INVERTEBRATE CAVE FAUNA OF KARTCHNER CAVERNS, KARTCHNER CAVERNS, ARIZONA

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The invertebrate cave fauna of Kartchner Caverns, Kartchner Caverns State Park, Cochise Co., Arizona, was surveyed between 1989 and 1991. Thirty-eight invertebrate species were recorded during the study, including (11%) troglobites, 19 (50%) troglophiles, 1 trogloxene and 12 (32%) accidentals. Of the remaining, 1 was an obligate parasite and the other a guanophile. Most of the Kartchner Caverns cave fauna depend upon guano deposited by a summer colony of Myotis velifer. *The dominant arthropods were mites found in the guano.*

Invertebrates, especially arthropods, make up the majority of all cave organisms. There have been few biospeleological surveys of invertebrates in the southwestern United States. Most work in this region has been concentrated in the Guadalupe Escarpment area, New Mexico (Barr & Reddell 1967; Welbourn 1978; Northup *et. al*. 1995; Cokendolpher & Polyak 1996). In addition, there have been surveys of lava caves in New Mexico and Arizona (Peck 1982; Northup & Welbourn 1997). The only published studies of Arizona cave invertebrates have been in the Grand Canyon (Peck 1980; Dorst & Blinn 1997), the earth crack caves of Wupatki National Monument (Welbourn 1979; Muchmore 1981), and four lava caves in the vicinity of Flagstaff (Peck 1982). Caves in southern Arizona are widely scattered in isolated mountain ranges (i.e. Catalina, Chiricahua, Huachuca, Santa Rita and Whetstone Mountains) making a survey of the cave invertebrates more difficult. The only cavernicolous species from southern Arizona are a troglobitic isopod, *Brackenridgia sphinxensis* Schultz from the Chiricahua Mountains and a troglophilic pseudoscorpion, *Tuberochernes ubicki* Muchmore from the Santa Rita Mountains.

Kartchner Caverns formed in limestone isolated near the base of the Whetstone Mountains (Jagnow 1999). Kartchner Caverns was discovered in 1974 and has been kept in nearly pristine condition (Tuffs & Tenen 1999). In 1988, the State of Arizona purchased the cave as a state park and initiated plans to develop a show cave. Kartchner Caverns offered a unique opportunity to establish a baseline survey of the invertebrate cave fauna before the cave was developed, and this survey should allow future studies to assess the effects of commercial development on the cave fauna.

MATERIALS AND METHODS

The inventory of the invertebrate cave fauna involved a total of 36 trips into Kartchner Caverns with over 164 hours underground between May 1989 and May 1991. Trips into the cave between late-April and mid-September were scheduled to minimize disturbance of the bats. This was done by avoiding the active roost areas or by working in the active roost areas at night. The survey for invertebrates was conducted by examination of substrate, organic material, loose rocks, walls, and pool surfaces visually using an OptiVisor with a 2.5x magnification lens. Eight other caves visited during this study were surveyed in the same manner.

Collection of specimens in the cave was limited to those necessary for identification and laboratory study. Samples of *Myotis velifer* (Allen) guano (10-30 cm³) were collected from various guano sites in the Front Section of the cave (Fig. 1). Two guano sites (guano piles #20 and 9c) in the Big Room (Fig. 1) were sampled monthly for a year and examined for arthropods. Arthropods were extracted from guano samples using a Berlese-funnel. Samples were kept in the Berlese-funnel for seven days and all specimens were preserved in 75% ETOH. The mites were separated into species groups, counted using a stereo microscope (Wilde M5), and recorded as number of mites/cm³ of guano. Representative specimens were mounted in a Hoyer's type mounting media on standard

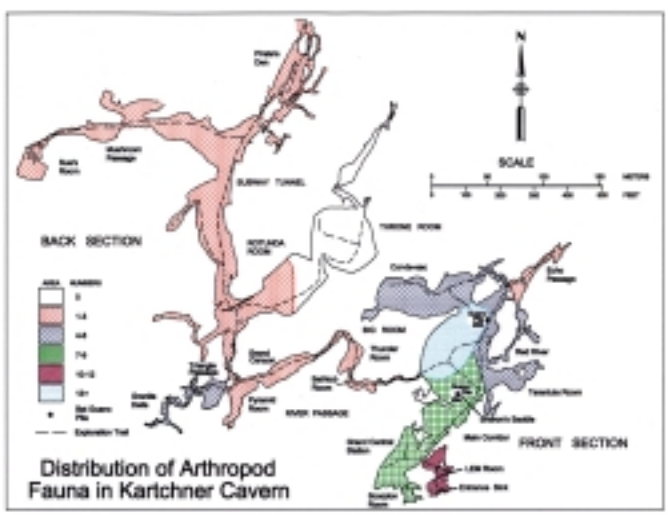

Figure 1. Distribution of arthropod fauna in Kartchner Caverns.

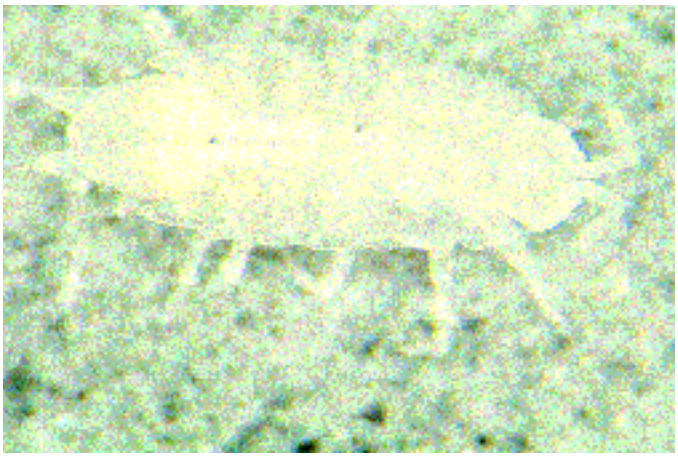

Figure 2. Microphotograph of *Brackenridgia* sp. (Isopoda, Trichoniscidae) from Kartchner Caverns.

microscope slides (76 x 25 x 1 mm) for identification under a compound microscope (Wilde M20 phase contrast). Unmounted specimens were stored in 75% ETOH. Samples collected in other guano piles in the Front Section (Fig. 1) were processed in the same manner. Representative specimens will be deposited in the Acarology Laboratory at Ohio State University, Columbus, Ohio, and the Florida State Collection of Arthropods, Gainesville, Florida.

Population estimates for the spider, *Eidmannella pallida* (Emerton) (Araneae, Nesticidae), in the Big Room were made by counting the number of spiders along ~175 m of marked trail that circled guano piles 9c and 20 (Fig.1). All individuals found on and up to 1 m on either side of the trail were counted.

To investigate the possible connection between a surface blowhole and the Granite Dells, 50 *Ceuthophilus pima* Hubbell (Orthoptera, Rhaphidophoridae) were collected at oatmeal bait around the surface blowhole above the Granite Dells area (Fig. 1). The crickets were placed in a plastic bag with a fluorescent dye and released after about 5 to 10 minutes. Crickets in the Granite Dells area were examined for the presence of dye. Cave crickets were randomly captured in Kartchner Caverns and around the surface blowhole and examined for mites and released. Representative mites were removed from some cave crickets for rearing and taxonomic study.

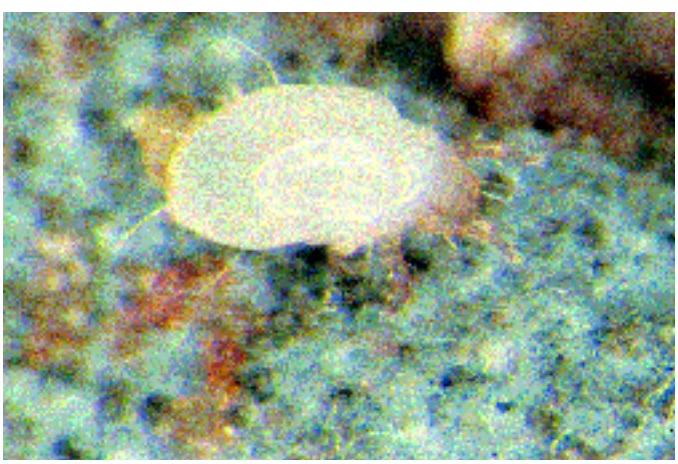

Figure 3. Microphotograph of an adult *Sancassania* sp. (Acari, Acaridae) from Kartchner Caverns.

RESULTS AND DISCUSSION

Thirty-eight invertebrate species were identified in Kartchner Caverns during this study (Table 1). The 38 species included 4 (11%) considered to be obligate cave dwellers (troglobites) and 19 (50%) facultative cave dwellers (troglophiles). The camel cricket, *C. pima*, was a trogloxene because they leave the cave to feed. Twelve accidentals, one obligate parasites, and one guanophile made up the remaining 14 species. The distribution of arthropod species in Kartchner Caverns is presented in Figure 1, and a list of species found in Kartchner Caverns is summarized in Table 1.

Table 1. Summary of invertebrate fauna collected from Kartchner Caverns. Ecological group: Accidental = an animal that wanders or falls into the cave, but cannot survive in the cave; Trogloxene = an animal that lives part of its life cycle in the cave, but must leave the cave to feed; Troglophile = an animal that can live its entire life in the cave, but is not restricted to the cave; Troglobite = an obligate cave animal.
Guild: What the animal does in the cave community. P = predator; F = fungivore (including bacteria); S = scavenger; PA = parasite; U = unknown.
Status: How frequently a group of animals was found in the cave. C = common; R = rare.

	Ecological Group	Guild	Status
NEMATODA			
undetermined material	troglophile?	F	C
ARTHROPODA			
Class Arachnida			
Order Palpigrada			
undetermined material	troglophile?	P	R
Order Scorpionida			
undetermined material	accidental	P	R
Order Araneae			
Nesticidae			
Eidmannella pallida (Emerton)	troglophile	P	C
Theraphosidae			
undetermined genus	accidental	P	R
Order Acari			
Acaridae			
Sancassania sp.	troglophile	S	C
Argasidae			
Ornithodorus nr. *haser* (Schulze)	parasite	PA	R
Cheyletidae			
Cheyletus sp.	troglophile	P	R
Histiostomatidae			
undetermined genus 1	troglophile	S	R
undetermined genus 2	troglophile	S	R
Laelapidae			
Geolaelaps sp.	troglophile	P	C

Neothrombiidae			
Ceuthothrombium sp.	troglobite	PA/P	C
Pygmephoridae			
undetermined genus	troglophile	S	R
Rosenteinidae			
Nycterglyphus sp.	guanophile	S	R
Rhagidiidae			
Poecilophysis sp.	troglobite?	P	R
Rhodacaridae			
Rhodacarus sp.	troglophile	P	R
Stigmaeidae			
Eustigmaeus sp.	troglophile	P	C
Tarsonemidae			
Tarsonemus sp.	troglophile	S	R
Oribatida			
undetermined material (4 species)	troglophile?	S	R
Order Pseudoscorpiones			
undetermined genus	accidental	P	R
Class Chilopoda			
Scolopendridae			
undetermined genus	accidental	P	R
Class Malacostraca			
Order Isopoda			
Trichoniscidae			
Brackenridgia sp. nr. *spinxensis* Schultz	troglobite	F	C
Oniscidae			
Porcellio sp.	accidental	F	C
Class Insecta			
Order Thysanura			
Nicoletiidae			
Nicoletia sp.	troglobite	F	C
Order Collembola			
Sminthuridae			
undetermined genus	troglophile	F	R
Entomobryidae			
undetermined genus	troglophile	F	R
Order Orthoptera			
Rhaphidophoridae			
Ceuthophilus pima Hubbell	trogloxene	S	C
Order Psocoptera			
Psyllipsocidae			
Psyllipsocus ramburii Selys-Longchamps	troglophile	F	C
Order Hemiptera			
Reduviidae			
undetermined genus	accidental	P	R
Order Coleoptera			
Staphylinidae			
undetermined material	accidental	F	R
Tenebrionidae			
Eleodes sp.	accidental	S	R
undetermined fragments	accidental	U	R
Order Lepidoptera			
undetermined material	accidental	U	R
Order Diptera			
Muscidae			
undetermined genus	accidental	S	C
Sciaridae			
undetermined genus (2 species)	troglophile	S	C
Order Hymenoptera			
Formicidae			
undetermined genus	accidental?	U	R

Invertebrates in Kartchner Caverns depend on guano deposited by the colony of about 1000 *M. velifer* between late-April and mid-September (Buecher & Sidner 1999). Small amounts of organic matter washed into the cave by periodic flooding provide a limited food supply to the Back Section. The camel crickets, *C. pima,* do not depend on organic material carried into the cave, but appear to take advantage of any available food source.

THE BACK SECTION

Few invertebrates were found in the Back Section (Fig. 1). Granite Dells was the exception with several invertebrate species present.

The only invertebrate regularly found beyond the Triangle Passage was a troglobitic terrestrial isopod, *Brackenridgia* nr. *sphinxensis* Schultz (Isopoda, Trichoniscidae) (Fig. 2). This isopod was observed feeding on wooden trail makers and plant debris (i.e., twigs, leaves, and other plant material) in the mud-covered areas. Evidence of *B.* nr. *sphinxensis* was also found along the trails where many of the wooden trail markers had been eaten, leaving only reflective tape and frass. Periodic flooding of the Back Section, especially the lower Rotunda Room, Mushroom Passage, Subway Tunnel and Pirate's Den, eliminated or displaced isopods, but the plant debris left behind provides a food resource for recolonization.

The only other arthropods observed in the Back Section were occasional camel crickets (*C. pima*), a fly (Diptera) and a hemipteran (Reduviidae) that probably wandered through the Triangle Passage from a surface connection in the Granite Dells area. No invertebrates were found in the Throne Room, Sue's Room and upper portion of the Rotunda Room (Fig. 1). The wooden trail markers in these areas had not been disturbed. The bat guano deposits in the Throne and Rotunda Rooms were dated at 50–40 Ka and suggest a former opening to the surface (Buecher & Sidner 1999). No invertebrates were found in or associated with the guano in the Back Section.

Other than the main entrance, the Granite Dells area was the only part of the cave known to have a current connection to the surface. The presence of *C. pima*, an unidentified surface spider, and an unidentified lepidopteran indicated a connection to the surface through the blowhole. Even with a connection to the surface, few arthropods were observed in this area. Attempts to locate marked *C. pima* that had been released on

Figure 4. Scanning electron micrograph of a *Sancassania* sp. deutonymph (Acari, Acaridae) from Kartchner Caverns.

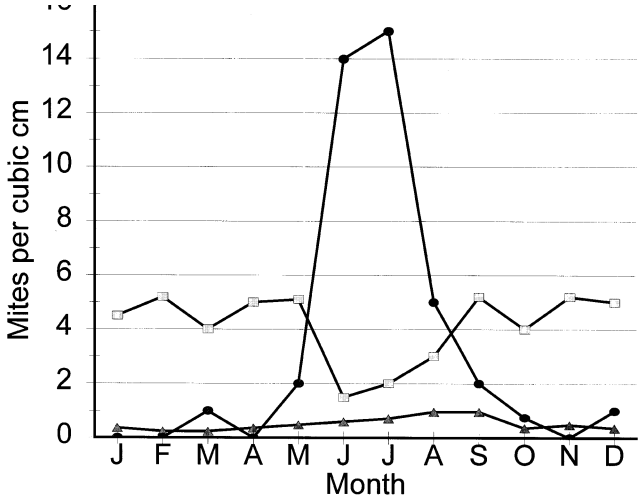

Figure 5. Average density of mites per month from samples at guano pile #20, Kartchner Caverns. ● = represents larvae, tritonymphs and adult *Sancassania* sp.; ■ = represents number of non-feeding deutonymphs (= hypopodes) of *Sancassania* sp.; ▲ represents number of *Geolaelps* sp. (all instars).

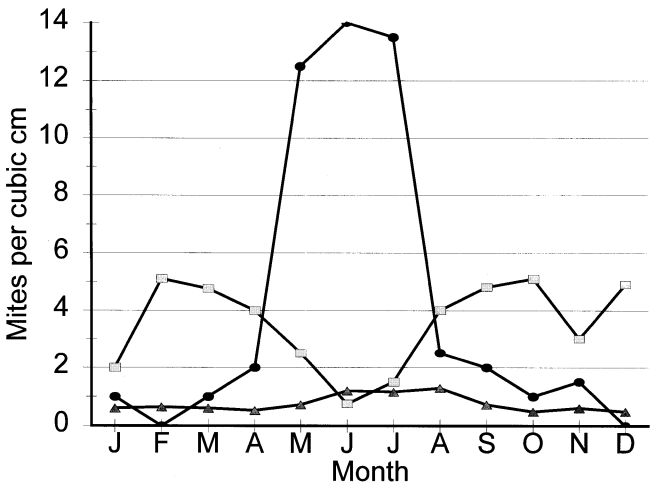

Figure 6. Average density of mites per month from samples at guano pile #9c, Kartchner Caverns. ● = represents larvae, tritonymphs and adult *Sancassania* sp.; ■ = represents number of non-feeding deutonymphs (= hypopodes) of *Sancassania* sp; ▲ represents number of *Geolaelps* sp. (all instars).

the surface were unsuccessful, suggesting there may be other cavities between the surface opening and Granite Dells area. All the invertebrates found in this area, except *C. pima* and *B.* nr. *sphinxensis*, were considered to be accidentals.

THE RIVER PASSAGE

The area between the Pyramid Room and Big Room (River Passage) was a transition zone between the two parts of the cave (Fig. 1). No invertebrates were regularly found in this area. Only an occasional *C. pima*, *B.* nr. *sphinxensis* or dipteran were observed in this section. Organic material in the River Passage was limited to occasional *M. velifer* guano pellets.

THE FRONT SECTION

The Front Section of Kartchner Caverns is the biological center of the cave with 38 invertebrate species distributed throughout that area (Fig. 1). Identified in the Big Room and Cul-de-sac, are numerous *M. velifer* guano piles of different size and age. These guano accumulations are the primary food source for most invertebrates in Kartchner Caverns. During this study, *M. velifer* roosted near the Lunch Spot (Fig. 1, Guano Pile #20) and Sharon's Saddle (Fig. 1, Guano Pile #9c). In late-summer, the bats were more likely to be dispersed in the Big Room, distributing guano over a wide area (Buecher & Sidner 1999). The movement of the bats significantly affected the number of invertebrates living in the guano.

The guano piles that were refreshed regularly supported more mold growth and higher nematode and arthropod populations. The first *M. velifer* guano of the year stimulated visible mold and bacteria growth and this was followed by an increase in the nematode and mite populations. The most abundant guano arthropod was *Sancassania* sp. (Acari, Acaridae) (Figs. 3 & 4). When fresh guano accumulated at a site, the dormant *Sancassania* sp. deutonymphs (= hypopodes) in the guano developed rapidly into adults and began their reproductive cycle. *Sancassania* sp. can be reared on fungus and yeast, but they also feed on insect eggs and larvae (Hughes 1976) and occasionally nematodes (C. Welbourn, unpub. data). Hughes (1976) reported that *S. berlesei* (Michael) completed it's life cycle in 8-9 days at 22°C and 100% relative humidity and that a female could produce over 1000 eggs in 39 days. The 99.4% relative humidity and temperature of 20.9°C (Buecher 1999) provided an ideal environment for *Sancassania* sp. to increase it's population very rapidly when a food source (i.e. fresh guano) was available. Within a month after the *M. velifer* deposit fresh guano on the two monitored piles (#20 & #9c), the mite population was as high as 17/cm³. The seasonal response of *Sancassania* sp. to the presence of fresh guano differed between the two major roost areas (Figs. 5 & 6). At guano pile #20, the peak period for *Sancassania* sp. was May through July, while the peak period for the same mite at guano pile #9c was July and August. Other fungivorous mites (Tarsonemidae, Histiostomatidae, and Pygmephoridae) fed on fresh guano, but never in large numbers (Table 1). Flies were also associated with the fresh guano.

In the monitored guano piles the dominant predator was another mite, *Geolaelaps* sp. (Acari, Laelapidae) (Fig. 7). While the population density of *Geolaelaps* sp. was never close to that of *Sancassania* sp., it was the second most common arthropod in the fresh guano with 0.24-1.28/cm³ (Figs. 5 & 6). The peak in the *Geolaelaps* sp. population usually occurred just after the peak in the *Sancassania* population.

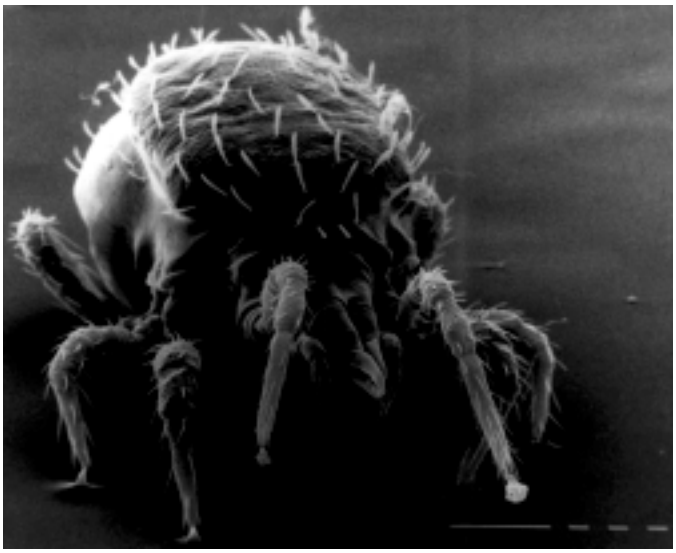

Figure 7. Scanning electron micrograph of *Geolaelaps* sp. (Acari, Laelapidae) from Kartchner Caverns.

Sancassania sp. and *Geolaelaps* sp. were the dominant arthropods during bat residence times (about mid-April to late-September). Other predator mites in the guano samples were *Eustigmaeus* nr. *lirella* (Summers & Price) (Stigmaeidae), *Cheyletus* sp. (Cheyletidae), and *Rhodacarus* sp. (Rhodacaridae). With the exception of *E.* nr. *lirella*, these predators were found in very low numbers. *Eustigmaeus* nr. *lirella* were in most samples from guano piles receiving a little fresh guano annually.

After the bats moved to another roost or migrated, the invertebrate fauna of the guano changed when food resources became depleted. Most *Sancassania* sp. stop development at the non-feeding deutonymphal instar (= hypopus). The deutonymph in many Acaridae can survive long periods without food and is the dispersal instar (Evans 1992). Within a month after the last fresh guano was deposited, almost the entire population of adult *Sancassania* sp. died leaving a reduced population (2-5/cm^3) of deutonymphs until the next year (Figs. 5 & 6). *Sancassania* sp. deutonymphs usually buried themselves in the guano and waited for the next fresh guano. Several clumps of one to several hundred deutonymphs were observed in the guano. It is not known how long the deutonymphs of this species can survive in the guano without food, but a few individuals were found in most of the inactive guano piles sampled. As the guano aged, other arthropods moved onto the guano, including crickets, oribatid mites, spiders, psocopterans, and an occasional isopod. Guano more than a year old supported very few invertebrates.

The area from the LEM Room to the entrance is anomalous within the cave. Here there is a significant seasonal fluctuation in temperature and humidity (Buecher 1999), and organic input is predominantly scattered *M. velifer* guano pellets and occasional surface material carried in by rodents. The dominant cave arthropods identified were camel crickets, *C. pima*. The other fauna in this area varied seasonally, but included many of the accidental species found in the cave.

COMPARISON OF CAVE FAUNA OF KARTCHNER CAVERNS WITH OTHER CAVES

The invertebrate cave fauna and cave community of Kartchner Caverns is unique. Although the cave fauna of southern Arizona is not well known, some comparisons can be made with eight other caves in four mountain ranges (Table 2). The most notable differences were the absence of *Sclerobunus* nr. *robustus* (Opiliones, Triaenonychidae) and a *Rhadine* sp. (Coleoptera, Carabidae). Briggs (1971) reported *S. robustus robustus* (Packard) from fir forests at elevations of 2933-3500 m msl in Arizona and 2166-2666 m msl in New Mexico. The *Sclerobunus* nr. *robustus* from the caves in Table 2 were at least 800 m to >1200 m below levels listed by Briggs (1971). In addition, the troglobitic dipluran *Plusiocampa* sp. (Diplura, Campodeidae) was in all caves examined except for Kartchner Caverns and the two caves in the Santa Rita Mountains (Table 2). Troglobitic diplurans have been noted in a wide variety of caves in New Mexico and Arizona (Barr & Reddell 1967; Welbourn 1978; Northup & Welbourn 1997; C. Welbourn unpub. data).

Table 2. Comparison of the cave fauna in Kartchner Caverns with other southern Arizona cave fauna. + = indicates that the species was observed in at least one of the caves examined; ϕ = indicates that the species was not observed in any of the caves examined; a. Only *Ceuthophilus papago* Hubbell; b. Only *Ceuthophilus paucispinosus* Rehn.

	Kartchner Caverns	Whetstone Mtns	Huachuca Mtns	Santa Rita Mtns	Catalina Mtns
Number of Caves Examined	1	1	3	2	2
Elevation (m, approximate)	1566	2033	1800-2100	1733-1833	1566-1666
Class Arachnida					
Order Opiliones					
Triaenonychidae					
Sclerobunus sp. (troglophile)	ϕ	+	+	+	+
Class Malacostra					
Trichoniscidae					
Brackenridgia sp. (troglobite)	+	+	+	ϕ	ϕ
Class Insecta					
Campodeidae					
Plusiocampa sp. (troglobite)	ϕ	+	+	ϕ	+
Rhaphidophoridae					
Ceuthophilus pima (troglophile)	+	+	ϕa	+	ϕb
Carabidae					
Rhadiine sp. (troglophile)	ϕ	+	+	+	+

There are two possible explanations for the absence of these cave species from Kartchner Caverns. One is that they were present at one time, but for unknown reasons they

became extinct. Another possibility is that Kartchner Caverns was only available for colonization after climatic conditions had eliminated these species from the area around the cave. Additional information on the climatic history of the area, and more detailed study of fauna in other caves, may help to explain these differences in the cave fauna distribution.

A comparison of *Ceuthophilus* in southern Arizona with Kartchner Caverns showed *C. pima* in another cave in the Whetstone Mountains and in caves of the Santa Rita Mountains (Table 2). Hubbell (1936) reported *C. pima* from the Santa Rita and Catalina Mountains at elevations above 1633 m msl and listed *C. papago* Hubbell from the Catalina Mountains at elevations below 1633 m msl. Only *C. papago* were found in the Catalina Mountains. *Ceuthophilus pima* in Kartchner Caverns appears to be a relict population at a lower elevation than previously reported, differing from other *C. pima* populations in it's pale coloration and year round breeding. No *C. pima* were found in the canyons west of Kartchner Caverns. Caves in the Huachuca Mountains had *C. paucispinosus* Rehn. This observation and the data in table 2 suggest that while Kartchner Caverns is unique, the cave fauna in the Whetstone and Santa Rita Mountains may share other cave fauna. Additional field work is needed to determine further cave fauna relationships.

SPECIES ACCOUNTS

Phylum Nematoda

Bacterial-feeding nematodes were found in the fresh bat guano of the Big Room. These invertebrates are common inhabitants of bat guano and probably serve as prey for some of the arthropod predators, especially mites.

Phylum Arthropoda
Class Arachnida
Order Palpigrada
Family Eukoeneniidae

A single immature palpigrade specimen of this family was found in the Big Room. These arachnids are uncommon and a single specimen is insufficient to determine its status or relationship to the cave.

Order Scorpionida
Family Vaejovidae

Scorpions were in the entrance area of Kartchner Caverns on several occasions. In May 1991, a single specimen was found on a guano pile in the Big Room (Fig. 1, 9c). Another specimen was found in the Scorpion Room near Grand Central Station. These arachnids represent only accidentals and were not cave adapted.

Figure 8. Microphotograph of *Eidmannella pallida* Emerton (Araneae, Nestidae) from Kartchner Caverns.

Order Araneae
Family Nesticidae

Eidmannella pallida (Emerton) (Fig. 8) was the only species of spider regularly found in Kartchner Caverns. This troglophilic species is a pale-colored spider that makes irregular webs in cracks and under rocks in caves throughout the southwest (Welbourn 1978; Cokendolpher & Polyak 1996; C. Welbourn, unpub. data). *Eidmannella pallida* webs were found in cracks, under rocks, and on the trail flagging, and were frequently observed near the guano piles in the Big Room. *Eidmannella pallida* was rarely observed on fresh guano, but was frequently found on older guano. On one occasion, 15 *E. pallida* were found on guano pile 9c (Fig. 1) six months after the bats had migrated. Females with egg cases were observed in May and October. *Eidmannella pallida* is a predator of small arthropods and probably utilize diptera and mites as their primary prey.

The population size for *E. pallida* was difficult to estimate because observations were restricted to sites along established trails and because the population size varied from year to year. The maximum Big Room population occurred in May 1990, with an average of one spider every 8 m. Most individuals were concentrated between Sharon's Saddle (Fig. 1, 9c) and in the Lunch Spot area (Fig. 1, 20). The population was usually much lower, with only 1 spider per 17-20 m of trail.

Order Acari
Family Acaridae

Sancassania sp. (Figs. 3 & 4) was the most common mite in fresh guano with 2-17/per cm³ of guano. *Sancassania* sp. have been reported from bat guano from gypsum caves (Cokendolpher & Polyak 1996) and Carlsbad Cavern, New Mexico (C. Welbourn, unpub. data).

Family Argasidae

Engorged larvae of the soft tick, *Ornithodoros* nr. *hasei* (Schulze), were found on guano piles 9 and 10 (~10 m west of 9c in Fig. 1). The presence of only immatures suggests that these parasites were carried into the cave from other roosts and probably do not reproduce in Kartchner Caverns. Kohles *et al*. (1965) reported this species from *M. velifer* in Sinaloa, Mexico.

Family Cheyletidae

A few immature specimens of *Cheyletus* sp. were found on an old guano pile in the Big Room. These mites are predators of other mites and small arthropods.

Family Histiostomatidae

An undetermined histostomatid was found throughout the sampled guano. Populations were low and most specimens came from the fresh guano. Like *Sancassania*, histiostomatids have a heteromorphic deutonymph for dispersal or survival in unfavorable conditions. Histiostomatids are filter-feeders and occur in a wide variety of habitats outside caves (OConnor 1982).

Family Laelapidae

Geolaelaps sp. (Fig. 7) was the primary invertebrate predator in the bat guano. This mite was common in fresh bat guano where they prey upon the *Sancassania* sp., nematodes, and other small arthropods. Unlike *Sancassania* sp., *Geolaelaps* sp. does not have a non-feeding stage, but regulated its population in response to the available prey. Another species of *Geolaelaps* occurs in the bat guano at Carlsbad Cavern (C. Welbourn, unpub. data) and some gypsum caves in New Mexico (Cokendolpher & Polyak 1996).

Family Neothrombiidae

The genus *Ceuthothrombium* is unique in that the larval instar is parasitic on camel crickets (*Ceuthophilus* sp.) while the free-living deutonymphal and adult instars are predators of other mites and small arthropods (C. Welbourn, unpub. data). The larvae of *Ceuthothrombium* sp. were common around the coxae of *C. pima* all year, with 1 to 8 mites per cricket. The parasitic larvae did not appear to have any effect on the cricket host as nearly all adult *C. pima* examined in Kartchner Caverns were parasitized. The white and eyeless deutonymphs (Figs. 9 & 10) and adults are known only from laboratory rearing (Webb *et. al*. 1977; C. Welbourn, unpub. data), but probably live in the cave soil. The species from Kartchner Caverns was distinct from *C. cavaticum* Robaux, Webb & Campbell from the Guadalupe Escarpment area, New Mexico and adjacent Texas (Robaux *et. al*. 1976; C. Welbourn, unpub. data).

Family Pygmephoridae

A few undetermined pygmephorids were found in guano in the Big Room. These mites are probably fungivores.

Family Rosensteindidae

Several specimens of *Nycteriglyphus* sp. (Rosensteineidae) were found in an isolated guano pile ~30 m northwest of guano pile 20 (Fig. 1). Three *Nycteriglyphus* species have been reported from bats, and in very high populations in the guano of *Tadarida brasiliensis* (I. Geof. St.-Hilaire) and *Leptonycteris nivalis* (Saussure) in the United States

Figure 9. Scanning electron micrograph of *Ceuthothrombium* sp. (Acari, Neothrombiidae) from Kartchner Caverns.

(Strandtmann 1962; OConnor *et. al.* 1977; Dood & Rockett 1985). The specimens from Kartchner Caverns were closer to *N. texanus* OConnor, Whitaker & Easterla from *L. nivalis* guano in Big Bend National Park, Texas, than to *N. bifolium* Strandtmann from *T. brasiliensis* guano in Frio Cave, Texas (Strandtmann 1962) or Carlsbad Cavern, New Mexico (C. Welbourn, unpub. data). The origin of these mites is unknown, but they could have been carried into the cave by *M. velifer*, or any of the other bats in the area reported by Buecher & Sidner (1999). The low number of mites suggests this species may not be a permanent resident. *Nycteriglyphus* observed in other southwestern caves were in relatively dry caves (C. Welbourn, unpub. data). The relative humidity of 99.4% in the Big Room of Kartchner Caverns (Buecher 1999) may prevent *Nycgerlyphis* sp. from becoming established in the guano or competing with *Sancasssnia* sp.

Family Rhodacaridae

A few specimens of an unidentified *Rhodacarus* sp. were found in older guano piles. These predators are usually found in the soil (Farrier & Hennessy 1993).

Family Rhagididae

Observations in the Main Corridor and near the LEM Room each revealed one specimen of the predaceous mite, *Poecilophysis* sp.. Members of this family reside in many caves as well as in soil and leaf litter (C. Welbourn, unpub. data).

Family Stigmaeidae

The predator mite *Eustigmaeus* nr. *lirella* (Summers & Price) was in guano piles that receive only small amounts of fresh guano each year, but it also occurred in active guano piles in very low numbers. The number of individuals ranged from 0.06 to 0.3/ cm^3 of guano. *Eustigmaeus lirella* was described from "soil and screenings" of a woodrat (*Neotoma* sp.) nest in Tulare County, California (Summers & Price 1961). Eustigmaeids are predators in soil and litter.

Family Tarsonemidae

An undetermined *Neotarsonemoides* sp. were found in the guano of the Big Room. These mites are probably fungivores.

Order Pseudoscorpiones

Two undetermined species of pseudoscorpions were found near the cave entrance, with the deepest penetration just past the Babbitt Gate. A gravid female was observed in October 1989. These arachnids are usually found under rocks and are predators of other arthropods. Only three individuals were observed, making a population estimate impossible.

Class Chilopoda
Order Scolopendra
Family Scolopendridae

A single individual of an undetermined centipede species was observed in Grand Central Station and probably represents an accidental occurrence for Kartchner Caverns.

Class Malacostraca
Order Isopoda
Family Trichoniscidae

Figure 10. Scanning electron micrograph of *Ceuthothrombium* sp. prodorsum (Acari, Neothrombiidae) from Kartchner Caverns.

The most widespread invertebrate in Kartchner Caverns was the troglobitic isopod, *Brackenridgia* nr. *sphinxensis* Schultz (Fig. 2), observed in nearly every part of the cave except the Throne Room and upper portion of the Rotunda Room. Although individuals were not always present, their frass and evidence of feeding was observed on old wooden survey markers throughout the cave. These isopods prefer damp to wet soil and mud substrate, but were occasionally found on old bat guano. They rarely occurred on breakdown or speleothems. Nothing is known of their biology. Populations were patchy throughout the cave, with no more than 5 individuals observed at a single food source (e.g., wood debris, guano, etc.).

Family Oniscidae

A surface isopod, *Porcellio* sp. was frequently observed in the entrance area and Main Corridor of the cave. Occasionally, individuals were observed on fresh bat guano in the Big Room. These surface isopods may be able to survive in the entrance area with frequent recolonization from the surface. Only adults were observed in the Big Room guano piles, suggesting they are probably accidentals and cannot survive in the deep cave.

Class Insecta
Order Collembola
Families Sminthuridae and Entomobryidae

Collembola were uncommon and only a few individuals of the families Sminthuridae and Entomobryidae were observed. Most collembolans were found between the Babbitt Gate and Main Corridor. The smithurids were usually on the surface of small pools from the Main Corridor to the Strawberry Room.

Order Psocoptera
Family Psyllipsocidae

The psocid, *Psyllipsocus ramburii* Selys-Longchamps, is widely distributed in cave and epigean environments (Mockford 1993). This species was found from the entrance to the Big Room, where they occurred on older guano piles and other organic material. The population levels were low with only 1-2 individuals observed at any site.

Order Thysanura
Family Nicoletiidae
Only three individuals of this rare bristletail, *Nicoletia* sp., were observed near the entrance to the Red River Passage. The genus is known from caves in Texas and this is the second record of this genus from an Arizona cave. Nothing is known of the biology and population density of this species in Kartchner Caverns.

Order Orthoptera
Family Rhaphidophoridae
The camel cricket, *C. pima*, was common from the entrance area to the Main Corridor. While concentrated near the entrance, crickets were frequently found in the Big Room, mostly on or near fresh guano deposits. Like other species in the genus, these crickets usually leave the cave to feed, but were observed feeding on carrion or bat guano in the cave. The Kartchner population may represent a distinct subspecies, but additional comparative study is needed to determine the status of this population (T. Cohn, pers. comm.). Counts between the entrance and Main Corridor ranged from 300 to 800 individuals, with the peak population occurring in mid to late summer. Occasionally, lost individuals (usually dead) were found in various parts of the cave, but only those areas with direct connection to the surface support cricket populations.

A second and probably small population of *C. pima* was found in the Granite Dells area of the cave, suggesting a direct opening to the surface in that area. However, no marked crickets were found in the Granite Dells area. The large number of crickets from the surface cracks and low numbers (3-12) in the Granite Dells area suggests there are additional voids between Granite Dells and the surface that can support a cricket population. *Ceuthophilus pima* was also found in two small caves on the north side of the hill from the Kartchner Caverns' entrance.

Egg deposition was observed in soft soil in the entrance area as far in as the LEM Room and into the sides of an abandoned stream passage in Grand Central Station. In the Granite Dells area, there is also a small area of soft soil that may be an egg deposition site. It is likely there are other inaccessible areas between Granite Dells and the surface that serve as cricket breeding areas.

Order Hemiptera
Hemipteran (Reduviidae) were found in several widely separated areas in 1990. They were considered accidental and not part of the regular cave fauna.

Order Coleoptera
Family Staphylinidae
An undetermined beetle was observed in the Big Room near guano pile 9 (Fig. 1).

Family Tenebrionidae
Undetermined beetle fragments were in the Tarantula Room and an *Eleodes* sp. was in the entrance area.

Order Lepidoptera
Three undetermined moths were observed. Two were near the entrance and the third was in the Granite Dells area. The moth in Granite Dells adds additional support to the possibility of a direct connection to the surface in that area.

Order Diptera
Family Sciaridae
Flies are common in the Big Room, frequently attracted to cavers' lights. These flies appeared to breed in the fresh guano where diptera larvae were found between May and August. Adult flies were the most common in the Big Room between Sharon's Saddle (Fig. 1, #9c) and Kartchner Towers (Fig. 1, near #20). Undetermined fly larvae were also found in a dead cave cricket in Grand Central Station.

Order Hymenoptera
Family Formicidae
Ants were not observed in the cave during this study, but what looked like ant trails were noted in mud areas near the entrance and along the first part of the Red River Passage. It was not possible to determine how long it had been since the ants were active in the cave, but some trails traversed footprints made during the exploration and/or mapping of the cave.

CONCLUSIONS

Thirty-eight invertebrate species were recorded during the study of Kartchner Caverns including 4 (11%) troglobites, 19 (50%) troglophiles, 1 trogloxene and 12 (32%) accidentals. Of the remaining species, one was an obligate parasite and the other a guanophile. Most of the cave fauna depend upon guano deposited by a summer colony of *Myotis velifer*. Mites were the most numerous arthropods found in Kartchner Caverns, with at least 14 species restricted to the annual guano cycle. Preliminary comparison of the Kartchner Caverns fauna with other caves in southern Arizona shows Kartchner to be unique.

ACKNOWLEDGMENTS

I would like to thank Bob and Debbie Buecher for their support and assistance during this project. Most of the guano samples were collected and processed in the Berlese-funnel by Debbie Buecher. Thanks also to Theodore Cohn for assistance with *Ceuthophilus* systematics. Funding for this research was provided by the Arizona State Parks Department through a contract with Arizona Conservation Projects, Inc.

REFERENCES

Barr, T.C. & Reddell, J.R. (1967). The arthropod fauna of the Carlsbad Caverns region, New Mexico. *Southwestern Naturalist 12(3)*: 253-274.

Briggs, T.S. (1971). The harvestmen of family Triaenonychidae in North America (Opiliones). *Occasional Papers of the California Academy of Sciences 90*: 1-43.

Buecher, R. H. (1999). Microclimate study of Kartchner Caverns, Arizona. *Journal of Cave and Karst Studies 61(2)*: 108-120.

Buecher, D.C. & Sidner, R.M. (1999). Bats of Kartchner Caverns State Park, Arizona. *Journal of Cave and Karst Studies 61(2)*: 102-107.

Cokendolpher, J.A. & Polyak, V.J. (1996). Biology of the caves at Sinkhole Flat, Eddy County, New Mexico. *Journal of Cave and Karst Studies 58(3)*: 181-192.

Dood, S.B. & Rockett, C.L. (1985). *Nycteriglyphus* fuscus (Acari: Rosensteinidae), a new species associated with big brown bats in Ohio. *International Journal of Acarology 11(1)*: 31-35.

Dorst, C.A. & Blinn, D.W. (1997). Invertebrate community of Roaring Springs Cave, Grand Canyon National Park, Arizona. *Southwestern Naturalist 42(4)*: 497-500.

Evans, G.O. (1992). *Principles of Acarology*. CAB International, Wallingford, UK: 563 pp

Farrier, M.H. & Hennessy, M.K. (1993). Soil-inhabiting and free-living Mesostigmata (Acari-Parasitiformes from North America. *North Carolina Agricultural Research Service Technical Bulletin 302*: 1-408.

Hubbell, T.H. (1936). Revision of the genus *Ceuthophilus*. *University of Florida Biological Science Series 2(1)*: 1-551.

Hughes, A.M. (1976). The mites of stored food and houses. *Ministry of Agriculture, Fisheries and Food Technical Bulletin 9*: 400 pp.

Jagnow, D.H. (1999). Geology of Kartchner Caverns, Arizona. *Journal of Cave and Karst Studies 61(2)*: 49-58.

Kohles, G.M., Sonenshine, D.E. & Clifford, C.M. (1965). The systematics of the subfamily Ornithodorinae (Acarina: Argasidae). II. Identification of the larvae of the Western Hemisphere and descriptions of three new species. *Annals of the Entomological Society of America 58(3)*: 331-364.

Mockford, E.L. (1993). North American Poscoptera (Insecta). *Flora & Fauna Handbook No*. 10, Sandhill Crane Press, Inc., Gainesville: xviii+455 pp.

Muchmore, W.B. (1981). Cavernicolous species of *Larca*, *Archeolarca*, and *Peudogarypus* with notes on the genera (Pseudoscorpionida, Garypidae and Pseudogarypidae). *Journal of Arachnology 9*: 47-60.

Muchmore, W.B. (1997). *Tuberochernes*, (Pseudoscorpionida, Chernetidae) a new genus with species in caves in California and Arizona. *Journal of Arachnology 25*: 206-212.

Northup, D.E., Carr, D.L., Crocker, M.T., Cunningham, K.I., Hawkins, L.K., Leonard, P. & Welbourn, W.C. (1995). Invertebrates and microorganisms of Lechuguilla Cave, Carlsbad Caverns National Park, New Mexico. *National Speleological Society Bulletin 56*: 54-63.

Northup, D. & Welbourn, W.C.. (1997). Life in the twilight zone-Lava-tube ecology. In Maybery, K. (comp.) *Natural History of El Malpais National Monument New Mexico, Bureau of Mines and Mineral Resources Bulletin 156*: 69-81.

OConnor, B.M. (1982). Astigmata. In Parker, S.B. (ed.). *Synopsis and classification of living organisms, Volume 2*. McGraw-Hill, New York: 1232 pp.

OConnor, B.M, Whitaker, J.O. & Easterla, D.A. (1977). A new species of *Nycteriglyphus* (Acari: Rosensteinidae) from guano of *Leptonycteris nivalis* (Chiroptera: Phyllostomatidae). *Annals of the Entomological Society of America 70(2)*: 237-241.

Peck, S.B. (1980). Climatic changes and the evolution of cave invertebrates in the Grand Canyon, Arizona. *National Speleological Society Bulletin 42*: 53-60.

Peck, S.B. (1982). Invertebrate faunas and zoogeographic significance of lava tube caves of Arizona and New Mexico. *Great Basin Naturalist 42(3)*: 405-412.

Robaux, P., Webb Jr, J.P. & Campbell, G.D. (1976). Une forme larvaire nouvelle de Thrombidiidae (Acari) parasite sue plesieurs especies d'orthopteres cavernicoles du genre *Ceuthophilus* (Orthoptera-Rhaphidophoridae). *Annales de Speleologie 31*: 213-218.

Schultz, G.A. (1984). *Brackenridgia sphinxensis* n. sp. from a cave with notes on other species from Arizona and California (Isopoda, Oniscoidea). *Southwestern Naturalist 29(3)*: 309-319.

Strandtmann, R.W. (1962). *Nycteriglyphus bifolium* n. sp., A new cavernicolous mite associated with bats (Chiroptera)(Acarina: Glycyphagidae). *Acarologia 9(4)*: 623-631.

Summers, F.M. & Price, D.W. (1961). New and redescribed species of *Ledermuelleria* from North America (Acarina: Stigmaeidae). *Hilgardia 31(10)*: 369-387.

Tufts, R. & Tenen, G. (1999). Discovery and history of Kartchner Caverns, Arizona. *Journal of Cave and Karst Studies 61(2)*: 44-48.

Webb Jr., J.P., Robaux, P. & Campbell, G.D. (1977). Notes on the biology of *Ceuthothrombium cavaticum* (Acari: Trombidiidae), a parasite of cave crickets (Raphidophoridae: *Ceuthophilus*). *Southern California Academy of Sciences Bulletin 76(2)*: 135-137.

Welbourn, W.C. (1978). Biology of Ogle Cave with list of cave fauna of Slaughter Canyon. *National Speleological Society Bulletin 40*: 27-34.

Welbourn, W.C. (1979). Invertebrate fauna of the earth cracks of Wupatki National Monument, Arizona. In Linn, E.M. (ed.) *Proceedings of the First Conference on Scientific Research in the National Parks, New Orleans, LA, November 9-12, 1976*. Vol. 1. National Park Service Transactions & Proceedings Serial No. 5: 387-391.