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2019 SUMMARY OF CAVE MANAGEMENT ACTIVITIES AT PENNIE'S CAVE, TRAVIS COUNTY, TEXAS



Formations in the lower pit of Pennie's Cave

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Abstract

Pennie's Cave, located on private property in southern Travis County, is one of 62 caves included in the Balcones Canyonlands Conservation Plan, a multi-species regional conservation effort operating under a 10(a) permit issued by the U.S. Fish and Wildlife Service under the Endangered Species Act. Pennie's Cave currently is known to contain two karst invertebrate species covered under the Balcones Canyonlands Conservation Plan: a troglobitic ground beetle (*Rhadine austinica*), troglobitic millipede (*Speodesmus* N.S.), and, although currently unverified, a potential variant of the *Cicurina bandida* troglobitic spider. Ongoing cave management measures were initiated in 2014. Management activities completed for 2019 included in-cave biological monitoring, red imported fire ant control activities in the spring and fall, and the inspection and use of a semi-permanent in-cave air ventilation system to provide safer air quality conditions for personnel during biological monitoring. Two species of concern known to occur in Pennie's Cave, *Speodesmus* N.S. and *Rhadine austinica*, were observed during the 25 July 2019 biological monitoring event. The biological monitoring event also resulted in a new species record of a *Texella* harvestman and *Stygobromus* amphipod, although the taxonomic status for both is currently unknown since the collection of specimens was not possible. The harvestman is possibly *T. mulaiki* and not *T. spinoperca* (a species of concern) or one of the federally listed *Texella* based on a preliminary assessment of morphology, although the future collection of a specimen will be required for confirmation. Both the spring and fall red imported fire ant control events were conducted. The numbers of observed and treated red imported fire ant mounds appear to be decreasing over time since first treating at the Pennie's Cave management area in October 2014. The successful installation of the in-cave air ventilation system in 2018 allowed safer access to all biomonitoring zones during the 2019 biological monitoring event.

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Introduction

The Balcones Canyonlands Preserve (BCP) is a system of preserved land that exists as a multi-species regional conservation effort operating under a 10(a) permit issued by the U.S. Fish and Wildlife Service (USFWS) under the Endangered Species Act. Ultimately, the permit goal is to set aside 30,428 acres in western Travis County as habitat for one federally listed endangered and one recently federally de-listed Neotropical migratory songbirds, six federally listed endangered karst invertebrates, and 27 species of concern. The Balcones Canyonlands Conservation Plan (BCCP) identified 62 caves for acquisition and protection within the BCCP area that are known to contain listed karst species and/or species of concern, most of which occur on the highly karstic Jollyville Plateau (City of Austin and Travis County 1996). Forty-five of these 62 designated caves have some degree of protection in place.

Pennie's Cave, previously one of the 15 unprotected BCCP caves, is a site located in southern Travis County on private property and is known to contain two karst invertebrate species covered under the BCCP (species of concern [SOCs]: *Rhadine austinica* and *Speodesmus* N.S. (BCP 2016)). The cave was first discovered by local cavers in the 1960s and had never been managed for karst species since its discovery. In the 1980s, the former landowner completely filled the cave entrance after noticing evidence of unauthorized entry. The entrance was reopened in 2012 as part of an adaptive cave management plan for a development project (Zara Environmental LLC [Zara] 2012). Other components of the management plan that have been completed since the cave's reopening include the establishment of a cave preserve area, construction of a cave gate, and development of a cave map.

Ongoing management activities initiated in 2014 include conducting in-cave biological monitoring for karst invertebrate species, performing red imported fire ant (*Solenopsis invicta*; RIFA) control work, and submitting annual summary reports to the BCP (Zara 2014, 2015, 2016, 2017, 2018). Since the initiation of in-cave biological monitoring in 2014, two karst invertebrate BCCP SOC have been detected (Troglobitic millipede *Speodesmus* N.S. [Zara 2014, 2015, 2016] and ground beetle *Rhadine austinica* [Zara 2018]). Although currently unconfirmed, it is possible that specimens of a variant of the *C. cueva* complex of troglobitic spiders, all of which were synonymized under *C. bandida* (Paquin and Hedin 2005; Paquin et al. 2008) and are SOCs covered under the BCCP, has been collected in Pennie's Cave during previous biological monitoring efforts through 2018 (Zara 2014, 2015, 2016, 2018). Hazardous air quality at the time of the planned 2017 biological monitoring event prevented safe access to the cave, so no in-cave data were recorded for that period.

To provide safer and (potentially more reliable) year-round access for personnel, Zara installed a corrugated polyethylene piping ventilation system throughout accessible areas of the cave in 2018. The ventilation system is semi-permanent, modular, and intended to be attached to an external blower as needed. The system originates just inside of the cave entrance gate and extends to both biomonitoring zones 3 and 5, with a split in the hose at the passage leading to biomonitoring zone 4. The ventilation system allows personnel to ventilate zones 1, 2, and 3 from the surface, and divert air to biomonitoring zones 4 and 5 once zones 1, 2, and 3 are ventilated

well enough to allow safe entrance into the cave. The increased access within the cave allows for sampling within the deeper zones of the cave.

Management activities completed during 2019 included two RIFA control events, one in-cave biological monitoring event, the inspection and operation of a semi-permanent in-cave air ventilation system to provide safer air quality conditions for personnel during biological monitoring, and the preparation of this annual report summarizing the completed activities for the year. This annual report details the methodologies, results, and a discussion of activities completed at Pennie's Cave during 2019.

Methods

Biological Monitoring

Annual biological monitoring for karst invertebrate species was conducted in an effort to append the list of known species and to detect the presence of protected species previously recorded at Pennie's Cave. The cave was delineated previously into five separate biological monitoring zones identified by marked orange flagging tape (Zara 2014). Personnel experienced in invertebrate biology visually inspected all surfaces in each zone for karst invertebrate species paying particular attention to the undersides of rocks, clumps of dried substrate, decaying carcasses, animal scat, and pools of water. Since there is no need to demonstrate absence of listed species in this study, not all protocols set forth in the USFWS document *Section 10(a)(1)(A) Scientific Permit Requirements for Conducting Presence/Absence Surveys for Endangered Karst Invertebrate Species* (USFWS 2015) were followed. All fauna encountered were noted on field sheets, and specimens of fauna not previously known from the site were collected to facilitate identification. Unless otherwise noted or directed by USFWS (2016), specimens collected will be deposited in the Texas Natural History Collection, University of Texas at Austin, and the list of known species for this cave will be updated based on the updated specimen records from biomonitoring events.

Microclimate data, including atmospheric pressure, temperature, and relative humidity (RH), were collected during the biological monitoring event. Before entering the cave, measurements were recorded within 5 m of the feature entrance, at ground level and in the shade. During the in-cave surveys, microclimate data were collected in each biological monitoring zone. Atmospheric pressure was measured using a digital barometer built into a Garmin GPSmap 60Csx unit or referenced from available hourly climate data (Menne et al. 2012). Temperature data were collected with either a fan-cooled wet and dry bulb psychrometer (Psychro-Dyne®, Industrial Instruments & Supplies, PO Box 416, County Line Industrial Park, Southampton, PA 18966), a Kestrel® Environmental Meter 5000 with LINK, or Kestrel® DROP D2 (Nielsen-Kellerman, 21 Creek Circle, Boothwyn, PA 19061). The Kestrel Meter 5000 and DROP D2 units provided a direct readout of both temperature and RH data, while the psychrometer provided wet and dry bulb temperatures for calculating RH using atmospheric pressure data and an online calculator (Scanlon 2015). When used, the Kestrel DROP D2 unit was left in the cave to provide automatic logging of microclimate data; the logging intervals typically were set at a collection rate of at least twice per day (every 12 hours or less) to monitor for daily microclimate changes

and for the post-use effects of the ventilation system on the cave atmosphere. Currently, the Kestrel DROP D2 unit is deployed in cave monitoring Zone 3.

Red Imported Fire Ant Control

The RIFA control activities were performed in accordance with the USFWS *Karst Preserve Management and Monitoring Recommendations* (USFWS 2014) and set forth in the BCP Land Management Plan (BCP 2016). Fire ants typically do not maintain their mounds during the summer, making them more difficult to see, but they begin rebuilding them as soon as rains and cooler temperatures return (Vinson and Sorensen 1986). In addition, the ants may remain relatively inactive and deep within their mounds during long periods of drought or cold (Vinson and Sorensen 1986), making them more difficult to eradicate. Because of these behavioral characteristics, RIFA control activities were conducted at least once in the spring and at least once in the fall.

Control activities consisted of an ant mound survey and subsequent treatments with hot water to eradicate RIFA colonies inhabiting the identified mounds. The USFWS (2014) recommends a distance of 80 m from the cave entrance for RIFA control activities, resulting in a total area of approximately 20,106 m^2. The circumference based on the 80-m radius was measured using a global positioning system unit and visibly delineated using pin flags. During the survey, all RIFA mounds within the delineated area were located by walking while visually scanning and marking the mounds with pin flags and paying particular attention to likely places for colonies such as clearings, stumps, cracks in rocks, and rotting logs. The survey methods are designed to yield an accurate account of RIFA mound densities. Any RIFA mounds within a 10-m radius of the cave entrance (an area of approximately 314 m^2) were distinguished from the remaining survey area, as the presence of only one mound within 10 m of the cave entrance is considered an infestation threshold (USFWS 2014). A density of 80 RIFA mounds within a 50-m radius (7,850 m^2), or one mound per 98.13 m^2, is considered as an infestation threshold for areas beyond 10 m of the cave entrance (USFWS 2014). The exceedance of these infestation thresholds may necessitate an increase in RIFA control frequency (USFWS 2014).

Eradication treatments were performed immediately following the mound survey during early to mid-morning when the queen(s) and larvae are likely to be near the top of the mound (Vinson and Sorensen 1986). Water was heated in the field either by heating metal buckets on propane-fired burners or using a diesel-fired pressure washer supplied by an 830-L water tank (if possible, based on site and equipment accessibility). Disturbance to RIFA mounds was minimized before treatment, as this may cause the ants to move the queen(s) and larvae to deeper locations within the mound or to a remote location. Mounds were excavated slowly with a pickaxe to expose the colony chambers and tunnels, and boiling water was then immediately poured on the mound and emerging ants. These steps were repeated layer by layer until excavation reached the bottom of the colony and ants ceased emerging from deeper chambers and tunnels. Native ant mounds were carefully differentiated from RIFA mounds during control activities to avoid treatment of native colonies. Abandoned mounds with no active RIFA colonies were not treated.

Results

Biological Monitoring

The biological monitoring event was conducted in Pennie's Cave on 25 July 2019. Zara biologists David McBee, Jacob Owen, Aubri Jensen, and Lucas Pustka spent a total of 105 person-minutes performing the biological monitoring at Pennie's Cave. Two BCCP species of concern, *Speodesmus* N.S. and *R. austinica*, were detected, along with an eyeless *Cicurina* spider. Two *Rhadine austinica* specimens were collected in 2019 (Specimen IDs: ZARA 12509, ZARA 12510), and the species identity was confirmed by James Reddell on 22 August 2019. A *Texella* troglobitic harvestman and *Stygobromus* stygobitic amphipod were observed during the biological monitoring; while both are new species records for the cave, the collection of specimens was not possible. All biomonitoring zones were accessible and surveyed during the 2019 survey event (Figure 1).

A comprehensive list of all taxa observed by biological monitoring zone during 2019 is presented in Table 1. A comprehensive list of biological survey data since 2014, including number of observed BCCP species of concern by biological monitoring zone, is provided in Table 3. Comprehensive microclimate data recorded since 2014 are presented in Table 4.

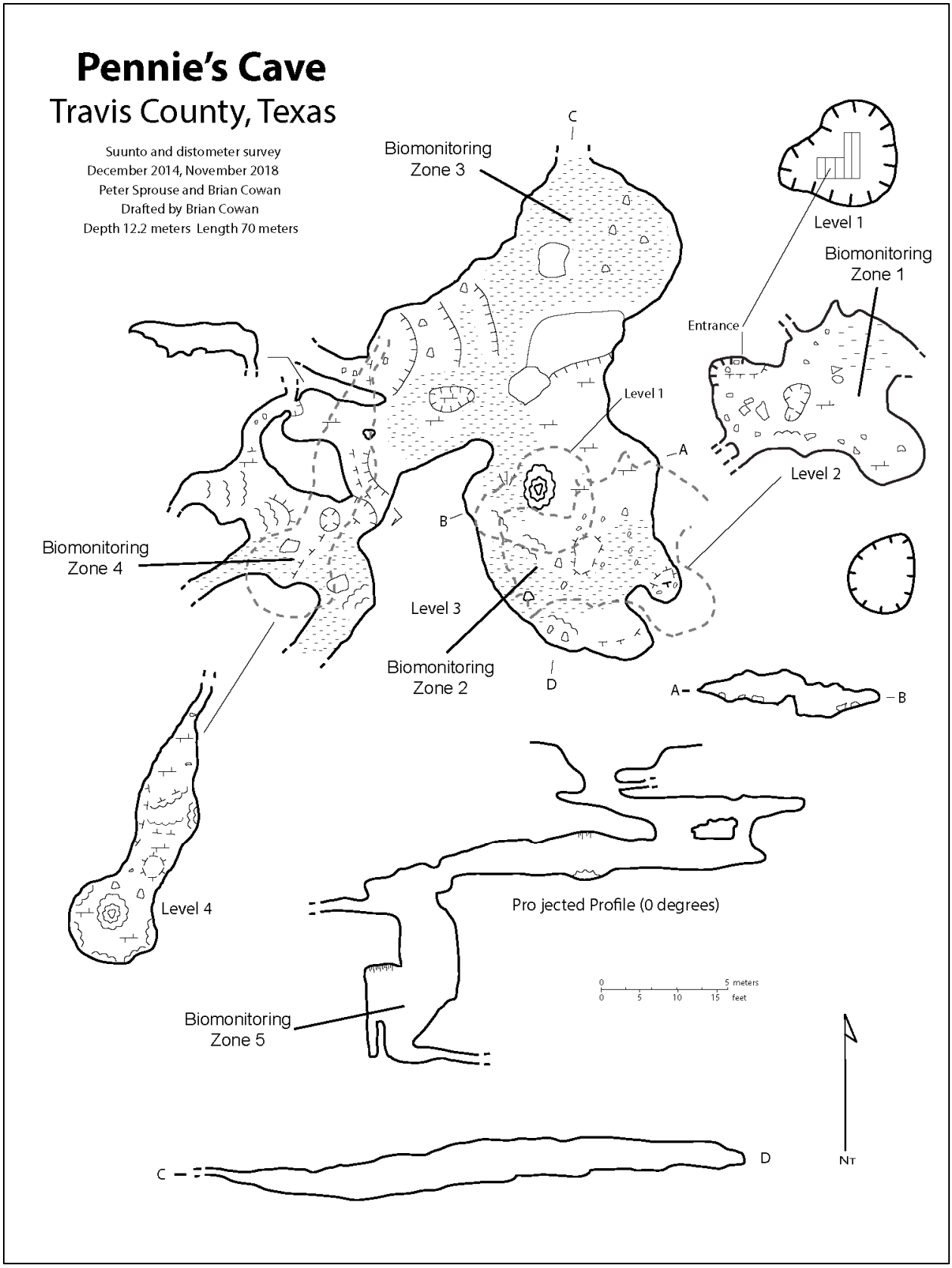


Figure 1. Map of Pennie's Cave including biomonitoring cave zones.

Table 1. Biological observations and collections at Pennie's Cave on 25 July 2019.

Common Name	Lowest Taxonomic Identification	# Observed	Collected Y/N? (#)
Amphipods	*Stygobromus* sp.*	4	N
Snails	Gastropoda (epigean)	8	N
	Helicodiscus sp.	50+	N
Woodlice	Armadillidae	5+	N
Mites	Acari (epigean)	5	N
Spiders	*Cicurina* sp. (eyeless)[1]	1	N
	Cicurina sp. (eyed)	15	N
Harvestman	*Leiobunum townsendi*	200+	N
	Texella sp.*	1	N
Millipedes	*Speodesmus* N.S.[2]	1	N
	Cambala sp.	1	N
Diplurans	Diplura	1	N
Silverfish	*Texoreddellia* sp.	1	N
Crickets	*Ceuthophilus secretus*	330	N
	Ceuthophilus cunicularis	4	N
	Ceuthophilus sp. nymph	81	N
Beetles	*Rhadine austinica*[2]	2	Y (2)[3]
	*Batrisodes uncicornis**	2	N
	Staphylinidae	2	N
Gnats	Diptera	27	N
Frogs	Anura	3	N
	Bufo nebulifer	1	N
Salamanders	*Plethodon albagula*	1	N
Mammal	Mammalia (scat)	1	N

[1] Potential BCCP species of concern
[2] BCCP species of concern
[3] Specimens (IDs Zara 12509, 12510) confirmed by J. Reddell
* New species records for 2019.

Table 2. Comprehensive biological observations of taxa by cave zone at Pennie's Cave since 2014.

Common Name	Lowest Taxonomic Identification	Biomonitoring Zone
Snails	*Helicodiscus* sp.	1, 2, 4, 5
	Gastropoda	1, 2, 3
Earthworm	Oligochaeta	1, 3
Amphipod	*Stygobromus* sp.*	5
Woodlice	*Porcellio* sp.	1
	Armadillidium sp.	1
Mites	Acari*	1
Spiders	*Cicurina* sp. (eyeless)[1]	1, 2, 3, 4, 5
	Cicurina sp.	2, 3, 4
	Araneae	1, 2
	Eidmanella sp.	2
Pseudoscorpion	Pseudoscorpionida	2
Harvestman	*Leiobunum townsendi*	1
	Texella sp.*	4
Centipedes	Lithobiomorpha	1, 2, 3
	Chilopoda	1, 3
Millipedes	*Speodesmus* N.S.[2]	2, 3, 4, 5
	Diplopoda	1, 2
	Cambala sp.	4, 5
Symphylan	Symphyla	1
Dipluran	Diplura	2, 3, 4
Springtail	Collembola	1, 2, 3, 4
Silverfish	*Texoreddellia* sp.	2, 4
Crickets	*Ceuthophilus secretus*	1, 2, 3, 4
	Ceuthophilus cunicularis	1, 2, 3, 4, 5
	Ceuthophilus sp. (Nymph)	1, 2, 3, 4, 5
	Ceuthophilus sp. (Sub-Adult)	2, 3, 4
Beetles	*Rhadine austinica*[2]	3, 4
	*Batrisodes uncicornis**	3
	Staphylinidae	1, 3
Cockroach	Blattaria	3
Gnats	Diptera	1, 2, 3, 4
Frogs	*Eleutherodactylus marnockii*	1
	Bufo nebulifer	1, 2
	Gastrophryne olivacea	1
	Lithobates sp.	2
	Anura	1
Salamander	*Plethodon albagula*	1, 2
Mammal	Mammalia (scat)	4

[1] Potential BCCP species of concern

[2] BCCP species of concern

*New species record for 2019

Table 3. Dates of biological monitoring events, total amount of survey effort, surveyed biological monitoring zones, and number of observed Balcones Canyonlands Conservation Plan species of concern by biological monitoring zone.

Survey Date	Total Person-Minutes Surveyed	Surveyed Biological Monitoring Zones[1]	Number of BCCP Species of Concern Observed by Biological Monitoring Cave Zone														
			Zone 1			Zone 2			Zone 3			Zone 4			Zone 5		
			Speodesmus N.S.	*Rhadine austinica*	*Cicurina* sp. (eyeless)[2]	*Speodesmus* N.S.	*Rhadine austinica*	*Cicurina* sp. (eyeless)[2]	*Speodesmus* N.S.	*Rhadine austinica*	*Cicurina* sp. (eyeless)[2]	*Speodesmus* N.S.	*Rhadine austinica*	*Cicurina* sp. (eyeless)[2]	*Speodesmus* N.S.	*Rhadine austinica*	*Cicurina* sp. (eyeless)[2]
7 August 2014	120	1, 2, 3, 4	0	0	0	2	0	0	1	0	0	0	0	0	--	--	--
4 December 2014	104	1, 2, 3, 4, 5	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0
18 February 2015	215	1, 2, 3, 4, 5	0	0	0	1	0	2	2	0	0	0	0	0	0	0	0
21 April 2015	133	1, 2, 3, 4, 5	0	0	0	2	0	0	2	0	0	0	0	1	0	0	0
28 January 2016	100	1, 2, 3, 4	0	0	1	0	0	0	0	0	1	0	0	0	--	--	--
21 November 2017[3]	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
15 November 2018	128	1, 2, 3, 4, 5	0	0	0	0	0	0	0	2	2	1	0	2	1	0	3
25 July 2019	105	1, 2, 3, 4, 5	0	0	0	1	0	0	0	0	1	0	2	0	0	0	0
Cumulative Total	***800***	***NA***	***0***	***0***	***1***	***6***	***0***	***3***	***5***	***2***	***6***	***1***	***2***	***3***	***1***	***0***	***3***

[1]All zones may not have been surveyed due to hazardous air conditions.

[2]Potential Balcones Canyonlands Conservation Plan (BCCP) species of concern

[3]Data were not collected on this date due to unsafe air quality in the cave

NA = Not Applicable

Table 4. Dates of biological monitoring events, surface and void temperatures, and humidity calculations at Pennie's Cave.

Date	Time	Location	Temperature (°C)			Pressure (mb)	Relative humidity (%)	
			Wet Bulb	Dry Bulb	Direct Read		Calculated	Direct Read
7 August 2014	14:32	Surface	25.7	37.6	--	1,012	38.2	--
7 August 2014	14:45	Zone 1	23.2	26.0	--	1,012	78.9	--
7 August 2014	14:58	Zone 2	21.2	24.2	--	1,012	76.5	--
7 August 2014	15:20	Zone 3	20.6	21.6	--	1,012	91.4	--
7 August 2014	15:25	Zone 4	20.7	22.0	--	1,012	89.0	--
7 August 2014	NM	Zone 5	NM	NM	--	NM	NM	--
4 December 2014	13:45	Surface	17.8	18.3	--	1,019	95.3	--
4 December 2014	13:55	Zone 1	29.0	29.5	--	1,019	96.3	--
4 December 2014	14:10	Zone 2	20.0	20.2	--	1,019	98.2	--
4 December 2014	14:27	Zone 3	21.5	21.7	--	1,019	98.3	--
4 December 2014	14:50	Zone 4	20.8	21.2	--	1,018	96.5	--
4 December 2014	15:55	Zone 5	NM	NM	--	1,018	NM	--
18 February 2015	09:59	Surface	9.5	13.5	--	1,029	59.0	--
18 February 2015	10:25	Zone 1	14.0	14.5	--	1,029	94.7	--
18 February 2015	10:53	Zone 2	25.5	26.0	--	1,028	96.0	--
18 February 2015	11:21	Zone 3	16.0	16.25	--	1,028	97.5	--
18 February 2015	11:50	Zone 4	18.0	18.5	--	1,027	95.3	--
18 February 2015	12:20	Zone 5	19.5	20.0	--	1,027	95.5	--
21 April 2015	11:10	Surface	16.5	22.5	--	1,016	53.8	--
21 April 2015	11:17	Zone 1	18.9	20.8	--	1,016	83.6	--
21 April 2015	11:42	Zone 2	18.25	19.2	--	1,016	91.3	--
21 April 2015	12:05	Zone 3	17.5	18.0	--	1,015	95.2	--
21 April 2015	12:27	Zone 4	18.5	19.0	--	1,015	95.4	--
21 April 2015	13:23	Zone 5	19.9	21.25	--	1,015	93.9	--
28 January 2016	10:50	Surface	--	--	17.5	1,024	--	30.5
28 January 2016	NM	Zone 1	--	--	NM	NM	--	NM
28 January 2016	11:22	Zone 2	--	--	17.0	1,023	--	89.7
28 January 2016	NM	Zone 3	--	--	NM	NM	--	NM
28 January 2016	12:08	Zone 4	--	--	19.3	1,022	--	95.2
28 January 2016	NM	Zone 5	--	--	NM	NM	--	NM
21 November 2017*	--	--	--	--	--	--	--	--
15 November 2018	12:10	Surface	--	--	16.8	999	--	32.0
15 November 2018	12:10	Zone 1	--	--	20.7	999	--	89.7
15 November 2018	NM	Zone 2	--	--	NM	NM	--	NM
15 November 2018	NM	Zone 3	--	--	NM	NM	--	NM
15 November 2018	11:30	Zone 4	--	--	22.0	1,002	--	84.6
15 November 2018	NM	Zone 5	--	--	NM	NM	--	NM

NM = Surveyed but not measured
*Microclimate data were not collected on this date due to unsafe air quality in the cave.

Table 4 cont. Dates of biological monitoring events, surface and void temperatures, and humidity calculations at Pennie's Cave.

Date	Time	Location	Temperature (°C)			Pressure (mb)	Relative humidity (%)	
			Wet Bulb	Dry Bulb	Direct Read		Calculated	Direct Read
25 July 2019	09:50	Surface	--	--	NM	NM	--	
25 July 2019	09:50	Zone 1	--	--	NM	NM	--	
25 July 2019	10:08	Zone 2	--	--	NM	NM	--	
25 July 2019	10:31	Zone 3	--	--	NM	1,032	--	100
25 July 2019	11:06	Zone 4	--	--	NM	NM	--	
25 July 2019	10:31	Zone 5	--	--	NM	NM	--	
NM = Surveyed but not measured								

Red Imported Fire Ant Control

Red imported fire ant control activities were performed on 02 May 2019 and 15 November 2019. Both RIFA treatments were performed during a period of cooler, wetter weather, thus facilitating the identification of RIFA activity (i.e., mound rebuilding). The 80-m RIFA control radius extended beyond the boundary of an adjacent, inaccessible property, resulting in a net total of approximately 14,245 m^2 that was surveyed and treated out of the intended 20,105-m^2 control area (Figure 2).

A total of 18 active RIFA mounds, 16 in May and 2 in November, were identified and treated during the two control events in 2019. Twelve abandoned mounds were identified, all in May. The resulting density of active RIFA mounds equates to one mound per 890.3 m^2 for the May treatment event and one mound per 7,122.5 m^2 for the November event. One active RIFA mounds were identified within the 10-m infestation threshold radius during the May control event. Native ant colonies were not identified within the treatment area during either of the 2019 RIFA control events.

The number of counted RIFA mounds, approximate colony sizes, the approximate volume of hot water used during control activities, and infestation threshold data are presented in Table 5. The comprehensive RIFA treatment results are also presented in Figure 3 and Figure 4.

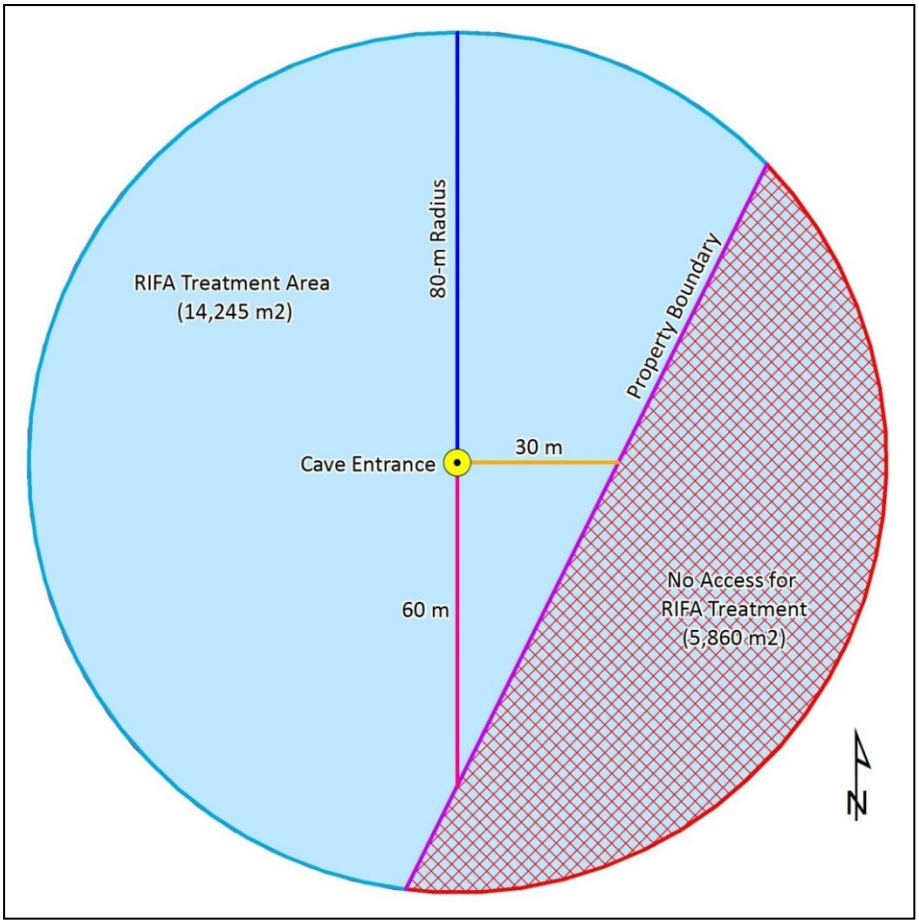


Figure 2. Diagram illustrating the entrance to Pennie's Cave, 80-m radius from the cave entrance, adjacent property boundary, RIFA treatment area, and inaccessible area located at the adjacent property.

Table 5. Dates of control activities, number of RIFA mounds and approximate colony sizes counted by radius distance, and approximate volume of hot water used during control activities.

Treatment Date	Surveyed Mounds by Approximate Colony Size					Total Mounds Surveyed (Abandoned plus Active)	Total Mounds Treated (Active Only)	Volume of Hot Water Used (gal)	Total Active Mounds by Distance from Cave Entrance[1] (m)		Active Mound Density[2] (m^2 per mound)
	Abandoned (No ants)	<100	<500	<1,000	<5,000				<10	<80	
18 Oct 2014	21	44	12	3	0	80	59	150	0	80	241.4
29 Apr 2015	13	8	20	12	10	63	50	115	0	63	284.9
13 Nov 2015	0	4	3	1	2	10	10	10	0	63	1,424.5
05 May 2016	6	15	15	7	2	46	40	50	1	39	356.1
17 Nov 2016	8	16	14	5	0	43	35	40	0	35	407.0
19 Jun 2017	16	1	13	4	0	34	18	32	2	16	791.4
25 Oct 2017	2	7	10	7	2	28	26	32	0	26	547.9
17 May 2018	14	0	8	6	7	35	21	10	0	21	678.3

Treatment Date	Surveyed Mounds by Approximate Colony Size					Total Mounds Surveyed (Abandoned plus Active)	Total Mounds Treated (Active Only)	Volume of Hot Water Used (gal)	Total Active Mounds by Distance from Cave Entrance[1] (m)		Active Mound Density[2] (m^2 per mound)
	Abandoned (No ants)	<100	<500	<1,000	<5,000				<10	<80	
22 Oct 2018	7	0	6	3	2	18	11	5	0	11	1,295.0
02 May 2019	12	0	8	2	6	28	16	20	1	15	890.3
15 Nov 2019	0	1	0	0	1	2	2	7.5	0	2	7,122.5

[1] The presence of one or more mounds within 10 m of the cave entrance is considered an infestation threshold (USFWS 2014)
[2] Based on an estimated 14,245 m^2 treatment area; a density of one mound per 98.13 m^2 is considered an infestation threshold for areas beyond 10 m of the cave entrance (USFWS 2014).

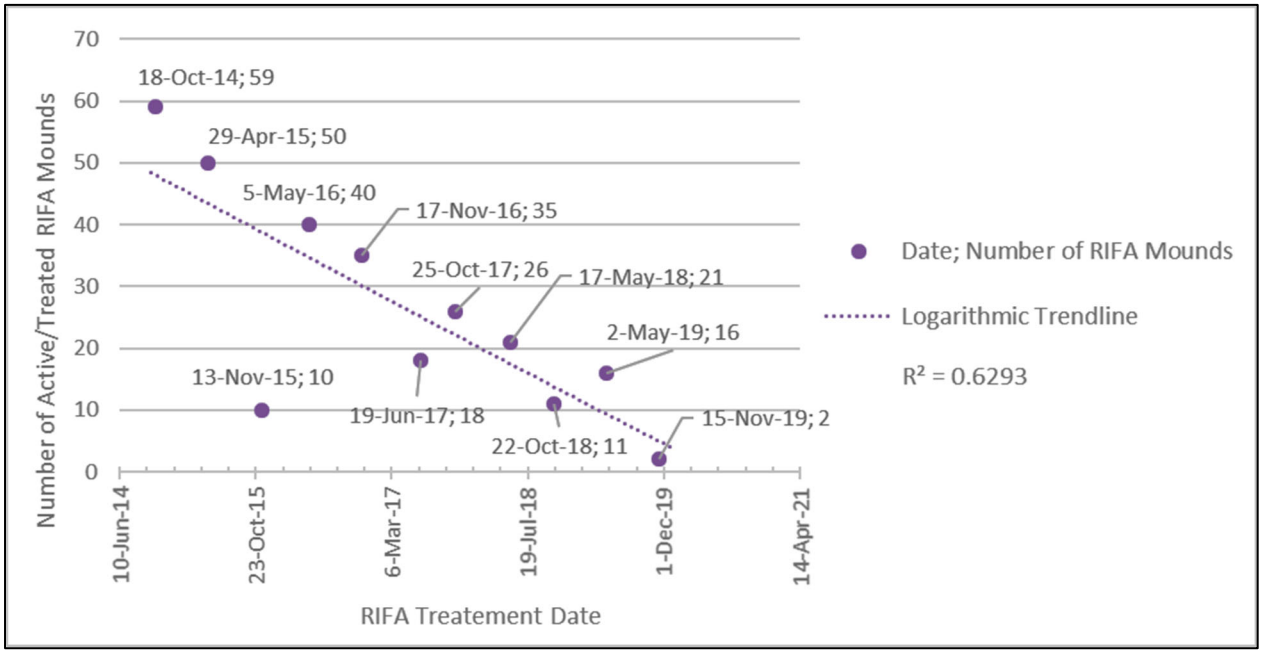


Figure 3. Total number of treated RIFA mounds by treatment date.

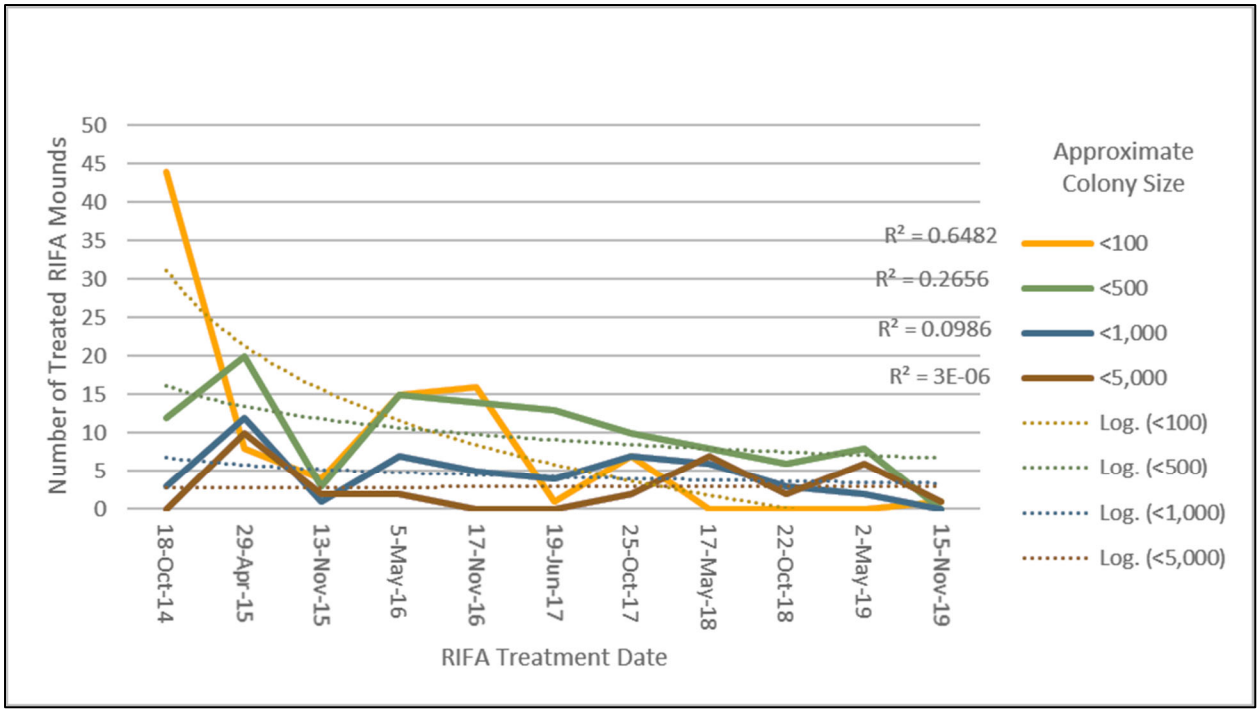


Figure 4. Number of treated RIFA mounds by treatment date and approximate colony size (date range not to scale).

Discussion

The ventilation system installed in 2019 performed well during the biological monitoring event while safely allowing access to all zones of the cave for extended periods, especially given the timing of the survey (July) when air quality conditions in the cave is typically poor and unsafe. A supplemental ventilation system, for temporary use during in-cave work, is recommended during warmer periods to allow expedited ventilation. A preliminary review of the in-cave microclimate data (collected using the Kestrel DROP D2 automatic dataloggers that were left in the cave) did not reveal any longstanding effects following the use of the ventilation system; these microclimate data are not reported here but will be available to BCCP staff upon request. The cave microclimate will continue to be monitored for effects associated with the use of the ventilation system.

Although *R. austinica* was not observed from 2014 through 2016, it has now been observed for two consecutive years (2018, 2019). The identity of the *Rhadine austinica* specimens collected in 2019 (Specimen IDs: ZARA 12509, ZARA 12510) were confirmed by James Reddell on 22 August 2019. The eyeless *Cicurina* spiders encountered may be a variant of the *C. bandida* complex (Paquin and Hedin 2005; Paquin et al. 2008), which are SOCs covered under the BCCP; one of these specimens (Specimen ID: ZARA 10244) was transferred to BCCP staff for future genetic analysis to determine the spider's identity. Based on a preliminary morphological assessment and range information, the troglobitic harvestman observed during the July 2019 biological monitoring is possibly *Texella mulaiki* and unlikely to be *T. spinoperca* (a BCCP SOC) or the federally listed *Texella*; scientists will attempt to collect this species in the future for confirmation of identity. No federally listed karst species were encountered at Pennie's Cave.

Compared to previous biological monitoring events (Zara 2014, 2015, 2016, 2017, 2018), generally higher numbers of karst invertebrates (i.e., number of taxa as well as individuals) were encountered during 2019, and both documented BCCP SOC (the *Speodesmus* N.S. millipede and *R. austinica* ground beetle) were observed, in addition to the troglobitic *Cicurina* that may be a variant of the *C. bandida* complex. Increased access to all biomonitoring zones (due the installation of an air ventilation system) may be an explanation for the increase in numbers of biota and recent observation of *R. austinica*, as the improvement of air quality in the cave resulted in safer, more comfortable conditions for personnel, which in turn could result in a subsequent increase in detection rates of karst biota. Another explanation may be associated with other variables such as localized precipitation patterns, drought duration and intensity (or lack thereof), differences in seasonality, or other undetermined factors. Conversely, these notable results might be explained simply as a result of the ongoing management of the cave. Further observations, however, would be necessary to identify any potential trends or correlation of data.

Based on the results of both the spring and fall RIFA control events, the total number of treated (i.e., active) mounds continued to decrease during 2019 (Figure 3). Since the initiation of RIFA control activities in 2014, the general trend of total active mounds appears to be decreasing with time. The very low number of active colonies observed in November 2019 is likely associated with the extended period of drought and heat that occurred between the two control events. In May 2019, one active RIFA mound was identified within the 10-m infestation threshold radius for the first time since June 2017, which highlights the continued importance of bi-annual RIFA control events. No ants have been observed inside the cave since biological monitoring began in 2014. Future RIFA control activities will help determine whether mound densities will continue to remain below the infestation threshold density and whether the number of mounds continues to decrease. It should be noted that these potential trends are based on a relatively minimal number of observations for determining correlation (11 treatment events to date).

In addition to ongoing RIFA control activities, the proliferation of herbaceous ground cover over time (i.e., compared to pre-cave management activities) may be contributing to the decreasing number of active mounds. Research has found that RIFA select for bare ground (Stiles et al. 1998) and tend to be found in lower densities in areas with higher canopy cover (Brown et al. 2014). Zara personnel have noted an increase in herbaceous ground cover since 2014 in the non-wooded area northeast of the cave, where the bulk of the active mounds have been encountered during control events relative to other areas of the cave preserve. This observation is based on anecdotal evidence; measurements of vegetative cover have not occurred.

Cave management activities planned for 2020 at Pennie's Cave include the continuation of annual biological monitoring. In addition, bi-annual RIFA control activities are planned for the spring and fall of the upcoming year. During in-cave activities, the ventilation system will be inspected and repaired, as necessary. Finally, an annual report summarizing the activities performed in 2020 will be prepared and submitted to the Travis County Transportation and Natural Resources Department for inclusion in the BCCP annual report for the year.

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