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2022 SUMMARY OF CAVE MANAGEMENT ACTIVITIES AT PENNIE'S CAVE, TRAVIS COUNTY, TEXAS

Additional ventilation being temporarily installed during the annual biological monitoring survey in 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 troglobitic spider (*Cicurina bandida*). Ongoing cave management measures were initiated in 2014. Management activities completed for 2022 included in-cave biological monitoring, red imported fire ant control activities in the 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. The ventilation system installed in 2018 was inspected and was operational in 2022; however, unsafe carbon dioxide levels did not permit access for survey in Zone 5. Personnel observed *Rhadine austinica*, *Speodesmus* N.S., and troglobitic *Cicurina bandida* (confirmed through phylogenetic analysis) spiders during the 2022 biological monitoring event. A total of 42 active red imported fire ant mounds were identified and treated during both the spring and fall control events in 2022. Active RIFA mounds were identified within the 10-m infestation threshold radius during the fall control 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. 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)).

Background

Pennie's 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 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, 2019, 2020, 2021). Since the initiation of in-cave biological monitoring in 2014, two karst invertebrate BCCP SOC have been detected (troglobitic millipede *Speodesmus* N.S. and ground beetle *Rhadine austinica*). Specimens of *Cicurina* (Gertsch 1992; Paquin and Hedin 2005; Paquin et al. 2008; Veni and Jones 2021), also an SOC covered under the BCCP, have been recorded and collected in Pennie's Cave during previous biological monitoring efforts, although verification of identify through phylogenetic analysis has been pending since the initial collection of a specimen (Zara 2018). Hazardous air quality has frequently been encountered during biological monitoring events, which prevented safe access to the cave; thus, so no in-cave data were recorded for those periods.

To provide safer and (potentially more dependable) 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 2022 included two RIFA control events, one in-cave biological monitoring event, the inspection and operation of the 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 2022.

Methods

Biological Monitoring

Annual biological monitoring for karst invertebrate species was conducted 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 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 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 locations 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 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 by heating metal buckets on propane-fired burners. 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 16 November 2022. Zara biologists Jimmy MacMillan and Ethan Perrine spent a total of 200 person-minutes performing the biological monitoring at Pennie's Cave in four zones. Biomonitoring zones 1, 2, 3, and 4 were accessible and surveyed during the 2022 survey event (Figure 1). Due to unsafe CO_2 levels, the survey was not performed within Zone 5. *Rhadine austinica,* eyeless *Cicurina*, and *Speodesmus* N.S. were observed during the 2022 biological monitoring event.

Previous reports by Zara (2018) suggested that the recorded eyeless *Cicurina* were likely *C. bandida*, pending phylogenetic analysis. Verification of species was received on 28 July 2022, which indicated that the collected specimen (ID: Zara-10244) is *C. bandida* (M. Hedin, personal communication, 28 July 2022).

A comprehensive list of all taxa observed by biological monitoring zone during 2022 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. Kestrel data were not downloaded during the 2022 biological monitoring event.

Red Imported Fire Ant Control

Red imported fire ant control activities were performed on 12 April and 16 November 2022 during a period of cooler 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 were identified and treated during the control event during the April event with 24 active mounds identified and treated in November. The resulting density of active RIFA mounds equates to one mound per 791.4 m^2 in April and one mound per 593.5 m^2 in November. No active RIFA mounds were identified within the 10-m infestation threshold radius during the April control event, and one active mound was observed within this radius during the November event. Fourteen abandoned mounds were identified in April while eight were identified in November. Native ant colonies were not identified within the treatment area during the 2021 RIFA control event.

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.

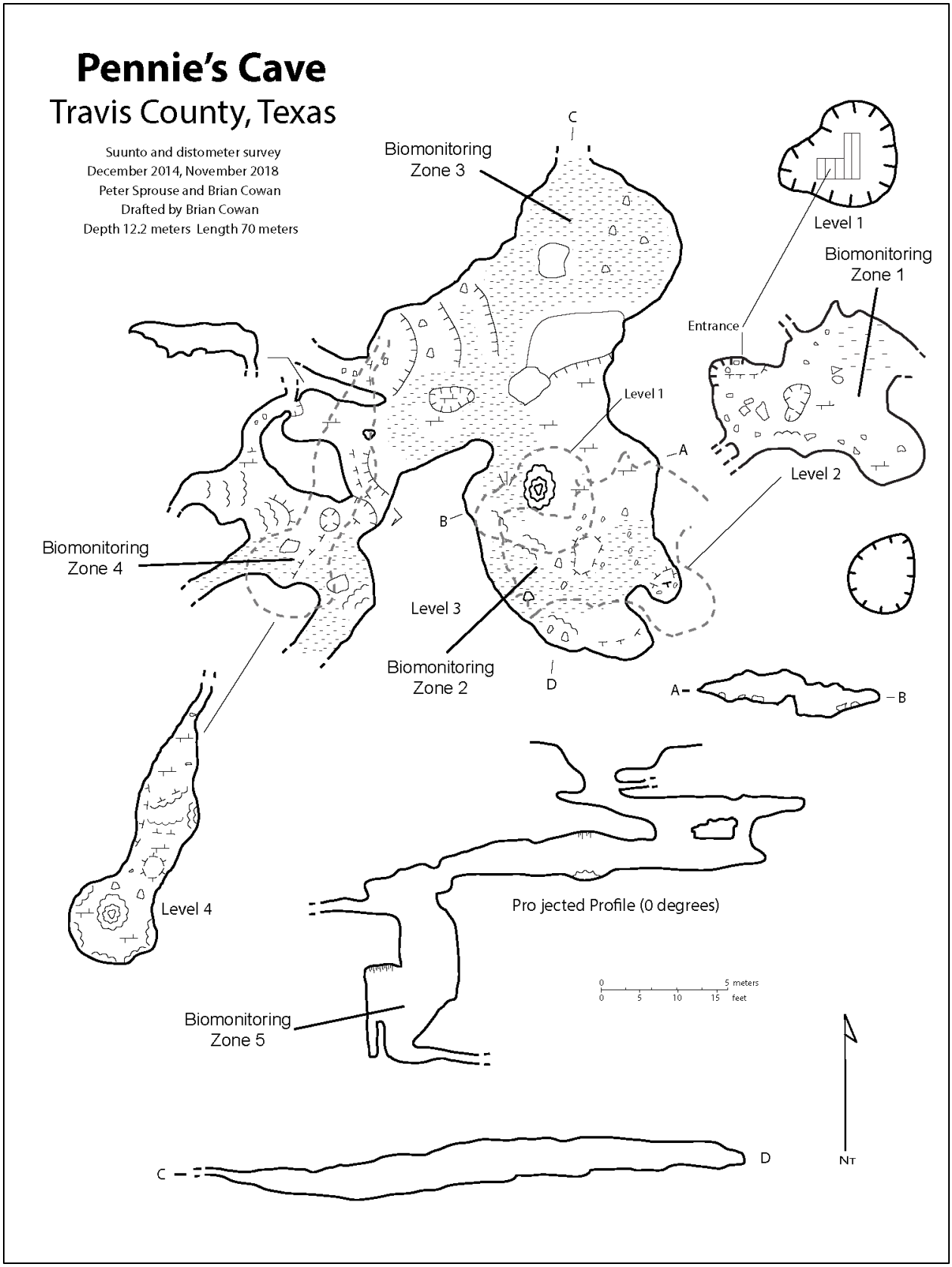

Figure 1. Map of Pennie's Cave including biomonitoring cave zones.

Table 1. Biological observations and collections at Pennie's Cave in 2022.

Common Name	Lowest Taxonomic Identification	# Observed	Collected Y/N? (#)
Spiders	*Cicurina bandida* [1] *Cicurina* sp. (eyed)	8	N
Western Slimy Salamander	*Plethodon albagula*	9	N
Springtails	Collembola	60	N
Fungus Moth	Tineidae	6	N
Pseudoscorpions	Pseudoscorpionida	1	N
Crickets	*Ceuthophilus secretus* *Ceuthophilus cunicularis* *Ceuthophilus* sp. nymph	2 4 5	N N N
Ground Beetle	*Rhadine austinicia*[2]	2	N
Millipede	*Speodesmus* N.S.[2]	1	N
Fungus Gnat	Mycetophilidae	1	N
Gnats	Diptera	6	N

[1] BCCP species of concern – confirmed (M. Hedin, personal communication, 28 July 2022)
[2] BCCP species of concern
* New species records for 2020.

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. Gastropoda	1, 2, 4, 5 1, 2, 3
Earthworm	Oligochaeta	1, 2, 3
Amphipod	*Stygobromus* sp.	5
Woodlice	*Porcellio* sp. *Armadillidium* sp.	1 1
Mites	Acari	1
Spiders	*Cicurina bandida*[1] *Cicurina* sp. (eyed) Araneae *Eidmanella* sp. Nesticidae	1, 2, 3, 4, 5 2, 3, 4 1, 2 2 1
Pseudoscorpion	Pseudoscorpionida	2
Harvestman	*Leiobunum townsendi* *Texella* sp.	1 4
Centipedes	Lithobiomorpha Chilopoda	1, 2, 3 1, 2, 3
Millipedes	*Speodesmus* N.S.[2] Diplopoda *Cambala* sp.	2, 3, 4, 5 1, 2 4, 5
Symphylan	Symphyla	1
Dipluran	Diplura	2, 3, 4
Springtail	Collembola	1, 2, 3, 4

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

Common Name	Lowest Taxonomic Identification	Biomonitoring Zone
Silverfish	*Texoreddellia* sp.	2, 4
	Lepismatidae	1
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
	Mycetophilidae	2
Moths	Tineidae	1, 3, 4
Frogs	*Eleutherodactylus marnockii*	1
	Bufo nebulifer	1, 2
	Gastrophryne olivacea	1
	Lithobates sp.	2
	Anura	1
Salamander	*Plethodon albagula*	1, 2, 3
Mammal	Mammalia (scat)	4

[1] BCCP species of concern – confirmed (M. Hedin, personal communication, 28 July 2022)
[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
25 July 2019	105	1, 2, 3, 4, 5	0	0	0	1	0	0	0	0	1	0	2	0	0	0	0
15 December 2020[4]	84	1, 2, 3, 4	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0
02 November 2021	115	1, 2, 3, 4, 5	0	0	0	0	0	0	0	0	1	0	3	1	0	0	0
16 November 2022	200	1, 2, 3, 4	0	0	0	0	0	1	0	0	2	1	2	5	--	--	--
Cumulative Total	***1115***	***NA***	***0***	***0***	***1***	***6***	***0***	***5***	***5***	***2***	***9***	***2***	***7***	***11***	***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

[4]Survey was truncated due to unsafe air quality in the cave. Survey was heavily focused on Zone 1.

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	--	NM
25 July 2019	09:50	Zone 1	--	--	NM	NM	--	NM
25 July 2019	10:08	Zone 2	--	--	NM	NM	--	NM
25 July 2019	10:31	Zone 3	--	--	NM	1,032	--	100
25 July 2019	11:06	Zone 4	--	--	NM	NM	--	NM
25 July 2019	10:31	Zone 5	--	--	NM	NM	--	NM
15 December 2020	13:00	Surface	--	--	15.8	NM	--	42.0
15 December 2020	13:11	Zone 1	--	--	18.2	NM	--	84.6
15 December 2020	14:00	Zone 2	--	--	18.6	NM	--	100
15 December 2020	14:10	Zone 3	--	--	18.9	NM	--	100
15 December 2020	12:50	Zone 4	--	--	NR	NM	--	NM
02 November 2021	12:30	Surface	--	--	19.6	1,002	--	78.0
02 November 2021	13:35	Zone 1	--	--	23.3	NM	--	90.2
02 November 2021	13:25	Zone 2	--	--	21.9	NM	--	92.7
02 November 2021	13:03	Zone 3	--	--	21.4	NM	--	90.0
02 November 2021	12:25	Zone 4	--	--	23.0	NM	--	93.0
02 November 2021	12:40	Zone 5	--	--	22.7	NM	--	91.7
16 November 2022	12:25	Surface	--	--	12.9	NM	--	--
16 November 2022	14:15	Zone 1	--	--	13.2	NM	--	--
16 November 2022	12:45	Zone 2	--	--	22.4	NM	--	89
16 November 2022	13:00	Zone 3	--	--	22	NM	--	95
16 November 2022	13:35	Zone 4	--	--	21	NM	--	97
16 November 2022	-13:37	Zone 5	--	--	--	NM	--	100
NM = Surveyed but not measured								

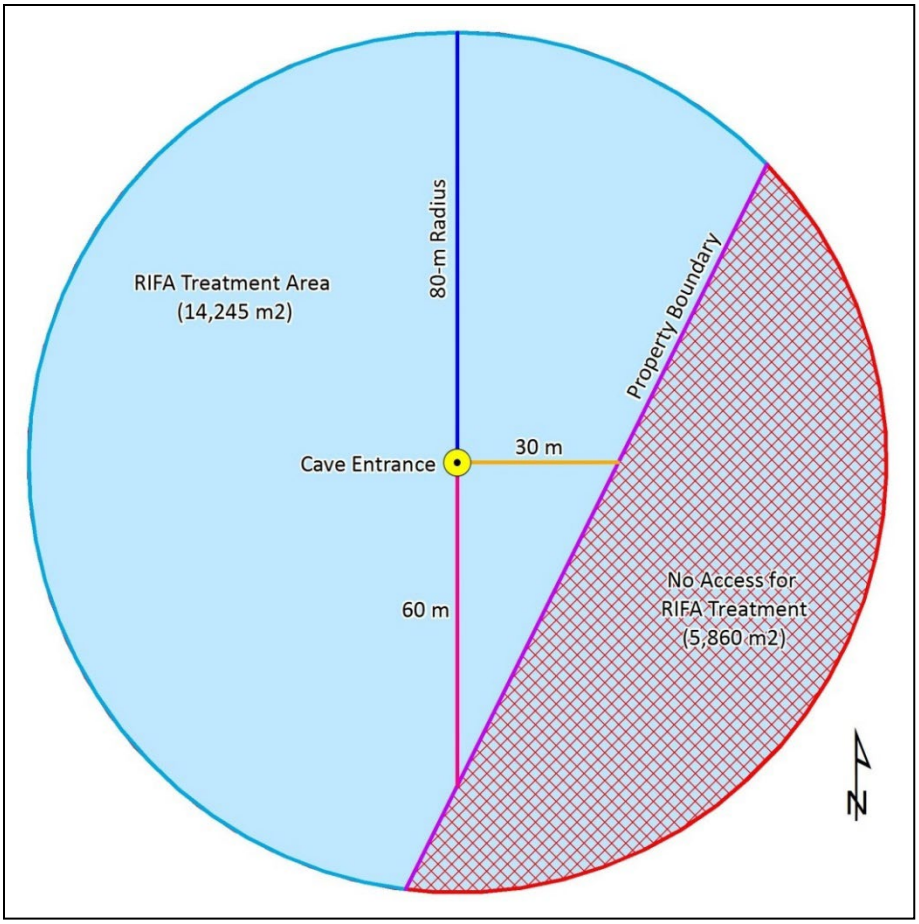

Figure 2. Diagram illustrating the entrance to Pennie's Cave, 80-m radius from the cave entrance, adjacent property boundary, RIFA treatment area, and inaccessible area located at the adjacent property.

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
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
Spring 2020[3]	--	--	--	--	--	--	--	--	--	--	--
15 Dec 2020	14	1	3	3	1	22	8	18	0	8	1,780.6
07 May 2021	15	10	7	4	3	39	24	120	0	20	593.5
02 Nov 2021	17	3	5	6	4	35	18	20	2	10	791.4
12 Apr 2022	14	3	7	5	3	32	18	20	0	8	791.4
16 Nov 2022	8	0	7	9	8	32	24	30	1	15	593.5

[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).
[3] The spring 2020 treatment event did not occur due to the onset of the COVID-19 pandemic.

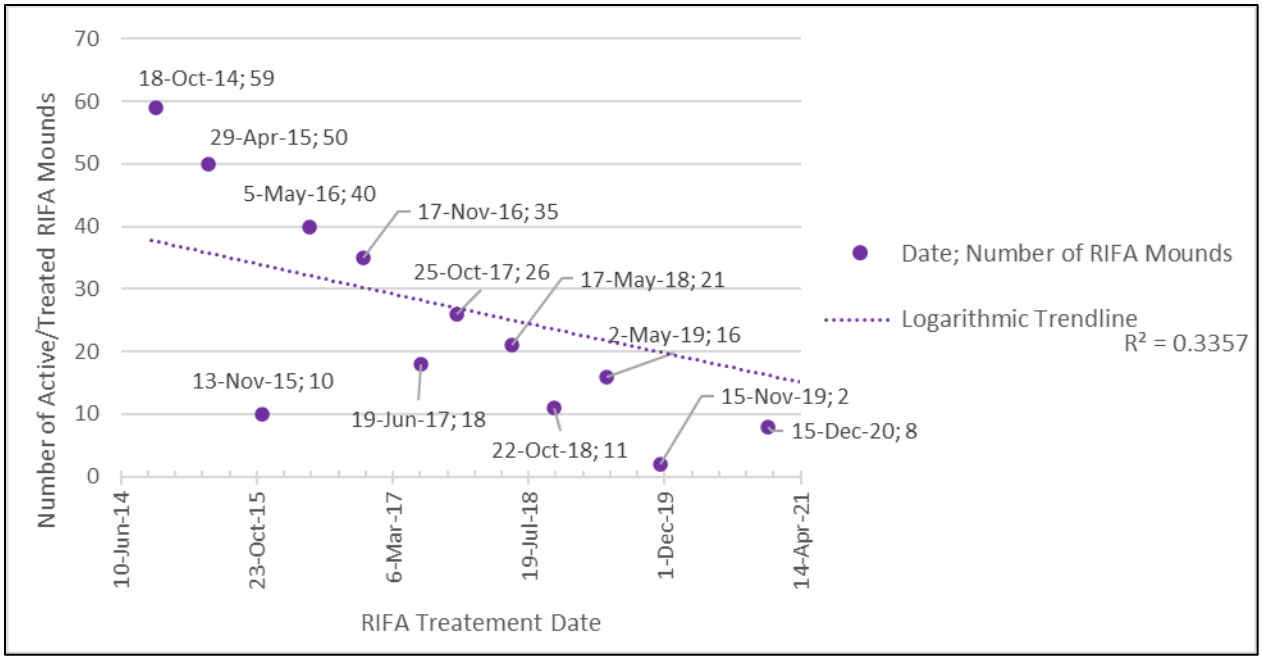

Figure 3. Total number of treated RIFA mounds by treatment date.

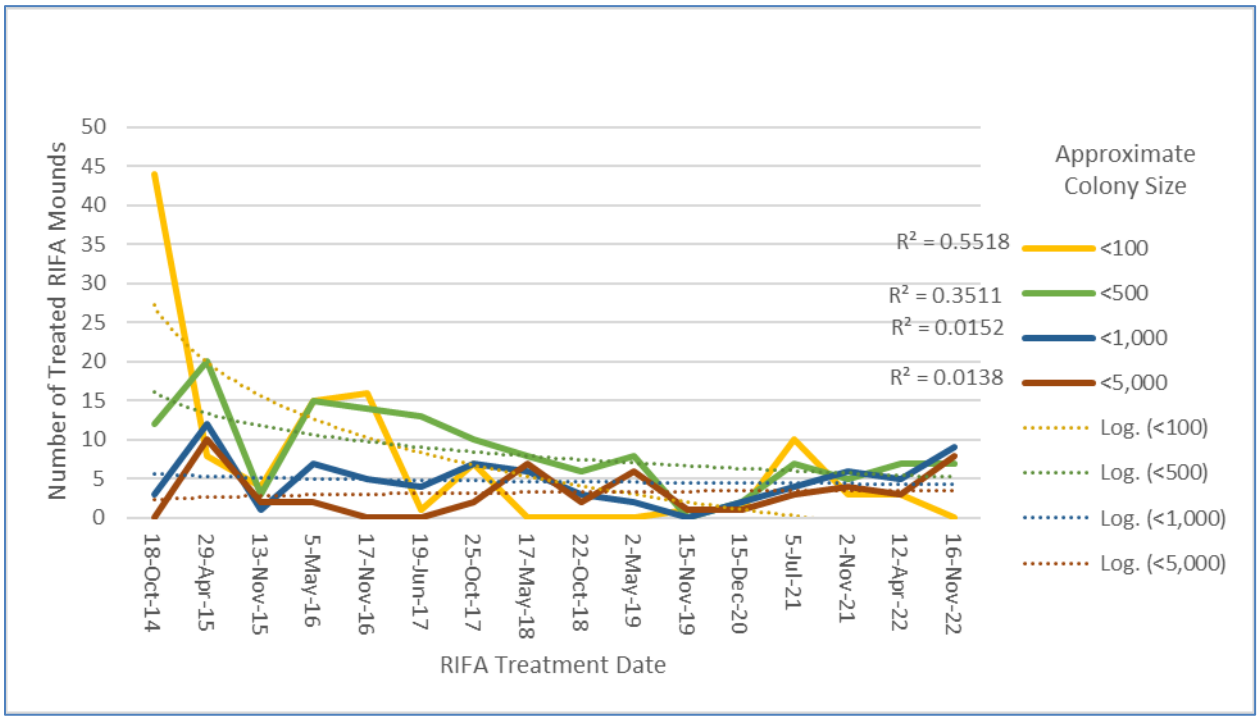

Figure 4. Number of treated RIFA mounds by treatment date and approximate colony size (date range not to scale).

Discussion

The ventilation system installed in 2018 was inspected and was operational in 2022. However, unsafe CO_2 levels did not allow for survey to be conducted in Zone 5. The-in-cave microclimate data (using the Kestrel DROP D2 automatic datalogger) were not downloaded, but the cave

microclimate will continue to be monitored for effects associated with the use of the ventilation system. These microclimate data collected through 2020 are not reported here but will be available to BCCP staff upon request.

The eyeless *Cicurina* spiders encountered in over time may be *C. bandida* (Paquin and Hedin 2005; Paquin et al. 2008; Veni and Jones 2021), which is an SOC covered under the BCCP. An eyeless Cicurina collected in 2018 (Specimen ID: ZARA 10244) was transferred to BCCP staff for genetic analysis to determine the spider's identity; however, at the time of this report the genetic analyses were pending. No federally listed karst species were encountered at Pennie's Cave. In general, the number of all recorded species, as well as total number of individuals per species, appeared to be lower than previous years. The reason for this apparent reduction and whether it is temporary is currently unknown.

Since the initiation of RIFA control activities in 2014, the general trend of total active mounds appeared to have been decreasing with time (Figure 3). However, based on the results of the 2021 and 2022 RIFA control events, the total number of treated (i.e., active) mounds increased between November 2019 and 2021, and then increased further between 2021 and 2022. Active mounds were recorded within 10 m of the cave entrance in November, although the density of active mounds in the treatment area remains well below the infestation threshold. 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 limited number of observations for determining correlation (16 treatment events to date). No ants have been observed inside the cave since biological monitoring began in 2014.

Cave management activities planned for 2023 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. Based on the continued, unsafe CO^2 levels encountered, modifications to the ventilation system may be necessary to provide safer conditions for personnel working in the cave. Finally, an annual report summarizing the activities performed in 2023 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.

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.

Gertsch, W.J. 1992. Distribution patterns and speciation in North American cave spiders with a list of the troglobites and revision of the Cicurinas of the subgenus Cicurella. Texas Memorial Museum Speleological Monographs 3,75-122.

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 10 December 2019.

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 10 December 2019.

USFWS. 2016. Endangered karst invertebrate taxonomy of central Texas, revised April 19, 2019. USFWS Ecological Services Field Office, Austin, Texas. 24 pp. Available at: http://www.fws.gov/southwest/es/Documents/R2ES/AUES_KarstInverts_Taxonomy.pdf. Accessed 10 December 2019.

_____. 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 10 December 2019.

_____. 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 10 December 2019.

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

Veni, G. and M. Jones. 2021. Statistical analysis and revision of endangered karst species distribution, Austin area, Texas. National Cave and Karst Research Institute report of investigation 10. Carlsbad, New Mexico. Available at: https://www.nckri.org/wp-content/uploads/2021/08/NCKRI-RI-10-final.pdf.

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.

_____. 2018. 2018 Summary of cave management activities at Pennie's Cave, Travis County, Texas. Manchaca, Texas.

_____. 2019. 2019 Summary of cave management activities at Pennie's Cave, Travis County, Texas. Manchaca, Texas.

_____. 2020. 2020 Summary of cave management activities at Pennie's Cave, Travis County, Texas. Manchaca, Texas.

_____. 2021. 2020 Summary of cave management activities at Pennie's Cave, Travis County, Texas. Manchaca, Texas.