abiotic factors. Further work on factors predicting THRU stream reach occupation would be valuable.

A. 2018 B. 2015–2018

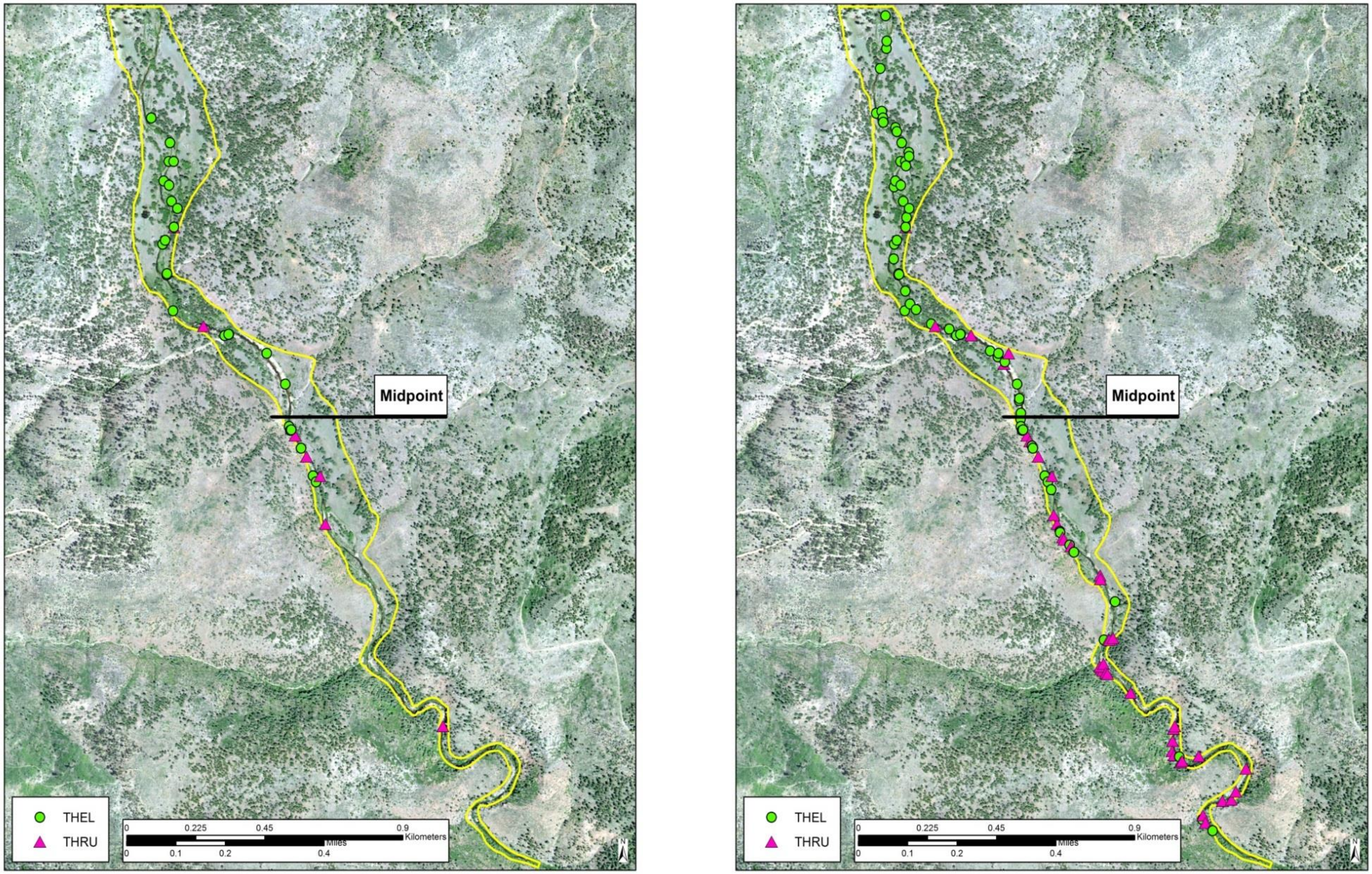

Figure 3. (A) Distribution of THRU and THEL along the 2.5 km Canyon Creek study reach in August 2018; (B) Distribution of THEL and THRU observations for all surveys, 2015–2018. See larger map figures (Figs A1 and A2) in the Appendix.

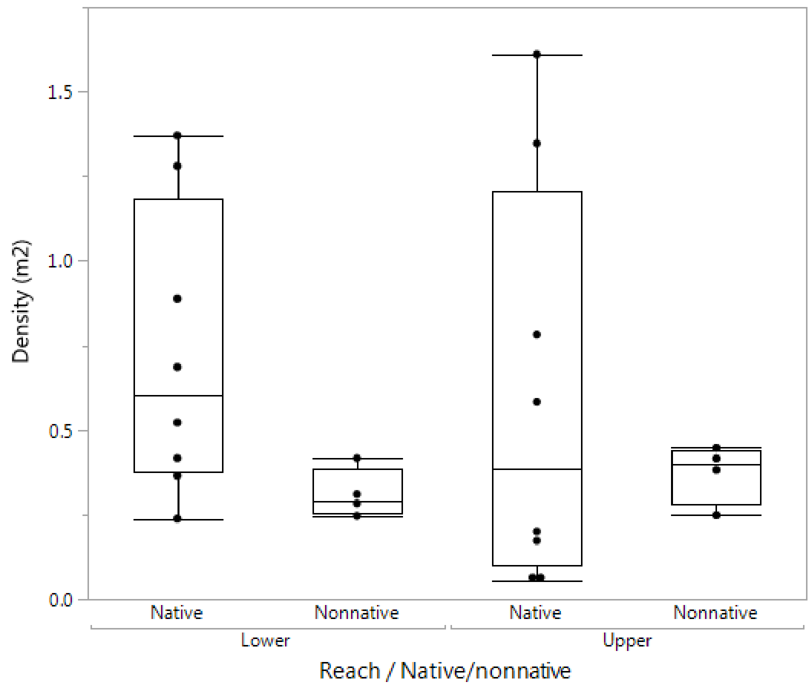

Figure 4. Native (pooled) and nonnative fish densities by upper and lower stream reaches at Canyon Creek. The only nonnative fish species detected in these reaches was SATR.

One interesting pattern that has emerged from this work is the apparent stream habitat partitioning between the two congeners, THEL and THRU. For our 2018 capture points, and for all years combined, there is a distinct partitioning with THEL dominating the upper stream reach and THRU dominating the lower stream reach, with an overlap, intermixing zone near the midpoint (Fig 3). Little is known on multi-*Thamnophis* species community habitat partitioning, but a three species *Thamnophis* community on Vancouver Island partitioned habitat by species-specific habitat associations, and the species differed in diet preferences (Gregory 1984). Kephart (1982) also found that differences in diet between THEL and *T. sirtalis* were based upon habitat usage, both species tended to eat the same prey when both occurred microsympatrically. THEL is a classic example of a generalist, feeding on both aquatic and terrestrial prey (Fitch 1940), compared to THRU, a prey specialist almost exclusively known to prey on fish (Fleharty 1967). Furthermore, where the two species co-occur in New Mexico THEL used habitats dominated by vegetation and THRU preferred rocky habitats near water bodies (Fleharty 1967). These two *Thamnophis* species at Canyon Creek appear to differ ecologically and we propose at least two possible explanations for this segregation: (1) competition for non-prey resources, or (2) physical stream and valley bottom habitat characteristics, but these may not be mutually exclusive. The apparent intermixing zone near Trap 44 (for 2018 surveys), the transect midpoint, is also a habitat transition zone where the habitat shifts from wider valley bottom and stream characteristics of cobble-pebble and pools, to a more narrow, rugged and rocky valley bottom with more boulder, cobble-pebble, riffles and runs (Fig A3). We are in the process of modeling the physical stream and valley habitat traits to determine whether or not certain habitat features can predict snake occurrences along streams and infer a putative mechanism of habitat segregation. The ability to model snake-habitat associations can help prioritize stream sections for future THRU surveys based on stream habitat characteristics.

Crayfish can pose a serious threat to THRU through direct predation or indirect, bottom-up factors that reduce or eliminate their prey base (e.g. Creed 1994; Carpenter 2005; Rosen et al. 2012). While crayfish are absent from Canyon Creek, they are known from nearby streams and there is a persistent risk of an accidental introduction. Continued monitoring of THRU should incorporate crayfish monitoring, and if crayfish are detected all available efforts should be made to eliminate any potential invasion before they can become established. The presence of non-native trout does not appear to have a negative effect on THRU according to the consistent number of captures and diverse age structure of THRU across survey years.

Future Directions

There is a lack of basic population ecology information for THRU, including natural population fluctuations and responses to stochastic environmental conditions. To better understand the population demographics, estimate population size, and detection probability would require an intensive mark-recapture study. Such a labor intensive effort would allow accurate estimation of survey and population parameters which are critical to population monitoring. Furthermore, parameter estimations from this population can be used as a baseline for monitoring other Tonto National Forest THRU populations, and elsewhere. A population parameter baseline from Canyon Creek can be valuable for population viability analysis, and help set goals and metrics in monitoring future recovery efforts. It would be beneficial for all partners to allocate time and resources in monitoring this population to better understand this valuable population.

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APPENDIX

Additional observations of note

On 13 August 2018 we observed an adult male *Rana chiricahuensis* (RACH) near Trap 16, at the upper end of the stream transect. This was this first record of RACH in Canyon Creek and a toe-clip was collected for DNA barcoding to determine its origin. In addition, we observed two more RACH further downstream on 16 August 2018, one of which was a subadult. Neither of these two frogs were captured. The AZGFD Ranid Frogs lead and USFWS lead were contacted and have the specific observation points.

Appendix Tables A1–A5 and Figures A1–A3

Table A1. THRU survey effort and capture summaries for 2004–2005 and 2015–2018. Number of people/VES in parentheses. *Did not report THEL captures.

Survey Dates	Trap hrs	THRU # VES:trap	THEL # VES:trap	VES hrs	Traps #	Source
18 May 2004	0	0	7	12	0	Holycross et al. 2006
9 July 2004	90	0	2:0	20	18	Holycross et al. 2006
12 Oct 2005	0	0	1	4	0	Holycross et al. 2006
16–19 Jun 2015	9600	8:7	9:6	135 (4)	100	Burger 2015
4–6 Aug 2015	8600	7:0	19:12	81 (7)	100	Holycross et al. 2015
13–14 Jun 2016	4584	7:1	NA*	57.4 (3)	75	Cotten 2017
16 May 2017	0	4 (–)	12 (–)	46 (6)	0	Lashway, pers. comm.
25 Jul 2017	0	6 (–)	12 (–)	76 (12)	0	Ryan et al. 2017
14–16 Aug 2018	4848	8:2	33:1	94 (10)	101	This Report

Table A2. August 2018 Canyon Creek survey participants and their affiliations.

Name	Date	Affiliation
Mason Ryan	13–16 Aug	Arizona Game & Fish Department
Kaleb Smith	13–16 Aug	Arizona Game & Fish Department
Sharon Lashway	13–15 Aug	Arizona Game & Fish Department
Sidney Riddle	13–16 Aug	Arizona Game & Fish Department
Ryan O'Donnell	14 Aug	Arizona Game & Fish Department
Sky Arnett-Romero	14 Aug	Arizona Game & Fish Department
Kevin Krahn	13–16 Aug	Phoenix Zoo
Christina Akins	13–14, 16 Aug	U.S. Forest Service, Tonto National Forest
Michelle Williams	13 Aug	U.S. Forest Service, Tonto National Forest
Tyler Keller	13–14 Aug	U.S. Forest Service, Tonto National Forest
John Newquist	15 Aug	U.S. Forest Service, Tonto National Forest
Toria Washburn	14–15 Aug	U.S. Forest Service, Tonto National Forest
Anthony Bush	16 Aug	U.S. Forest Service, Tonto National Forest
Brian Blais	13–15 Aug	University of Arizona

Table A3. August 2018 amphibian and reptile species observed and counts from VES and trap captures (parentheses). *Note, for amphibians and lizards this includes recently metamorphosed frogs and hatchling lizards.

Species	# Neonates*	# Juveniles	# Adults	Total
Amphibians (3 species)	1	4	2	7
Anaxyrus microscaphus	3	-	1 (1)	4 (1)
Hyla wrightorum	1	-	-	1
Rana chiricahuensis	-	1	1	2
Lizards (5 species)	5	6	15	26
Elgaria kingii	-	1	0	1
Plestiodon multivirgatus	1	-	2	3
Phrynosoma hernandezi	2	-	0	2
Sceloporus tristichus	2	5	11	18
Urosaurus ornatus	-	-	2	2
Snakes (4 species)	30	6	7 (3)	43 (3)
Crotalus cerberus	-	3	-	3
Diadophis punctatus	-	1	2	3
Thamnophis elegans	27	3	3 (1)	36 (1)
T. rufipunctatus	4	-	2 (2)	8 (2)

Table A4 [not referenced in text]. Amphibian and reptile species list from the 2.5 km Canyon Creek study area since 2015. *New locality record.

Species	Common Name
Anurans (4)	
Anaxyrus microscaphus	Arizona Toad
Hyla arenicolor	Canyon Treefrog
Hyla wrightorum	Arizona Treefrog
*Rana chiricahuensis**	Chiricahua Leopard Frog
Lizards (5)	
Elgaria kingii	Madrean Alligator Lizard
Phrynosoma hernandesi	Greater Short-horned Lizard
Plestiodon multivirgatus	Many-lined Skink
Sceloporus virgatus	Striped Plateau Lizard
Urosaurus ornatus	Ornate Tree Lizard
Snakes (5)	
Crotalus cerberus	Arizona Black Rattlesnake
Diadophis punctatus	Ring-necked Snake
Pituophis catenifer	Gophersnake
Thamnophis cyrtopsis	Black-necked Gartersnake
T. elegans	Terrestrial Gartersnake
T. rufipunctatus	Narrow-headed Gartersnake

Table A5 [not referenced in text]. Other species of note observed in August 2018.

Species	**Common name**	**Notes**
Birds		
Buteogallus anthracinus	Black Hawk	
Megaceryle alcyon	Belted Kingfisher	
Mammals		
Cervus canadensis	Elk	
Odocoileus hemionus	Mule Deer	
Mephitis mephitis	Striped Skunk	
Sciurus aberti	Abert's Squirrel	
Mollusks		
Sonorella sp.	Talus Snail	Specimens collected for Jeff Sorensen
Oreohelix sp.	Mountain Talus Snail	Possibly undescribed, Jeff Sorensen collected

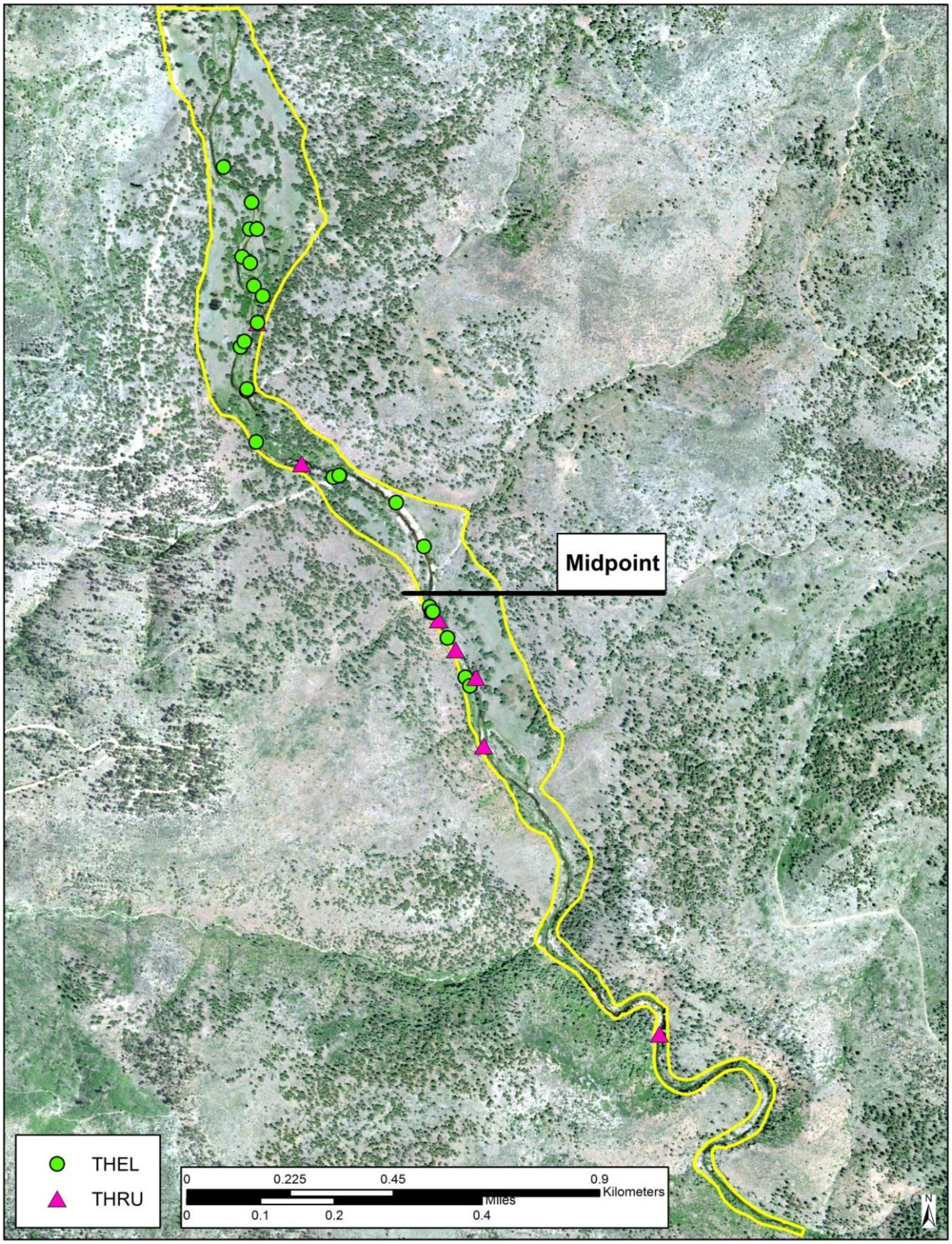

Figure A1. A letter-sized map of the distribution of THRU and THEL along the 2.5 km Canyon Creek study reach in August 2018.

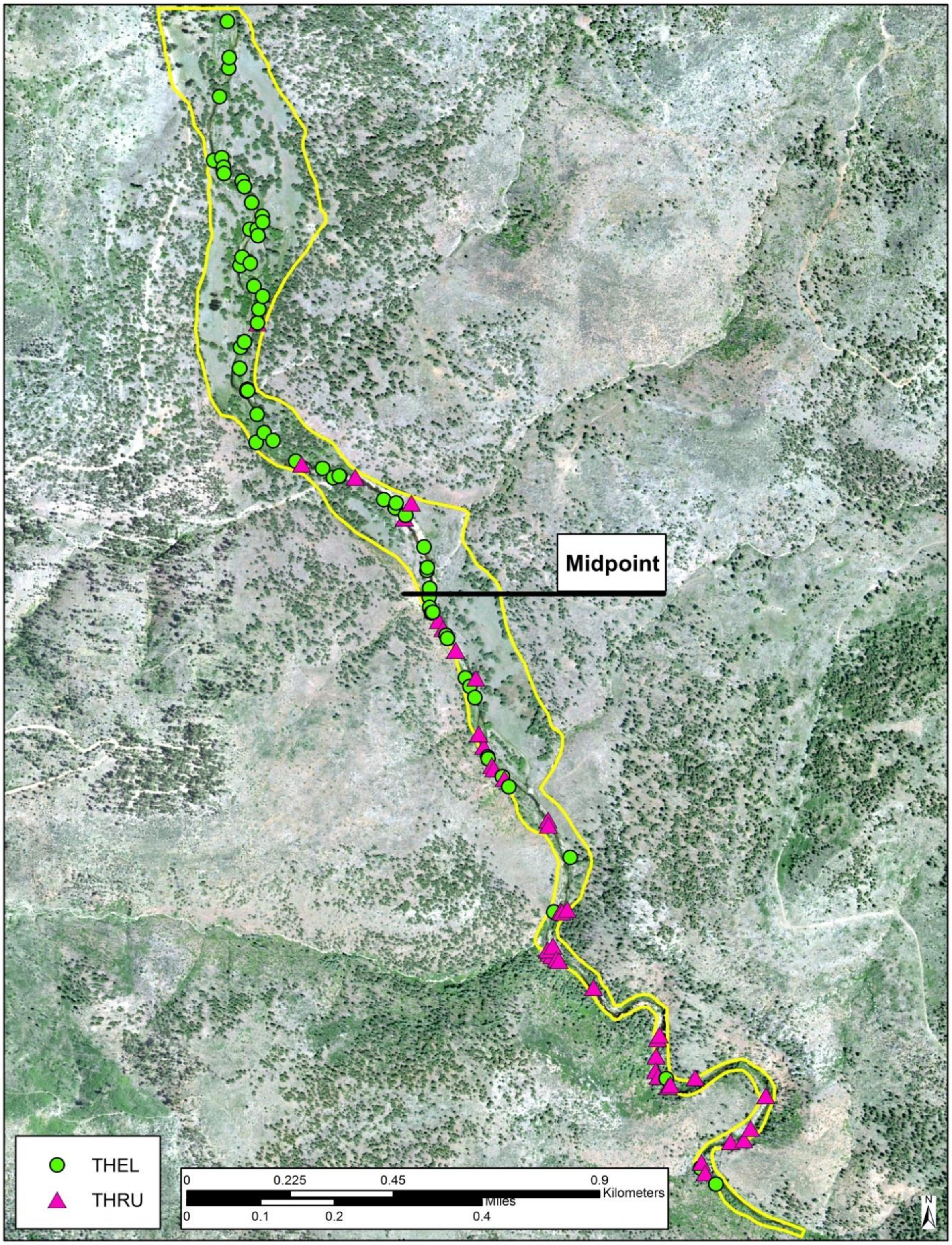

Figure A2. A letter-sized map of the distribution of THEL and THRU observations for all of 2015–2018.

A. Upper Canyon Creek Habitat

Figure 3A. Canyon Creek habitat characteristics of the (A) upper section showing wide valley bottom with little rocky habitats and (B) the lower stream reach showing a the narrow canyon and increase in rocky habitat.

B. Lower Canyon Creek Habitat

Figure 3A continued. Canyon Creek habitat characteristics of the (A) upper section showing wide valley bottom with little rocky habitats and (B) the lower stream reach showing a the narrow canyon and increase in rocky habitat.