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2018 SUMMARY OF CAVE MANAGEMENT ACTIVITIES AT PENNIE'S CAVE, TRAVIS COUNTY, TEXAS



The air ventilation system installed in 2018

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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 2018 included biological monitoring, red imported fire ant control activities in the spring and fall, and the installation of a semi-permanent in-cave air ventilation system to provide safer air quality conditions for personnel. All three species of concern known to occur in Pennie's cave were observed during the 15 November 2018 biological monitoring event, including the first recorded *Rhadine austinica* since regular monitoring began in 2014. The biological monitoring event also resulted in a new species record of a pseudoscorpion, although the taxonomic status of the specimen is currently unknown. Both 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 occurred on 27 February 2018, allowing safer access to all biomonitoring zones during the biological monitoring event.

Table of Contents

Abstract i
Table of Contents ii
List of Figures and Tables ii
Introduction 1
Methods 2
Air Ventilation System Installation 2
Cave Map 2
Biological Monitoring 2
Red Imported Fire Ant Control 3
Results 4
Air Ventilation System Installation 4
Cave Map 4
Biological Monitoring 4
Red Imported Fire Ant Control 10
Discussion 12
Literature Cited 14

List of Figures and Tables

Figure 1. Map of Pennie's Cave including biomonitoring cave zones. 5
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. 10
Figure 3. Total number of treated RIFA mounds by treatment date. 11
Figure 4. Number of treated RIFA mounds by treatment date and approximate colony size (date range not to scale). 12

Table 1. Biological observations and collections at Pennie's Cave on 15 November 2018. 6
Table 2. Comprehensive biological observations of taxa by cave zone at Pennie's Cave since 2014. 6
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. 8

Table 4. Dates of biological monitoring events, surface and void temperatures, and humidity calculations at Pennie's Cave. 9
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. 11

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). Since the initiation of in-cave biological monitoring through 2016, the only karst invertebrate BCCP SOC detected is the troglobitic millipede, *Speodesmus* N.S. (Zara 2014, 2015, 2016). 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 2016 (Zara 2014; Zara 2015; Zara 2016). 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.

Management activities completed during 2018 included two RIFA control events, one biological monitoring event, the installation of a semi-permanent in-cave air ventilation system to provide safer air quality conditions for personnel, updating the cave map previously produced by Zara (2014), 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 2018.

Methods

Air Ventilation System Installation

Biological monitoring was not performed in 2017 due to hazardous air quality inside Pennie's Cave. In an effort 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. The ventilation system is semi-permanent, modular, and intended to be attached to an external blower as needed.

Cave Map

The cave map previously produced by Zara (2014) was updated to incorporate previously inaccessible areas (due to hazardous air conditions). Pennie's Cave was mapped according to standard cave mapping methods (Dasher 1994) using Stanley Fat Max laser distance finders and Suunto Tandem compasses and clinometers. Passages and any important features such as speleothems and potential leads were sketched. Survey notes and sketches were used to produce a cave map showing plan and profile views. The map produced for this study incorporates measured distance, azimuth, and inclination from a series of survey stations set up throughout the cave to ensure accuracy. The entrance of the cave was georeferenced using a handheld Garmin GPSmap 62Csx global positioning system unit.

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 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.

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

Air Ventilation System Installation

Zara installed a corrugated polyethylene piping ventilation system on 27 February 2018. The ventilation system is semi-permanent and is designed to attach to an external blower when ventilation is 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 also allowed for personnel to map additional areas that were not accessible during the first mapping event (Zara 2014) due to hazardous air conditions at that time.

Cave Map

The cave map was updated to reflect additional areas now accessible due to safer conditions provided by the ventilation system. The updated cave map is presented as Figure 1.

Biological Monitoring

The biological monitoring event was conducted in Pennie's Cave on 15 November 2018 following the passage of a strong cold front (Menne et al. 2012). Zara biologist Jet Joost spent a total of 128 person-minutes performing the biological monitoring survey at Pennie's Cave. Two BCCP species of concern, *R. austinica* and *Speodesmus* N.S., were detected, along with an eyeless *Cicurina* spider. Two individuals each of *R. austinica* and *Speodesmus* N.S. and seven eyeless *Cicurina* spiders were detected. One eyeless *Cicurina* spider was collected. All biomonitoring zones were accessible and surveyed during the 2018 survey event (Figure 1).

A comprehensive list of all taxa observed by biological monitoring zone during 2018 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.

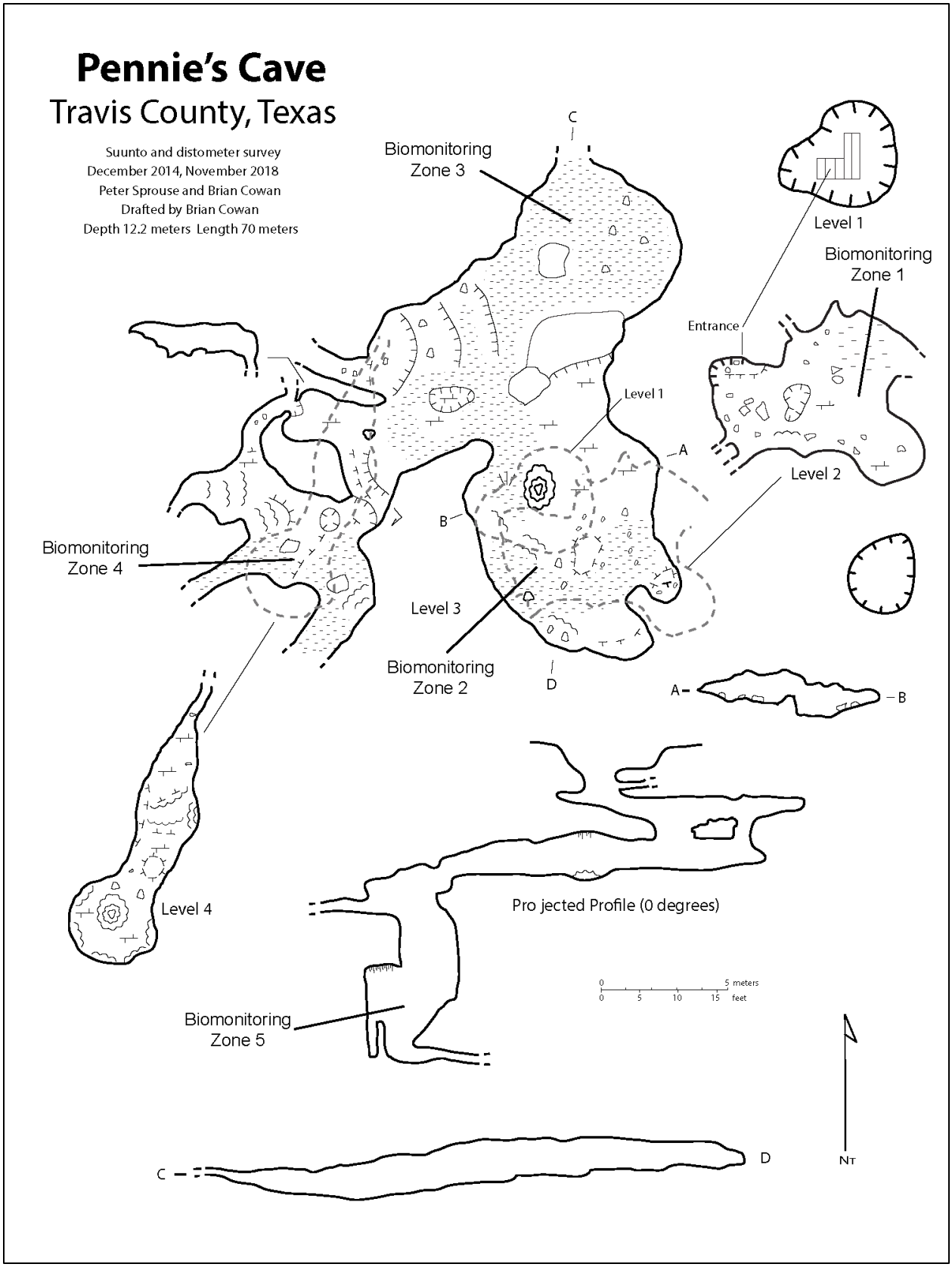

Figure 1. Map of Pennie's Cave including biomonitoring cave zones.

Table 1. Biological observations and collections at Pennie's Cave on 15 November 2018.

Common Name	Lowest Taxonomic Identification	# Observed	Collected Y/N? (#)
Snails	Gastropoda	1	N
Spiders	*Cicurina* sp. (eyeless)[1]	7	Y (1)
	Cicurina sp.	9	N
	Araneae	1	N
Pseudoscorpion	Pseudoscorpionida*	1	Y (1)
Centipedes	Lithobiomorpha	1	N
Millipedes	*Speodesmus* N.S.[2]	2	N
Diplurans	Diplura	4	N
Springtails	Collembola	104	N
Silverfish	*Texoreddellia* sp.	4	N
Crickets	*Ceuthophilus secretus*	3	N
	Ceuthophilus cunicularis	16	N
	Ceuthophilus sp. (Nymph)	47	N
Beetles	*Rhadine austinica*	2	N
	Staphylinidae	1	N
Woodlice	*Armadillidium* sp.	1	N
Gnats	Diptera	26	N
Frogs	*Gastrophryne olivacea*	1	N
	Anura	1	N
Salamanders	*Plethodon albagula*	3	N

[1] Potential BCCP species of concern
[2] BCCP species of concern
*New species record for Pennie's Cave

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
	Gastropoda	2
Earthworms	Oligochaeta	1, 3
Spiders	*Cicurina* sp. (eyeless)[1]	1, 2, 3, 4, 5
	Cicurina sp.	2, 3
	Araneae	1, 2
	Eidmanella sp.	2
Pseudoscorpion	Pseudoscorpionida	2
Harvestman	*Leiobunum townsendii*	1
Centipedes	Lithobiomorpha	1, 2, 3
	Chilopoda	1, 3
Millipedes	*Speodesmus* N.S.[2]	2, 3, 4, 5
	Diplopoda	1, 2
Symphylans	Symphyla	1
Diplurans	Diplura	2, 3
Springtails	Collembola	1, 2, 3, 4
Silverfish	*Texoreddellia* sp.	2, 4

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

Common Name	Lowest Taxonomic Identification	Biomonitoring Zone
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*	3
	Staphylinidae	1
Cockroaches	Blattaria	3
Woodlice	*Porcellio* sp.	1
	Armadillidium sp.	1
Gnats	Diptera	1, 2, 3, 4
Frogs	*Eleutherodactylus marnockii*	1
	Bufo nebulifer	2
	Gastrophryne olivacea	1
	Lithobates sp.	2
	Anura	1
Salamanders	*Plethodon albagula*	1, 2

[1] Potential BCCP species of concern

[2] BCCP species of concern

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
Cumulative Total	***800***	***NA***	***0***	***0***	***1***	***5***	***0***	***3***	***5***	***2***	***5***	***1***	***0***	***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.

Red Imported Fire Ant Control

Red imported fire ant control activities were performed on 17 May 2018 and 22 October 2018. 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).

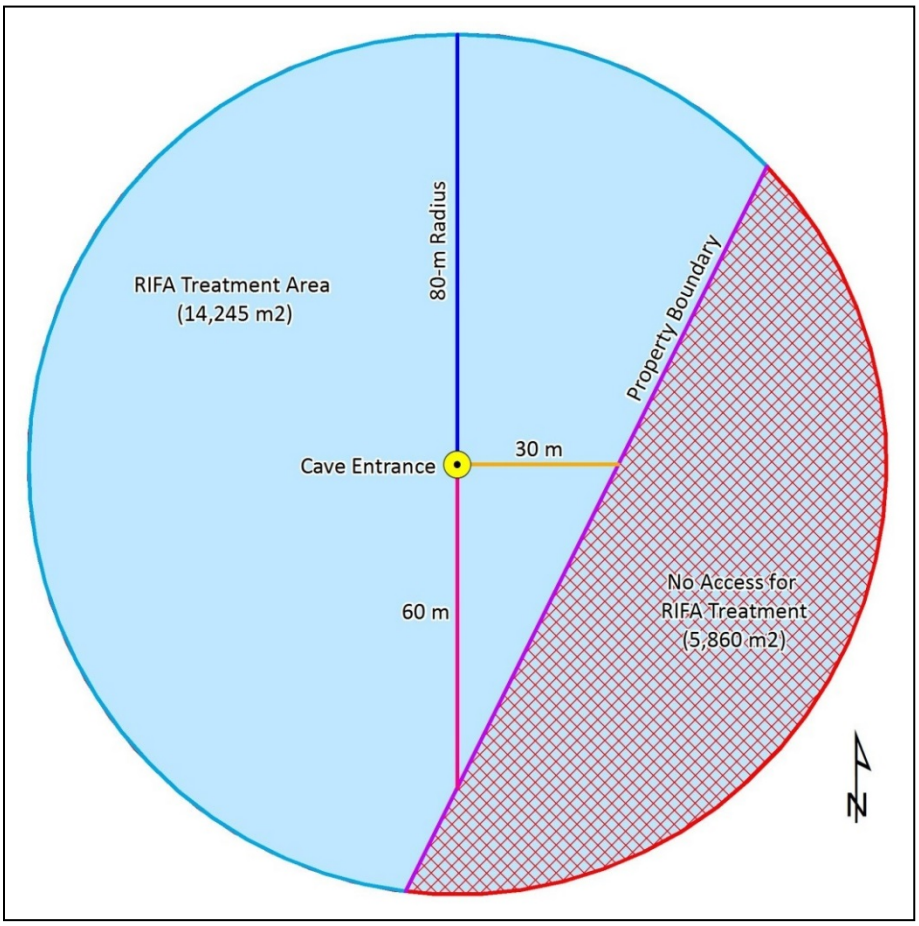

Figure 2. Diagram illustrating the entrance to Pennie's Cave, 80-m radius from the cave entrance, adjacent property boundary, RIFA treatment area, and inaccessible area located at the adjacent property.

A total of 32 active RIFA mounds, 21 in May and 11 in October, were identified and treated during the two control events in 2018. Eighteen abandoned mounds were identified (14 in May and seven in October). The resulting density of active RIFA mounds equates to one mound per 678.3 m^2 for the June treatment event and one mound per 1,295 m^2 for the October event. No active RIFA mounds were identified within the 10-m infestation threshold radius during either control event. Native ant colonies were not identified within the treatment area during either of the 2018 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.

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
22 Oct 2018	7	0	6	3	2	18	11	5	0	11	1,295.0

[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).

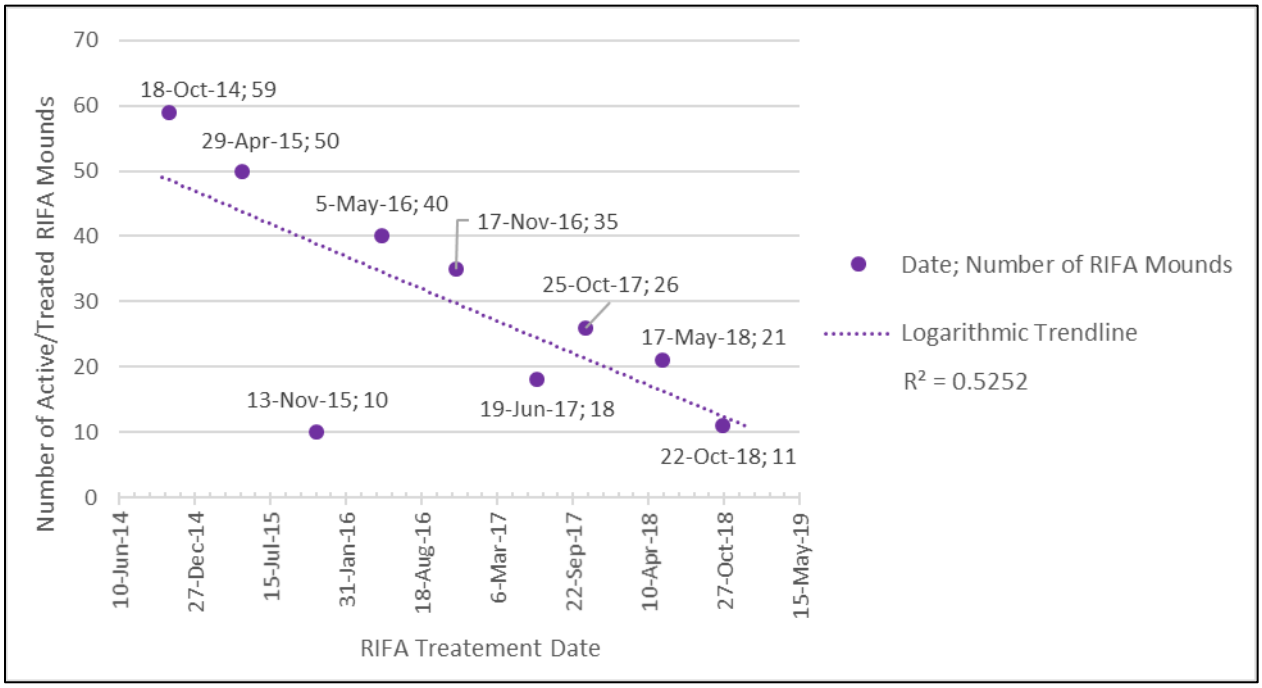

Figure 3. Total number of treated RIFA mounds by treatment date.

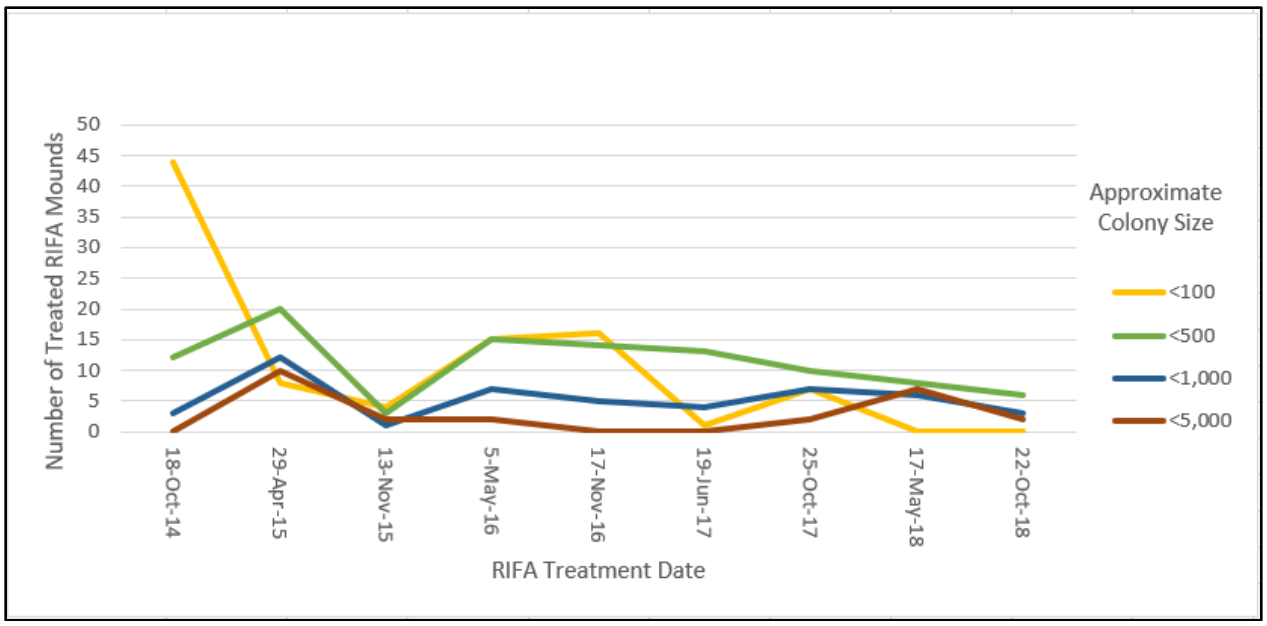

Figure 4. Number of treated RIFA mounds by treatment date and approximate colony size (date range not to scale).

Discussion

The ventilation system performed well during the biological monitoring event while safely allowing access to all zones of the cave for extended periods. A supplemental ventilation system, for temporary use during in-cave work, is recommended during warmer periods to allow expedited ventilation of zones 1 and 2. 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 previously recorded in Pennie's Cave before the initiation of cave management activities (BCP 2016), it had not been detected during any of the previous Zara monitoring events since the program began in 2014. 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. No federally listed karst species were encountered at Pennie's Cave. The observation of the pseudoscorpion, which is a new species record for the cave, is intriguing. While immature, the pseudoscorpion did not appear to be troglobitic. However, further evaluation of the specimen may be warranted to determine its taxonomic status, particularly since many of these taxa are known to be short-range endemics, some of which are covered under the BCCP (BCP 2016). Future collection of this pseudoscorpion (preferably adult specimens) in Pennie's Cave likely would facilitate identification.

Compared to previous biological monitoring events (Zara 2014, 2015, 2016), generally higher numbers of karst invertebrates (i.e., number of taxa as well as individuals) were encountered

during 2018, and both documented BCCP species of concern, the *Speodesmus* N.S. millipede and *R. austinica* ground beetle, were observed. 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 2018, a potential trend which began in October 2017 after a period of fluctuation (Figure 3). Despite the fluctuation since the initiation of RIFA control activities in 2014, the general trend of total active mounds appears to be decreasing with time. A decrease in the number of smaller colonies (less than 500 ants) continued during both 2018 control events, though no trend is immediately apparent in larger colonies (Figure 4). No active mounds consisting of less than 100 ants were treated during either of the two 2018 control events, and overall active mound density remains well below the associated infestation threshold. In June 2017, two active RIFA mounds were identified within the 10-m infestation threshold radius, but none have been observed within the 10-m threshold since that date. 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 (nine 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 2019 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 2019 will be prepared and submitted to the Travis County Transportation and Natural Resources Department for inclusion in the BCCP annual report for the year.

Literature Cited

Balcones Canyonlands Preserve (BCP). 2016. BCP land management plan, Tier II-A, Chapter IX, Karst species management.

Brown, D.J., B. DeVolld, W.H. Nowlin, M.R.J. Forstner. 2012. Fire ants in Houston Toad habitat: Annual activity and responses to canopy cover and fire. Journal of Fish and Wildlife Management 3(1):142-149.

City of Austin and Travis County. 1996. Habitat conservation plan and final environmental impact statement. U.S. Fish and Wildlife Service (USFWS) Ecological Services Field Office, Austin, Texas.

Menne, M.J., I. Durre, B. Korzeniewski, S. McNeal, K. Thomas, X. Yin, S. Anthony, R. Ray, R.S. Vose, B.E. Gleason, and T.G. Houston. 2012. Global Historical Climatology Network - Daily (GHCN-Daily), Version 3. [Station IDs: US1TXTV0164 and USW00013958]. NOAA National Climatic Data Center. doi:10.7289/V5D21VHZ. Available at https://www.ncdc.noaa.gov/data-access. Accessed 12 December 2018.

Paquin, P. and M. Hedin. 2005. Genetic and morphological analysis of species limits in *Cicurina* spiders (Araneae, Dictynidae) from southern Travis and northern Hays counties (Texas), with emphasis on *Cicurina cueva* Gertsch and relatives. Report to USFWS. Austin, Texas.

Paquin, P., N. Dupérré, J.C. Cokendolpher, K. White, and M. Hedin. 2008. Fundamental importance of taxonomy in conservation biology: the case of the case of the eyeless spider *Cicurina bandida* (Araneae: Dictynidae) of Central Texas, including new synonyms and the description of the male of the species. Invertebrate Systematics, 22.

Scanlon, S. 2015. Relative humidity calculator webpage. Available at http://www.ringbell.co.uk/info/humid.htm. Accessed 17 November 2016.

Stiles, J.H. and R.H. Jones. 1998. Distribution of the Red Imported Ant, Solenopsis invicta, in Road and Powerline Habitats. Landscape Ecology 335 335-346.

USFWS. 2016. Endangered karst invertebrate taxonomy of central Texas, revised October 17, 2016. USFWS Ecological Services Field Office, Austin, Texas. 24 pp. Available at: http://www.fws.gov/southwest/es/Documents/R2ES/AUES_KarstInverts_Taxonomy.pdf. Accessed 6 December 2018.

_____. 2015. Section 10(a)(1)(A) Scientific permit requirements for conducting presence/absence surveys for endangered karst invertebrate species, revised May 21, 2015. USFWS Ecological Services Field Office, Austin, Texas. 24 pp. Available at:

https://www.fws.gov/southwest/es/Documents/R2ES/Karst_Survey_Procedures_20150528.pdf. Accessed 5 December 2018.

_____. 2014. Karst preserve management and monitoring recommendations, revised April 8, 2014. USFWS Ecological Services Field Office, Austin, Texas. 12 pp. Available at: https://www.fws.gov/southwest/es/Documents/R2ES/TX_Karst_Preserve_Mgmt_module.pdf. Accessed 5 December 2018.

Vinson, S.B. and A.A. Sorenson. 1986. Imported fire ants: life history and impact. Texas Department of Agriculture. Austin, Texas.

Zara Environmental LLC (Zara). 2012. Management plan for Pennie's Cave, Travis County, Texas. Manchaca, Texas.

_____. 2014. 2014 Summary of cave management activities at Pennie's Cave, Travis County, Texas. Manchaca, Texas.

_____. 2015. 2015 Summary of cave management activities at Pennie's Cave, Travis County, Texas. Manchaca, Texas.

_____. 2016. 2016 Summary of cave management activities at Pennie's Cave, Travis County, Texas. Manchaca, Texas.

_____. 2017. 2017 Summary of cave management activities at Pennie's Cave, Travis County, Texas. Manchaca, Texas.