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CAVE CRICKET FORAGING STUDY
FROM STARK'S NORTH MINE TO PROPOSED NORTH WALNUT CREEK TRAIL
AUSTIN, TRAVIS COUNTY, TEXAS



Ceuthophilus secretus cave crickets on foraging on Agaricales mushrooms at the cave entrance.

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Abstract

Biologists painted 413 cave crickets (*Ceuthophilus secretus*) from Stark's North Mine, and surveyed outside of the entrance for six nights in order to answer questions about foraging patterns. Only two marked crickets were recaptured outside of the cave. Searchers recorded a total of 350 cave crickets foraging within the 105 m search area around the cave, and 95% were found within 45 m. Searchers detected the remainder up to 96 m from the entrance. Surveyors recorded a total of seven crickets on the far (east) side of Walnut Creek, on and near the proposed North Walnut Creek Trail.

Mound searches as well as opportunistic and baited collections of ants around the mine entrance and along the path of the proposed trail yielded no evidence of red imported fire ants or tawny crazy ants. The nearest known population at this time for tawny crazy ants is about 8 km to the north-northwest. We recommend best management practices, including preserving dense canopy cover, for construction and maintenance of the trail that favor a healthy arthropod community including native ants and cave crickets.

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Introduction

RPS contracted Zara Environmental LLC (Zara) to analyze cave cricket use of the area surrounding Stark's North Mine. Cave cricket use is in question because of the proposed development of a public access trail within 105 meters of the cave entrance, a buffer commonly used for cave cricket foraging area based on Taylor et al. (2005).

Biologist designed this study to answer the following research questions:

1. Do cave crickets forage across Walnut Creek from Stark's North Mine?
2. Where do cave crickets forage around Stark's North Mine?
3. Do the crickets forage up to the proposed trail?
4. Are red imported fire ant mounds or tawny crazy ants observed within the 105 m area around the cave?

In small caves in central Texas, cave crickets (*Ceuthophilus* spp.) act as keystone species, providing exogenous energy to cave invertebrate communities by depositing feces, eggs and their dead bodies inside the cave (Taylor et al., 2005). Development within cave cricket foraging range may increase the potential for both predation upon and competition with cave crickets. Accurate estimates of cave cricket foraging range are important for establishing best management practices when planning development near caves where listed and endangered cave invertebrates are known to occur.

Stark's North Mine is a man-made feature in karst bedrock that has become inhabited by a community of cave organisms, including the federally listed troglobitic harvestmen *Texella reddelli*, and trogloxenes such as harvestmen (*Leiobunum townsendii*) and cave crickets. The mine sits on a 0.87 acre site maintained for karst invertebrate mitigation as part of the Balcones Canyonlands Conservation Plan's regional section 10(a)(1)(B) U.S. Fish and Wildlife Service permit.

Methods

Trial surveys and study timing

Zara (2013) describes work performed on this project for two evenings in October 2013. A combination of low cricket numbers and cooler temperatures informed biologists that the study performed during that time of year would not be viable because of the low sample size. In addition to informing the importance of seasonality, these surveys were valuable for determining that a 3-4 person field crew is an appropriate effort given the search area size. Biologists determined a priori that six nights were the minimum sample by comparing the survey effort with Taylor et al. (2005) who surveyed a 105 m complete radius in 17 nights. Given this study only examined one quarter of the radius, and somewhat less due to land access, six nights was a comparable effort to the prior study. Research on closely related cave crickets in New Mexico and Kentucky shows daily activity patterns (Campbell, 1976), with approximately one-third of the population exiting the cave each night to forage on the surface

and presumably return to the cave (Campbell, 1976; Park and Reichle, 1964; Reichle et al., 1965; Sullivan, 1962). Thus our choice of a minimum of six nights was designed to capture approximately two cycles of exiting. Finally, examination of nightly variation of cricket exit patterns in central Texas (Zara and Veni and Associates 2011, section 4.2.3.2.7) indicated a high variance within consecutive nights and recommended several nights of data to capture a realistic snapshot of the population. Biologists timed field surveys according to recommendations by Weckerley (2012) higher nighttime temperatures and in-cave observations of increasing cricket numbers. These 2014 field surveys included six nights of a three to four person field-crew in June.

In-Cave Survey

Observers arrived at least sixty minutes prior to sunset to perform a count of cave crickets inside Stark's North Mine. Within the mine, researchers counted all *Ceuthophilus* species and lifestages, and attempted to mark every subadult and adult with fluorescent paint (Figure 1). In-cave surveys lasted between 10 and 30 minutes. All surveyors exited the cave at least 30 minutes before sunset to avoid influencing cricket exit patterns.



Figure 1. Surveyor marking a cave cricket with fluorescent paint.

Exit Count

Between sunset and the end of nightly surveys, observers stationed one person at the cave entrance to record data on crickets exiting the cave. Data collected included:

- Weather at beginning and end of survey (barometric pressure, temperature, cloud cover and rainfall)
- number of marked and unmarked crickets exiting the cave
- time of cricket exits
- fluorescent mark color of exiting crickets
- details about new marks made during exit count
- other fauna present

Foraging Area Survey

In order to facilitate search patterns and nighttime navigation, biologists searched within three designated areas between the mine entrance and the edge of the property across Walnut Creek, which includes the path of the proposed trail. The 'near cave' transect area includes everything west of Walnut Creek within the search area, the 'bluff' transect area includes the entire rock bluff and associated breakdown to water's edge on the west bank of the creek, and the 'far cave' transect includes the entire accessible area across Walnut creek from Stark's North Mine (Figure 2). Observers rotated between search areas in order to vary the observer in case of inadvertent biases and equalize the person-minutes of effort across the entire study area. Rotation patterns were also designed to avoid resampling an area soon after the most recent search, and to maximize data collection when observers encountered many crickets in a cluster.

Observers performed searches using a bright white headlamp. To detect animals not on bare ground or bedrock, observers pushed aside vegetation, turned over logs and other possible cover, leaned over to look through branches and shrubs, and sometimes knelt on the ground to look underneath low branches or rock ledges, paying particular attention to potential karst features. Other karst features on the property that are potential daytime cover for cave crickets include enlarged joints and bedding plane partings in the bluff extending from the cave entrance and at a small bedrock wall in the 'far cave' transect. When a cricket was detected, the observer assigned a unique encounter ID consisting of the date, observer initials, and time of encounter (mmddiihhmm). Observers wrote the encounter ID in permanent marking pen on a white marking flag and planted the flag at the encounter point and recorded the following data for each encounter:

- unique encounter ID
- time of encounter
- specific search area
- cricket distance from ground
- species, sex and lifestage
- whether or not cricket was marked
- number of crickets encountered

Ant Survey

Observers collected ants opportunistically during in-cave, exit count, and foraging area surveys. In addition, on 27 June 2014 observers set out bait lines along the path of the proposed trail and within the near cave area. Following methods presented in Porter and Tschinkel (1987), the bait lines consisted of 20 disposable glass culture tubes baited in one end with small bits of hotdog (0.5 g) and mint jelly, spaced six to ten meters apart. Mint jelly was added to the bait protocol based on the foraging preferences of tawny crazy ants (cite). After 45 minutes, observers capped the tubes and collected them for later identification. The staff of the Brackenridge Field Laboratory under the supervision of Dr. Rob Plowes performed ant identification.



Figure 2. Map of Starks North Mine Cricket Foraging Survey Areas.

Results

Observers spent 546 person minutes performing in-cave cricket counts, 660 person minutes performing cricket exit counts, and 1576 minutes surveying within the foraging area over six nights and one additional in-cave survey, for a total of seven in-cave surveys. Surveyors reduced field efforts on the night of 12 June 2014 due to inclement weather and tornado warnings in the area near Stark's North Mine.

During in-cave surveys, observers encountered and marked 392 *C. secretus* and seven *C. cunicularis* crickets (Figure 3). Typically every cricket encountered was painted, with fewer than 3% of crickets (or 9/397 crickets) evading painting by retreating into inaccessible cracks or hopping into one of the two pools of water in the mine where they would remain for extended periods using surface tension to stay afloat. Of the 397 crickets marked, observers recaptured a total of 117 marked crickets during the six in-cave surveys. During the seventh and final in-cave visit on 27 June 2014, observers recaptured 15 previously marked crickets.

Biologists recorded behaviors, particularly associated with mark retention. In October 2013, freshly painted crickets were seen scraping their backs against the bedrock walls, in an apparent effort to remove the paint. During the June 2014 effort, this was not seen, however marks were sometimes found to be somewhat worn or flaked off and in those cases surveyors re-painted the cricket. In a few cases, painted crickets were seen during the molting process, an action that clearly causes loss of mark (Figure 4). Overall mark retention was excellent considering the short timeline of the survey, with marks as old as 15 days observed (Figure 5).

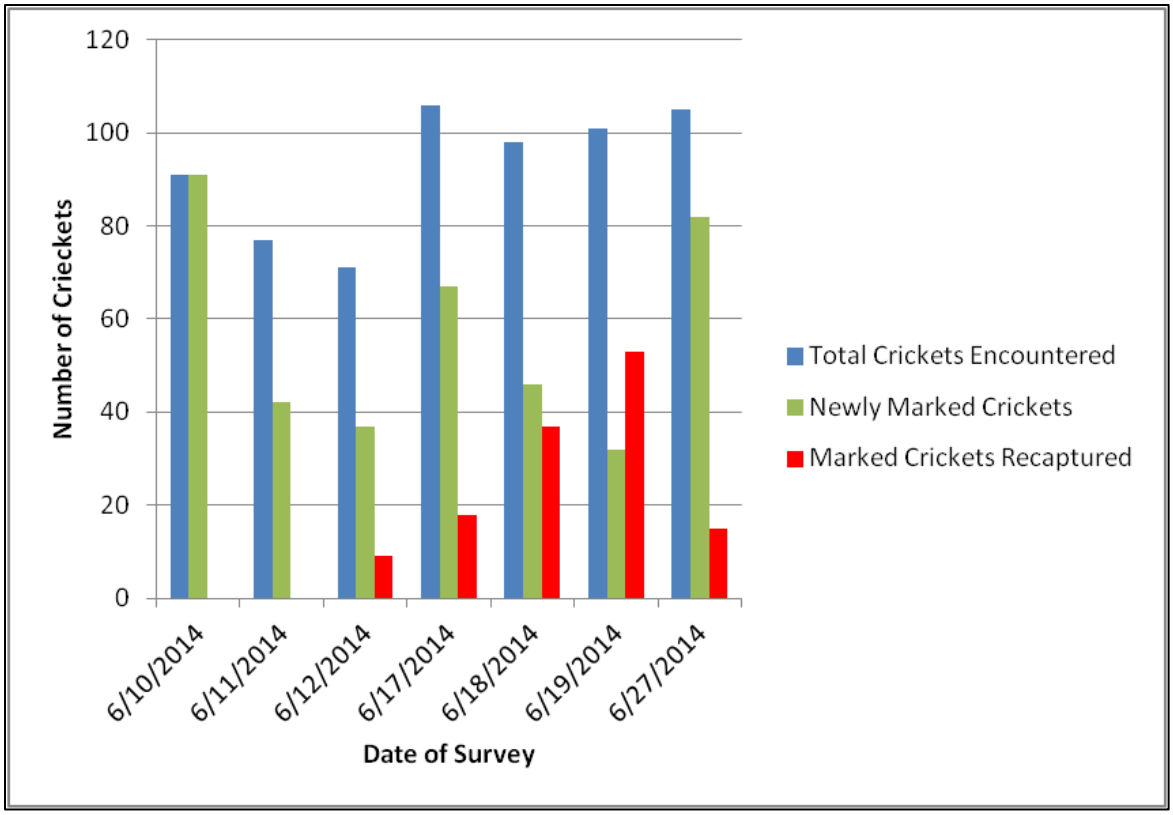

Figure 3. Number of crickets captured during in cave surveys.


Figure 4. Cricket molting witin Stark's North Mine. Note pink paint on back and legs of exuviae.



Figure 5. A cricket with florescent paint visible under black light. Surveyors applied pink paint 15 days before the date of the photo.

During exit surveys, observers encountered 100 crickets. Forty-one of those had been previously marked during either in-cave surveys or exit surveys from previous nights (Table 1). Of the 59 unmarked animals found exiting, 21 were captured and marked, leaving a total number of known unmarked crickets that evaded capture and exited the cave at only 38.

Behaviorally speaking, during the June 2014 surveys the crickets tended to emerge from the cave and immediately leave the area. This is in contrast to the two nights of observations in October 2013 when crickets tended to linger near the cave mouth then either re-enter the cave or engage in mating behaviors (males chasing males or females, females hopping away or found in close proximity to one or two males, frequent stopping to clean genital area, copulation). On only one day, 12 June 2014, during an approaching storm, observers noted crickets approaching the mine opening from within, then retreating back into the mine. Surveyors observed this behavior more often as inclement weather approached.

Table 1. Number of crickets observed during exit surveys.

Date	*Ceuthophilus* nymphs	*Ceuthophilus* Subadults	*C. secretus* Adults	Total Crickets Encountered	Marked Crickets Encountered
6/10/14	0	0	20	20	3
6/11/14	3	3	18	24	9
6/12/14	0	0	0	0	0
6/17/14	0	5	16	21	9
6/18/14	0	5	13	18	9
6/19/14	1	9	7	17	11
Total	4	22	74	100	41

During foraging area surveys, observers spent unequal person-minutes of effort per square meter of area surveyed, therefore a correction factor was used following Taylor et al. (2005). Using these corrected proportions, of the 350 crickets encountered, 95.3% were encountered within the 'near cave' area, 0.5% within the 'bluff' area, and 4.2% within the 'far cave' area (Table 2). Biologists found only two marked animals, both very close to the cave entrance. Of the crickets encountered within the far cave area, surveyors encountered five on the north end of the search area near the creek and a small bedrock feature, and two on the south end of the search area. The greatest distance of an encounter from the entrance was 96 meters (Figure 6).

Table 2. Correction table for unequal sample effort across survey areas.

Survey area	Size (m^2)	Search effort (min)	Correction factor	Actual number of Crickets (proportion)	Corrected proportion
Far Cave	5204	531	11.98	7 (2%)	4.21 %
Bluff	554	678	1	10 (2.86%)	0.50 %
Near cave	1711	367	5.70	333 (95.14%)	95.29 %
Total	7469	1576		350 (100%)	100 %



Figure 6. Map of cricket encounters.

During these foraging area searches, there was a stark difference of cricket encounters between days three and four, which was also between week one and two (Figure 7). On June 12 a major rainstorm came through the area, and after that the cricket encounters increased by an order of magnitude. The majority of the encounters that second week, June 17-19, were at a large patch of mushrooms which had appeared near the cave entrance. This mushroom patch was approximately 3 m^2 and consisted of 100-200 gilled mushrooms, order Agaricales (see cover photo).

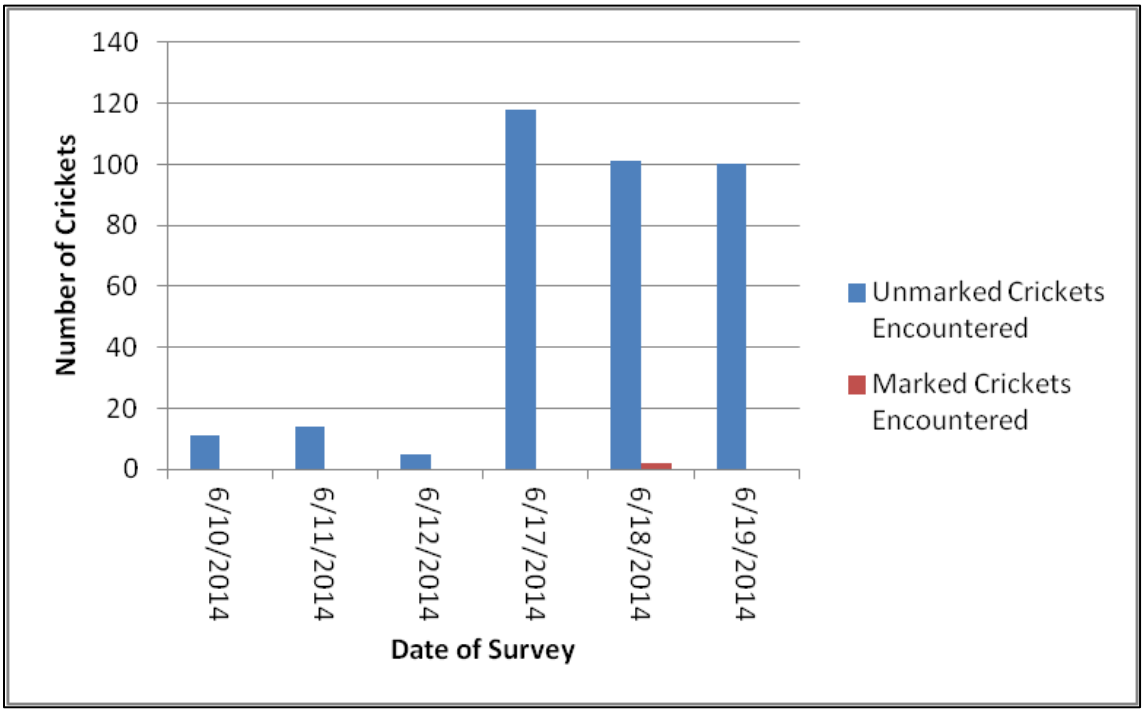

Figure 7. Number of crickets encountered during foraging area surveys. A large rain event occurred on 12 June, most likely accounting for the major increase in detections the second week.

Surveyors captured a total of 39 ants for identification (Table 3). Surveyors did not capture any red imported fire ants or tawny crazy ants during opportunistic and baited surveys. Additionally, observers encountered no red imported fire ant mounds during 2014 survey efforts. Observers reported one red imported fire ant mound in Zara (2013).

Table 3. Ant taxa collected.

Taxa	n
Solenopsis geminata	4
Crematogaster laeviuscula	1
Pheidole floridana	3
Solenopsis sp. (native Thief Ant, not *invicta*)	6
Pheidole dentate	25
Total	**39**

Discussion

We addressed these four primary questions:

1. Do cave crickets forage across Walnut Creek from Stark's North Mine (SNM)?

Yes. We detected 4.21% of cave crickets foraging on the far side of Walnut Creek (Table 2, Figure 6).

The observations on the far side of Walnut Creek were of unpainted crickets; therefore, it is not certain that these particular crickets came from SNM. They could have come from another karst feature or other cover area on the property, or they could have come from SNM as one of the 38 crickets seen exiting that evaded capture, and therefore were not painted. Finally, they could have formerly been painted but shed or otherwise lost their paint (e.g. Figure 4). The data herein cannot confirm nor deny whether individuals that use SNM for some part of their lifespan also cross Walnut Creek and use the 'far cave' transect area for foraging, but it does demonstrate cave cricket use of the 'far cave' area near the trail.

Given the bulk of observations of foraging crickets were unpainted (348/350, or 99%), in spite of the fact that many individuals were painted during in-cave and exit counts (392 + 21 = 413 marked crickets total), it is likely that the total population of cave crickets in the area is large compared to the portion marked during this study. This large population of crickets may take daytime cover in other areas besides SNM. Another interesting observation is that while 392 crickets were painted inside the cave, only 41 (10%) were seen exiting. Did the painting impact their behavior such that 90% of the painted crickets remained in the mine? Do a significant number of crickets exit through the narrow borehole entrance above the main entrance, or another small, undocumented entrance that was not monitored? Another possibility is that individual crickets exit the mine less frequently, such as once every seven days, therefore our

study design of only 6 nights was not enough to capture the real exit patterns and not enough to find painted crickets during foraging.

Ceuthophilus secretus are encountered by biologists in the highest densities in caves and karst features, and are thus typically studied in those environs and thought of as cave-dwelling species. However they are also well known to occur outside of caves and karst features, and even outside of karst regions. Their life history and migration patterns are not well studied, however radio tracking studies in central Texas indicate that some individuals are highly motile, spending nights outside of the cave and also not loyal to one cave (Taylor et al. 2004). Observations of cricket populations inhabiting formerly entranceless caves in as little as 6 months to one year after they are dug open (James Reddell, pers. comm. 2014) indicate that surface populations must be migrating through the area to encounter the new feature. Molecular data from central Texas indicates genetic exchange across large areas (Taylor et al. 2007). In sum, the conservation of this species may rely equally or more on rural corridors and greenspaces than on specific cave sites, even though the bulk of the observed population is in the caves.

There are no specific data in the literature regarding the propensity for *C. secretus* to cross surface creeks or rivers. We observed them regularly hopping into pools, and floating on the surface tension of the water in SNM, indicating they are able to move across wetted areas. Whether they would voluntarily, or occasionally involuntarily cross Walnut Creek is not known. Molecular data on this species indicates a discontinuity at a large river (the Colorado), however many well supported clades occur across other large river basins (Pecos, Rio Grande, Nueces, San Antonio, Guadalupe) (Taylor et al. 2007).

2. Where do cave crickets forage around Stark's North Mine, and do the crickets forage up to the proposed trail?

Most crickets forage within 30 m of the mine entrance, and a small portion do forage up to the proposed trail.

The ‘near cave’ survey area was found to have 95.29% of all cricket detections. This survey area extends to about 45 m from the mine entrance, however the bulk of the observations were within 30 m of the entrance (Figure 6). The trail, which is approximately 90 m away, is in the ‘far cave’ survey area where 4.21% of the encounters occurred. A portion of those ‘far cave’ occurrences (5/7 crickets) were on the trail itself. Those five crickets, represented by a single dot on the north end of the study area in Figure 6, were near a short bedrock undercut wall that may provide daytime cover for crickets.

3. Are red imported fire ant mounds observed within the 105 m area around the cave?

No. Initial observations (Zara 2013) indicated a single mound on the east bank of Walnut Creek, however specimens identified in this study indicate no red imported fire ants, only native *Solenopsis geminata* and another native *Solenopsis* sp. Proving absence is a difficult task, thus

this survey does not absolutely prove they do not exist somewhere within the survey area, however they were not detected during this effort and if they are present it must be in low numbers.

4. Are tawny crazy ants observed within the 105 m area around the cave?

No. Sampling around the cave and on the proposed trail detected no tawny crazy ants. The nearest known population of this species at this time is about 8 km to the north northwest.

The most significant results of this study include the documentation of a large population of crickets in the study area. While most animals were encountered within or near the mine, some individuals used the 'far cave' area on the other side of Walnut Creek. Given a mobile species that uses various caves and karst features opportunistically, conservation of wildlife corridors between these cover areas may be vitally important to the persistence of individual populations that support listed troglobites. We recommend best management practices for construction and maintenance of the proposed trail that minimize vegetation disturbance, encourage native species, and protect cave crickets. Maintenance of canopy cover is also significant for inhibiting red important fire ant infestation, a known foraging competitor for cave crickets (Taylor et al. 2003).

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Appendix A. Cricket Encounter Data.

Date	Time	Location	Species	Sex	Lifestage	Marked	ID	n=	Height From Ground
6/10/14	21:24	Near	Secretus	Unk	Adult	Unk	0610DM2124	1	10
6/10/14	21:30	Near	Secretus	Unk	Sub-adult	Unk	0610DM2130	1	Ground
6/10/14	21:31	Near	Secretus	Unk	Adult	N	0610DM2131	1	Ground
6/10/14	22:29	Near	Secretus	Unk	Adult	N	0610DM2229	1	Ground
6/10/14	22:34	Near	Secretus	Unk	Adult	N	0610DM2234	1	Ground
6/10/14	22:39	Near	Secretus	Unk	Adult	Unk	0610DM2239	1	5
6/10/14	21:43	Bluff	Secretus	M	Adult	N	0610KM2143	1	4
6/10/14	21:56	Near	Secretus	Unk	Adult	N	0610KM2156	1	0
6/10/14	22:01	Near	Secretus	M	Adult	N	0610KM2201	1	1
6/10/14	22:08	Near	Secretus	Unk	Adult	N	0610KM2208	1	1.5
6/10/14	22:14	Near	Secretus	Unk	Adult	Unk	0610KM2214	1	0
							Sum	**11**	
6/11/14	23:00	Near	Secretus	F	Adult	N	0611CC2300	1	Ground
6/11/14	23:04	Near	Secretus	F	Adult	N	0611CC2304	1	0.2
6/11/14	22:04	Near	Secretus	Unk	Adult	N	0611DM2204	1	Ground
6/11/14	22:05	Near	Secretus	Unk	Sub-adult	N	0611DM2205	1	Ground
6/11/14	22:06	Near	Secretus	Unk	Adult	N	0611DM2206	1	Ground
6/11/14	21:27	Bluff	Secretus	M	Sub-adult	N	0611CC2127	1	Ground
6/11/14	21:41	Near	Secretus	M	Adult	N	0611CC2141	1	Ground
6/11/14	21:48	Near	Secretus	M	Adult	N	0611CC2148	1	Ground
6/11/14	22:36	Bluff	Secretus	M	Adult	N	0611CC2236	2	Ground
6/11/14	22:40	Bluff	Secretus	F	Adult	N	0611CC2240	1	Ground
6/11/14	22:55	Near	Secretus	M	Adult	N	0611CC2255	1	Ground
6/11/14	22:57	Near	Secretus	F	Adult	N	0611CC2257	1	0.5

Date	Time	Location	Species	Sex	Lifestage	Marked	ID	n=	Height From Ground
6/11/14	22:59	Near	Secretus	M	Adult	N	0611CC2259	1	Ground
							Sum	**14**	
6/12/14	21:21	Near	Secretus	Unk	Adult	N	0612JM2121	1	Ground
6/12/14	21:25	Near	Secretus	Unk	Adult	N	0612JM2125	1	Ground
6/12/14	21:25	Near	Secretus	Unk	Nymph	N	0612JM2125	1	Ground
6/12/14	21:27	Near	Secretus	Unk	Sub-adult	N	0612JM2127	1	Ground
6/12/14	21:30	Near	Secretus	Unk	Sub-adult	N	0612JM2130	1	Ground
							Sum	**5**	
6/17/14	21:29	Near	Secretus	Unk	Adult	Unk	0617DM2129	1	Ground
6/17/14	22:35	Bluff	Secretus	M	Adult	N	0617DM2235	1	Ground
6/17/14	23:04	Near	Secretus	M	Adult	N	0617DM2304	1	Ground
6/17/14	23:06	Near	Secretus	F	Adult	N	0617DM2306	1	Ground
6/17/14	23:07	Near	Secretus	F	Adult	N	0617DM2307	1	Ground
6/17/14	23:08	Near	Secretus	M	Adult	N	0617DM2308	1	Ground
6/17/14	23:09	Near	Secretus	M	Adult	N	0617DM2309	1	Ground
6/17/14	23:10	Near	Secretus	F	Adult	N	0617DM2310	1	Ground
6/17/14	23:12	Near	Secretus	M	Adult	N	0617DM2312	1	Ground
6/17/14	23:12	Near	Secretus	F	Adult	N	0617DM2312	1	Ground
6/17/14	23:14	Near	Secretus	M	Adult	N	0617DM2314	1	Ground
6/17/14	23:16	Near	Secretus	Var	Var	N	0617DM2316	5	Ground
6/17/14	23:17	Near	Secretus	F	Adult	N	0617DM2317	1	Ground
6/17/14	23:18	Near	Secretus	M	Sub-adult	N	0617DM2318	1	Ground
6/17/14	23:20	Near	Secretus	Var	Var	N	0617DM2320	22	Ground
6/17/14	23:23	Near	Secretus	Var	Var	N	0617DM2323	9	Ground
6/17/14	23:25	Near	Secretus	Var	Var	N	0617DM2325	2	Ground

Date	Time	Location	Species	Sex	Lifestage	Marked	ID	n=	Height From Ground
6/17/14	23:26	Near	Secretus	Var	Adult	N	0617DM2326	2	Ground
6/17/14	23:27	Near	Secretus	M	Adult	N	0617DM2327	3	Ground
6/17/14	23:29	Near	Secretus	F	Adult	N	0617DM2329	2	Ground
6/17/14	23:32	Near	Secretus	Var	Adult	N	0617DM2332	4	Ground
6/17/14	21:38	Near	Secretus	M	Adult	N	0617JK2138	1	Ground
6/17/14	21:42	Near	Secretus	F	Adult	N	0617JK2142	1	Ground
6/17/14	21:45	Near	Secretus	M	Adult	N	0617JK2145	1	Ground
6/17/14	21:46	Near	Secretus	M	Adult	N	0617JK2146	1	Ground
6/17/14	21:48	Near	Secretus	M	Adult	N	0617JK2148	1	Ground
6/17/14	21:49	Near	Secretus	Unk	Sub-adult	N	0617JK2149A	1	Ground
6/17/14	21:49	Near	Secretus	Unk	Sub-adult	N	0917JK2149B	1	Ground
6/17/14	21:55	Near	Secretus	M	Sub-adult	N	0617JK2155	1	Ground
6/17/14	21:56	Near	Secretus	Unk	Adult	N	0617JK2156	1	Ground
6/17/14	22:00	Near	Secretus	Unk	Adult	N	0617JK2200	9	Ground
6/17/14	22:10	Near	Secretus	Unk	Adult	N	0617JK2210	28	Ground
6/17/14	22:13	Near	Secretus	Var	Adult	N	0617JK2213	2	0.5
6/17/14	22:15	Near	Secretus	M	Adult	N	0617JK2215	1	Ground
6/17/14	22:16	Near	Secretus	F	Adult	N	0617JK2016	1	0.3
6/17/14	22:18	Near	Secretus	F	Adult	N	0617JK2218	1	Ground
6/17/14	22:45	Near	Secretus	M	Adult	N	0617JK2215	1	Ground
6/17/14	22:51	Far	Secretus	M	Adult	N	0617JK2251	1	Ground
6/17/14	22:45	Far	Secretus	M	Adult	N	0617jkk2245	1	Ground
6/17/14	21:23	Near	Secretus	Unk	Adult	N	0617DM2123	1	Ground
6/17/14	21:26	Near	Secretus	M	Adult	N	0617DM2126	1	Ground
6/17/14	21:28	Near	Secretus	Unk	Adult	Unk	0617DM2128	1	Ground

Date	Time	Location	Species	Sex	Lifestage	Marked	ID	n=	Height From Ground
							Sum	**119**	
6/18/14	22:21	Near	Secretus	M	Sub-adult	N	0618NCM2221	1	Ground
6/18/14	22:29	Near	Secretus	Unk	Adult	N	0618NCM2229	1	Ground
6/18/14	22:39	Near	Secretus	F	Adult	N	0618NCM2239	1	Ground
6/18/14	22:41	Near	Secretus	Unk	Adult	1	0618NCM2241	1	Ground
6/18/14	22:41	Near	Secretus	Unk	Adult	N	0618NCM2241	4	Ground
6/18/14	22:44	Near	Secretus	Unk	Adult	1	0618NCM2241	1	Ground
6/18/14	22:44	Near	Secretus	Unk	Adult	N	0618NCM2241	29	Ground
6/18/14	22:47	Near	Secretus	Unk	Nymph	N	0618NCM2247	1	Ground
6/18/14	22:47	Near	Secretus	Unk	Adult	N	0618NCM2247	2	Ground
6/18/14	22:48	Near	Secretus	Unk	Adult	N	0618NCM2248	2	Ground
6/18/14	22:49	Near	Secretus	M	Adult	N	0618NCM2249	3	Ground
6/18/14	22:51	Near	Secretus	M	Adult	N	0618NCM2251	2	Ground
6/18/14	22:52	Near	Secretus	Unk	Sub-adult	N	0618NCM2252	5	Ground
6/18/14	22:54	Near	Secretus	M	Adult	N	0618NCM2254	4	3
6/18/14	23:02	Far	Secretus	F	Adult	N	0618NCM2302	2	Ground
6/18/14	23:02	Far	Secretus	M	Adult	N	0618NCM2302	1	Ground
6/18/14	23:35	Near	Secretus	F	Adult	N	0618NCM2335	1	Ground
6/18/14	23:36	Near	Secretus	M	Sub-adult	N	0618NCM2336	1	Ground
6/18/14	23:44	Near	Secretus	F	Adult	N	0618NCM2344	2	Ground
6/18/14	23:47	Near	Secretus	M	Nymph	N	0618NCM2347	1	Ground
6/18/14	23:49	Near	Secretus	M	Adult	N	0618NCM2349	2	Ground
6/18/14	23:49	Near	Secretus	F	Adult	N	0618NCM2349	1	Ground
6/18/14	21:16	Near	Secretus	F	Adult	N	0618DM2115	1	Ground
6/18/14	21:16	Near	Secretus	F	Adult	N	0618DM2116	1	Ground

Date	Time	Location	Species	Sex	Lifestage	Marked	ID	n=	Height From Ground
6/18/14	21:16	Near	Secretus	F	Adult	N	0618DM2117	1	Ground
6/18/14	21:21	Near	Secretus	Unk	Adult	N	0618DM2121	4	Ground
6/18/14	21:25	Near	Secretus	Unk	Adult	N	0618DM2125	4	Ground
6/18/14	21:30	Near	Secretus	Unk	Nymph	N	0618DM2130	1	Ground
6/18/14	21:30	Near	Secretus	Unk	Adult	N	0618DM2130	2	Ground
6/18/14	21:34	Near	Secretus	M	Adult	N	0618DM2134	1	Ground
6/18/14	21:37	Near	Secretus	Unk	Adult	Unk	0618DM2137	4	Ground
6/18/14	23:00	Bluff	Secretus	F	Adult	N	0618DM2300	1	Ground
6/18/14	23:01	Bluff	Secretus	M	Sub-adult	N	0618DM2301	1	Ground
6/18/14	23:39	Near	Secretus	M	Sub-adult	N	0618DM2339	2	Ground
6/18/14	23:39	Near	Secretus	M	Adult	N	0618DM2339	2	Ground
6/18/14	23:42	Near	Secretus	M	Adult	N	0618DM2342	2	Ground
6/18/14	23:42	Near	Secretus	F	Adult	N	0618DM2342	1	Ground
6/18/14	23:45	Near	Secretus	M	Adult	N	0618DM2345	1	Ground
6/18/14	21:25	Far	Secretus	Unk	Nymph	N	0618NCM2125	2	Ground
6/18/14	22:20	Near	Secretus	M	Adult	N	0618NCM2220	1	Ground
6/18/14	22:21	Near	Secretus	F	Adult	N	0618NCM2221	1	Ground
							Sum	**101**	
6/19/14	22:48	Near	Secretus	M	Sub-adult	N	0619BC2248	2	Ground
6/19/14	22:49	Near	Secretus	M	Adult	N	0619BC2249	1	Ground
6/19/14	22:49	Near	Secretus	F	Sub-adult	N	0619BC2249	1	Ground
6/19/14	22:53	Near	Secretus	M	Adult	N	0619BC2253	1	Ground
6/19/14	22:54	Near	Secretus	M	Sub-adult	N	0619BC2254	1	Ground
6/19/14	22:58	Near	Secretus	M	Adult	N	0619BC2258	4	Ground

Date	Time	Location	Species	Sex	Lifestage	Marked	ID	n=	Height From Ground
6/19/14	22:59	Near	Secretus	Unk	Unk	N	0619BC2259	39	Ground
6/19/14	23:03	Near	Secretus	M	Adult	N	0619BC2303	2	Ground
6/19/14	23:03	Near	Secretus	F	Adult	N	0619BC2303	2	Ground
6/19/14	23:03	Near	Secretus	M	Sub-adult	N	0619BC2303	1	Ground
6/19/14	23:04	Near	Secretus	Unk	Adult	N	0619BC2304	1	Ground
6/19/14	21:46	Bluff	Secretus	M	Sub-adult	N	0619DM2146	1	Ground
6/19/14	21:47	Near	Secretus	Unk	Adult	Unk	0619DM2147	1	Ground
6/19/14	21:55	Near	Secretus	M	Adult	N	1619DM2155	3	Ground
6/19/14	21:59	Near	Secretus	F	Adult	N	0619DM2159	1	Ground
6/19/14	21:59	Near	Secretus	M	Adult	N	0619DM2159	2	Ground
6/19/14	21:59	Near	Secretus	Unk	Adult	N	0619DM2159	1	Ground
6/19/14	21:19	Bluff	Secretus	F	Nymph	N	0619BC2119	1	Ground
6/19/14	21:29	Near	Secretus	M	Adult	N	0619BC2129	1	Ground
6/19/14	21:33	Near	Secretus	F	Adult	N	0619BC2123	1	Ground
6/19/14	22:02	Near	Secretus	Unk	Adult	Unk	0619DM2202	1	Ground
6/19/14	22:06	Near	Secretus	Var	Adult	N	0619DM2206	32	Ground
							Sum	**100**	

Appendix B. Personnel.

David McBee, Biologist. David supervised field surveys performed data analysis and participated in report preparation. David holds a Bachelor's Degree in Range and Wildlife Management from Texas A&M University-Kingsville. He is a scientific diving specialist with years of professional experience in dive team management and equipment maintenance. He has assisted researchers off the Texas coast tracking dispersal patterns in the red snapper fishery. As an undergraduate he conducted research to determine freshwater wetland carrying capacity along the middle coast of Texas. David also has experience conducting field surveys and lab analysis for projects studying rangeland niche overlap, wetland delineation and shorebird habitat preference. In addition to his biological background, David has been a professional SCUBA instructor and diving safety officer since 2007. In that time he has led dive teams throughout Texas and Florida, as well as Micronesia and the Caribbean.

Dr. Jean Krejca, Subterranean species specialist. Jean participated in field surveys and report preparation. Jean has a Bachelor's degree in Zoology, and a Ph.D. in Evolution, Ecology, and Behavior from the University of Texas at Austin. Her dissertation work focused on cave adapted aquatic fauna, biogeography and hydrology of Texas and North Mexico. Since 1991, she has worked as a cave biologist and her experience in that area spans across the United States (Arkansas, California, Texas, Nevada, Illinois, Missouri, Indiana, Tennessee, North and South Carolina) as well as Mexico, Belize, Thailand, China and Malaysia. Her publication list on these areas is extensive. Her Texas consulting experience started in 1997 and includes endangered species permit compliance and working as a Karst Invertebrate Specialist for the U.S. Fish and Wildlife Service (USFWS). In 2003, she co-founded Zara Environmental LLC where she continued her work from independent consulting and expanded to regional Habitat Conservation Plans (Section 10(a)(1)(A) permits), endangered species litigation support, USFWS consultations, and performing custom research projects. The Zara team she supports includes species specialists (mussels, birds, herps), groundwater and geology specialists, and field crews. In addition, she has been involved with a variety of public outreach efforts such as public talks, field trips, and cave biology photography. She holds USFWS and Texas Parks and Wildlife rare and endangered species permits covering listed karst invertebrates, aquatic invertebrates, mussels, and salamanders in Texas.

Krista McDermid, Ecologist. Krista participated in field surveys, performed GIS analysis and participated in report preparation. Krista holds a Master's degree in Wildlife Ecology from Texas State University in San Marcos, where she studied the Common Musk Turtle, *Sternotherus odoratus*. She also holds a bachelor's degree in Evolution, Ecology, and Behavior from The University of Texas at Austin, where she worked on behavioral and genetic development of the zebra fish, *Danio rerio.* Krista has worked as a biologist for Texas Parks & Wildlife Department monitoring white-winged dove migration and population, and the City of Austin assisting with a mark-recapture study on the Jollyville Plateau Salamander, *Eurycea tonkawae*. Krista is a GIS technician; she received her certification in ArcView 3.x in 2005, and completed the post baccalaureate certification program in geographic information systems through Penn State

University in 2010. She has worked with Zara since 2007 and in that time has participated in numerous habitat surveys for listed karst invertebrates, cave fauna surveys, karst feature surveys, presence/absence surveys, and biological monitoring for listed karst invertebrates. She has also conducted aquatic macro-invertebrate habitat and presence/absence surveys for aquifer species in Hays, Bexar, Uvalde and Medina Counties. She holds a Texas Parks and Wildlife Scientific Research Permit (SPR-0608-082) to collect and study aquifer fauna, bats, state-listed reptiles, amphibians, and mussels. She also holds a USFWS Permit (TE85077A) to collect and study federally listed endangered Texas karst invertebrate and aquatic species.

Jeanette Larsen, Biologist. Jeanette participated in field surveys. Jeanette has a Bachelor's degree in aquatic biology, with a minor in chemistry. She began studying caves in 1995. She has worked as a karst technician since 2000. Much of her work has been in the San Antonio and Austin areas, and has included grid-searches for caves, excavation of caves and karst features, collection of invertebrate karst species for study, and biologically monitoring caves. She has also participated in several dye traces where she collected and analyzed samples. She has also participated in freshwater mussel surveys. She holds a USFWS permit (TE85077A) covering listed karst invertebrates, aquatic invertebrates, and the Golden-cheeked Warbler.

Clover Clamons, Geologist. Clover participated in field surveys, and provided quality assurance/quality control of the report document. Clover received a Bachelor's degree in Geology from James Madison University and a Master's degree in Geology from Baylor University, where she studied soils and groundwater monitoring of seasonal wetlands on Galveston Island. She has worked on environmental compliance, project management, and inter-agency coordination for large-scale construction projects in the transportation, water, and electric utility industries since 1998. She holds Texas Professional Geoscientist license 3639. Clover has extensive experience with National Environmental Policy Act (NEPA) project documentation for transportation and energy projects in Texas including the preparation and management of categorical exclusions, biological assessments environmental assessments (EAs), and technical documents in support of EAs and environmental impact statements. In addition, she has managed coordination and consultations with state and federal agencies (USFWS, TGLO, USACE, FEMA, TCEQ, and TPWD) in support of a variety of projects. Clover has also conducted TCEQ Geologic Assessments and karst feature surveys and excavations. In previous positions, Clover has conducted wetland delineations, stream channel assessments, watershed evaluations, water sampling, designed and prepared erosion control plans, performed groundwater geochemistry analyses, pump test analyses, installed and monitored piezometers, and performed ground-water contaminant flow mapping studies and hazardous materials assessments in support of Phase I and II Environmental Site Assessments, and RCRA Field Investigations. In her spare time, Clover keeps her geosciences skills sharp by teaching Geology and Environmental Science classes at Austin Community College.

Jimmy MacMillan, Biologist. Jimmy participated in field surveys. Jimmy is a biologist with a Bachelor's degree in Marine and Freshwater Biology as well as a certified commercial diver. He has over ten years of experience diving in support of engineering and scientific projects and has participated in eleven projects studying mussel habitat, conducting presence/absence surveys

and mussel relocation. Other assignments include aquatic ecology research, cave biology studies, technical geology documentation, bird surveys and bat population monitoring.

Brian Cowan, Hydrogeologist. Brian participated in field surveys. Brian received a Bachelor of Science in Geology from the University of West Georgia and a Master of Science in Geology from the University of Texas at Austin. His thesis work focused on the temporal and spatial variability of cave-air CO_2 in central Texas and he also conducted extensive research on natural tracers of groundwater flow in karst settings and the preservation of paleoenvironmental signals in speleothems. As an undergraduate, Brian conducted research on the interaction of groundwater and surface water beneath a Georgia Piedmont floodplain. Since moving to Texas, Brian has worked as a Hydrogeologist for the City of Austin, studying upland recharge and conducting tracing experiments to determine how quickly contaminants move through the soils overlying the Edwards Aquifer. While working for the City, Brian also assisted with a wide range of projects including aquifer-wide dye tracing experiments and groundwater sampling. Brian taught fifth and seventh grade science for two years and has been involved in a number of public outreach activities including talks, field trips, and service projects. Before moving to Texas, Brian worked for the West Georgia Center for Water Resources where he assisted with nearly all aspects of a multi-year watershed assessment.

Norman "Cass" Meyer, Geologist. Cass participated in field surveys. Cass is a geoscientist focusing on surface water movement and its interaction with groundwater migration. He earned a B.S. in Geology from the University of Texas, where he worked as a laboratory technician in the Structural Geology department, as well as a researcher at the Bureau of Economic Geology. Upon graduation, Cass worked for two years in the Austin office of Fugro Geotechnical Consultants, Inc., until spring 2010 when he began at Zara Environmental LLC. Cass has spearheaded the updating of the Zara website www.zaraenvironmental.com, as well as database/geospatial database management, and cartographic figure preparation. Cass is a member of the Austin Geological Society, Central Texas Mountaineers, and has become an avid caver.

Todd Bayless, Travis County Natural Resources. Todd assisted with field surveys.

Dr. Rob Plowes, Brackenridge Field Laboratory. Rob provided taxonomic analysis of ants captured during field surveys.