2011 Belize Biospeleology Expedition Report

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Summary

We report on preliminary findings from the first biospeleological expedition undertaken between 6 and 19 April 2011 in caves of the Toledo District, southern Belize. Also included is a review of the present state of knowledge of subterranean invertebrates in Belize, with no prior data being available for the Toledo District.

During the April 2011 expedition, we sampled more than 1,150 invertebrates, representing more than 80 unique taxa, recorded from 7 caves in the Toledo District of Belize. This material includes a number of species already determined to be new to science, including various arachnids, crustaceans, and insects.

The findings of this study form the beginnings of a foundation for future work, which can help inform decision-making regarding cave resources. Caves in Belize are an important socioeconomic resource – they support ecotourism, harbor unique archeological resources. In serving as conduits for water, organic materials, and contaminants, these caves also play important roles within the landscape. The data from the present study, and future biospeleological work will provide land managers and agency personnel with better knowledge of important cave resources in Belize.

Table of Contents

List of Tables

List of Figures

2011 Belize Biospeleology Expedition Report

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Introduction

Previous studies of the cave fauna of Belize have focused on the fauna of the Cayo District, summarized by Reddell (1981). In subsequent years, a number of new species descriptions have come out of this work in the Cayo District, and variety of troglobites (i.e. cave-adapted or obligate subterranean species) are now known, including a troglobitic crab, troglobitic psuedoscorpions, spiders, opilionids, and other taxa (Table 1).

We report on preliminary findings from the first biospeleological expedition focusing on the understudied Toledo District, in southern Belize, undertaken between 6 and 19 April, 2011, and building on previous exploratory and mapping trips by Tom Miller and associates, Trekforce (UK), the South Wales Caving Club, and others.

Our sampling of seven caves and three wells in the Toledo District has yielded a number of probable undescribed species of troglobites, including a polydesmid milliped, a pseudoscorpion, a philosciid isopod, a phalangodid harvestman, entomobryiid springtails, a schizomid, a campodeid dipluran, a rhagidiid mite, and spiders. Other organisms recorded include rhaphidophorid crickets, troglomorphic gryllid crickets, amblypigids, chernetid pseudoscorpions, pselaphid beetles, and scutigeromorph centipedes. Though further analysis is needed, it is also likely that other material collected represents range extensions for known species. No cave-limited organisms were collected from aquatic habitats. These new discoveries from the Toledo District are compared to the known cave fauna of the Cayo District of Belize.

Table 1. Cavernicoles previously recorded from Belize.

Phylum:Class Order Family Species	Source	District	Adp[1]
Arthropoda:Crustacea			
Decapoda			
Pseudothelphusidae			
Typhlopseudothelphusa acanthochela Hobbs 1986	Hobbs 1986	Cayo	TB
Potamocarcinus aspoekorum (Pretzmann 1968)	Rodríguez & Hobbs 1989	Cayo	TP
Palaemonidae			
Macrobrachium catonium Hobbs & Hobbs 1995	Hobbs & Hobbs 1995	Cayo	TB
Isopoda			
Cirolanidae			
Haptolana belizana Botosaneanu & Iliffe 1997	Botosaneau & Iliffe 1997	Cayo	TB
Philosciidae			
Troglophiloscia belizensis Schultz 1984	Schultz 1984	Cayo	TB
Platyarthridae			
Spherarmadillo schwarzi Richardson 1907	Schultz 1984	Cayo	TP
Sphaeroniscidae			
Trichorhina squamapleotelsoma Schultz 1984	Schultz 1984	Cayo	TP
Arthropoda:Arachnida			
Pseudoscorpionides			
Bochicidae			
Mexobisium goodnighti Muchmore 1973	Muchmore 1973b, 1977, 1980; Reddell 1981;	Cayo	TB
Mexobisium venii Muchmore 1998	Muchmore 1998	Cayo	TB
Vachoniidae			
Vachonium belizense Muchmore 1973	Muchmore 1973a, 1977; Reddell 1981; Harvey 1990	Cayo	TB

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Table 1. Continued.

Phylum:Class Order Family Species	Source	District	Adp[1]
Schizomida			
Shizomidae			
Schizomus sp. (undescribed)	Rowland 1975, Rowland & Reddell 1977, Reddell 1981	Cayo	TB
Schizomus portoricensis (Chamberlin 1922)	Rowland & Reddell 1977	Cayo	EP
Ricinulei			
Ricinoididae			
Pseudocellus krejcae Cokendolpher & Enriquez 2004	Cokendolpher & Enriquez 2004	Cayo	TB
Amblypygida			
Charontidae			
Undescribed	Reddell 1981	Cayo	TB
Phrynidae			
Paraphrynus raptator (Pocock)	Mullinex 1975, Reddell 1981	?	TP
Araneae			
Mysmenidae			
Maymena mayana (Chamberlin & Ivie)	Reddell 1981	?	TB?
Oonopidae			
Triaeris patellaris Bryant	Reddell 1981	?	TP
Oonops coecus (Chamberlin & Ivey)	Chamberlin & Ivie 1938b, Gertsch 1977b, Reddell 1977b, Reddell 1981	?	TB
Pholcidae			
Metagonia jarmila Gertsch 1973	Gertsch 1973b, Reddell 1981	Cayo	TB
Metagonia belize Gertsch 1986	Gertsch 1986	Cayo	TP
Metagonia cara Gertsch 1986	Gertsch 1986	Cayo	TP
Scytodidae			
Loxosceles yucatana Chamberlin & Ivie	Reddell 1981	Cayo	TP

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Table 1. Continued.

Phylum:Class Order Family Species	Source	District	Adp[1]
Opiliones			
Cosmetidae			
Erginulus serratipes (Cambridge)	Reddell 1981	Cayo	TP
Phalangodidae			
Cynortina misteca Goodnight & Goodnight 1977	Goodnight & Goodnight 1977, Reddell 1981	Cayo	TB
Stygommo pecki Goodnight & Goodnight 1977	Goodnight & Goodnight 1977, Reddell 1981	Cayo	TB
Arthropoda:Diplopoda			
Julida			
Pyrgodesmidae			
Myrmecodesmus brevis Shear 1977	Shear 1977a, Reddell 1981	Cayo	TP?
Myrmecodesmus unicorn Shear 1977	Shear 1977a, Reddell 1981	Cayo	TP
Rettenmeyeria cryptymoides Shear 1977	Shear 1977a, Reddell 1981	Cayo	TP?
Spirostreptida			
Cambalidae			
Jarmilka alba Shear 1973	Shear 1973, Reddell 1981	Cayo	TB?
Platydesmida			
Platydesmidae			
Undetermined genus	Reddell 1981	Cayo	AC
Arthropoda:Hexapoda			
Orthoptera			
Gryllidae			
Mayagryllus apterus Desutter-Grandcolas & Hubbell 1993	Desutter-Grandcolas 1993, Reddell 1981	Cayo	TP
Heteroptera			
Reduviidae			
Triatoma dimidiata (Latrielle)	Reddell 1981	Cayo	TP

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Table 1. Concluded.

Phylum:Class Order Family Species	Source	District	Adp[1]
Coleoptera			
Leiodidae			
Dissochaetus hetschkoi Reitter 1884	Peck 1973, Reddell 1981	Cayo	TP
Ptomaphagus (*Adelops*) *barbarae* Peck	Peck 1973, Reddell 1981	Cayo	TP
Diptera			
Psychodidae			
Brumptomyia spp.	Williams 1976a, b,c; Reddell 1981	Cayo	AC
Lutzomyia beltrani (Vargas & Díaz Nájera)	Williams 1976a, b,c; Reddell 1981	Cayo	TP?
Lutzomyia deleoni (Fairchild & Hertig)	Williams 1976a, b,c; Reddell 1981	Cayo	TP?
Lutzomyia trinidadensis (Newstead)	Williams 1976a, b,c; Reddell 1981	Cayo	TP?
Lutzomyia shannoni (Dyar)	Williams 1976a, b,c; Reddell 1981	Cayo	TP?
Lutzomyia spp.	Williams 1976a, b,c; Reddell 1981	Cayo	AC
Vertebrata: Pisces			
Siluriformes			
Pimelodidae			
Rhamdia laticauda typhla	Greenfield et al. 1982	Cayo	TB?

[1]Adp = Adaptation relative to the subterranean environment: AC=accidental, EP=epigean, TP=troglophile, TB=troglobite

History of Biospeleological Studies in Belize

Beginning relatively recently with the efforts of Stewart Peck in 1972 (Peck 1974), there have been many speleological expeditions to Belize (Williams 1996). Most of these expeditions have focused on cave mapping, and relatively few biospeleological investigations have been focused on this country (Reddell 1981, Reddell & Veni 1996, Wynne & Pleytez 2005). The biospeleological work up to now has focused on the Cayo District, with no efforts in the Toledo District. With improved access and the completion of much work in locating and mapping many area caves, there are now opportunities for studies of the biotic communities of Toledo District caves, their structure and function, and interactions with land use practices, as well as the description of new species.

A variety of specialists have described new species from caves in Belize (Table 1). But again, these have been almost exclusively recorded from caves of the Cayo District.

Tropical Cave Biology

Howarth (2003) notes that spiders are often dominant predators in tropical caves, whereas ground beetles are more commonly top predators in temperate caves. Golvatch & Klime (2009) note several examples of tropical faunas rich in millpeds (Diplopoda). Minor arachnid groups such as ricinuleids and schizomids are much more frequently commonly encountered in tropical than in temperate caves.

Socioeconomic Context

Caves play an important role in the growing ecotourism business in southern Belize. Some better known caves in the Toledo District, such as Blue Creek Cave, are visited by tourists, who are often accompanied by a local guide (Figure 1). Upon returning to their vehicles after the cave trip, the tourists commonly are greeted by women and children selling baskets and other local goods spread out next to the trail. Associated services such as restaurants, stores, and hotels also profit from these visits. Thus, the ecotourism associated with caves is an important and growing source of income for the local communities. Training of guides on safe caving practices, cave conservation, protection of archeological resources, and interpretation of biological resources is needed to better sustain and improve the opportunities for ecotourism in southern Belize.

Figure 1. A local guide (left) leads us to Tiger Cave. The entrance to Bat Cave is visible in the background. Payment to local guides injects resources directly into the communities most affected by outside visitors. Photo © Geoff Hoese/SEI.

Goals & Scope

Our study has several goals that we have begun to accomplish through our April 2011 fieldwork:

- Identify study areas suited to cave ecology research
- Identify potential in-country collaborators, contacts, and bases of operation
- Preliminary documentation and assessment of biodiversity in select Belizean caves
- Collect data suitable for publication in peer reviewed journals
- Publish popular articles achieving outreach and education objectives related to subterranean ecology

Materials and Methods

Study Area

We have focused all of our efforts on the Toledo District, in the far south of Belize (Figure 2). Nearly all of the previous cave biology research in Belize has focused on the more accessible caves of the Cayo District.

Figure 2. Map of Belize, showing Districts. Our study took place in the general vicinity of the communities of Big Fall and San Antonio, in the far south.

Field Methods

Terrestrial collections were made by hand, with a paintbrush, or with an aspirator (Figure 3). In some cases, leaf litter was brought back to our base of operations in the field, where invertebrates were extracted using Berlese funnels (Figure 4). At the same time that field collections were being made, detailed notes were taken on specimen identities and microhabitats (Figure 5). Material was collected into ethanol, ~70%, and shipped to the laboratory in Illinois, USA for later sorting, curation, and preliminary

identification. Select biological material from this study is being examined by taxonomic specialists. Further identification and species description is a protracted process that will take place gradually over several years.

Aquatic collections were made using small dip nets and eyedroppers for arthropods from isolated pools, and larger nets used to obtain shrimp and catfish from larger pools while wading or snorkeling. No scuba surveys were undertaken. We attempted baiting for aquatic species using raw shrimp in submerged funnel traps both in Tiger Cave and in water wells, however no fauna were obtained by these methods.

Figure 3. Researcher using an aspirator to collect springtails (Collembola). Photo © Geoff Hoese/SEI.

Figure 4. Portable Berlese funnels were used to extract small invertebrates from leaf litter samples taken near cave entrances. Photo © Geoff Hoese/SEI.

Figure 5. Fieldwork being conducted in one of the Toledo District (Belize) caves in which we inventoried invertebrates. Photo © Mike Slay/SEI.

Permits

Appropriate permits were secured from Institute of Archaeology, Archaeology Museum & Research Centre (Culvert Road, Belmopan City, Belize C.A.) and Forest Department (Ministry of Natural Resources and the Environment, Forest Drive, Belmopan City, Belize C.A.). In addition, we worked closely with a customs broker in Belize and US Fish & Wildlife Service personnel to complete appropriate paperwork to get material legally into the United States. Requests for specific cave locations from the present study should be directed to the Belize Institute of Archeology.

Results & Discussion

Study Sites

Our study area is located in the Toledo District. In 2011 we focused on caves in the general vicinity of San Antonio and Big Fall (Figure 2).

Bat Cave

This is modest sized cave (Figure 6) almost directly across the stream from Tiger Cave. Most of our sampling here was in the deep twilight zone (Figure 7). The cave apparently harbors a colony of bats in a wet side passage, but we chose not to explore that passage at this time.

Blue Creek Cave

This cave is one of the larger, better known caves of the Toledo District. The impressive resurgence entrance (Figure 8) is commonly visited by tourists, often accompanied by guides. In addition to sampling via this entrance, we also visited an upper entrance to the same cave, called Hokeb Ha.

cave near Pueblo Creek Cave

We had intended to visit Pueblo Creek Cave but the available guide was unfamiliar with the exact location of the cave. While exploring the area looking for the entrance, we located this cave, which contained habitat suitable for collecting.

Okebal Ha

This cave has a large entrance and large skylights. Much of the passage appears to flood extensively during the rainy season, and this made many parts of the cave unsuited for some troglobitic species. Nonetheless, some interesting material was found.

Small cave near Okebal Ha

We found this small, dry cave on the hike back from Okebal Ha. Essentially a tube (Figure 9), it has two entrances, one at each end, allowing airflow that tends to make the passage rather dry.

Tiger Cave

This cave is large (Figure 10), easily accessible, and relatively visitor-friendly. The large passage has several skylights (Figure 11).

Yok Balum

This cave, also known a Jaguar Paw due to the formation in the cave entrance, had a rich fauna of troglobites. The cave is perched well above the valley floor.

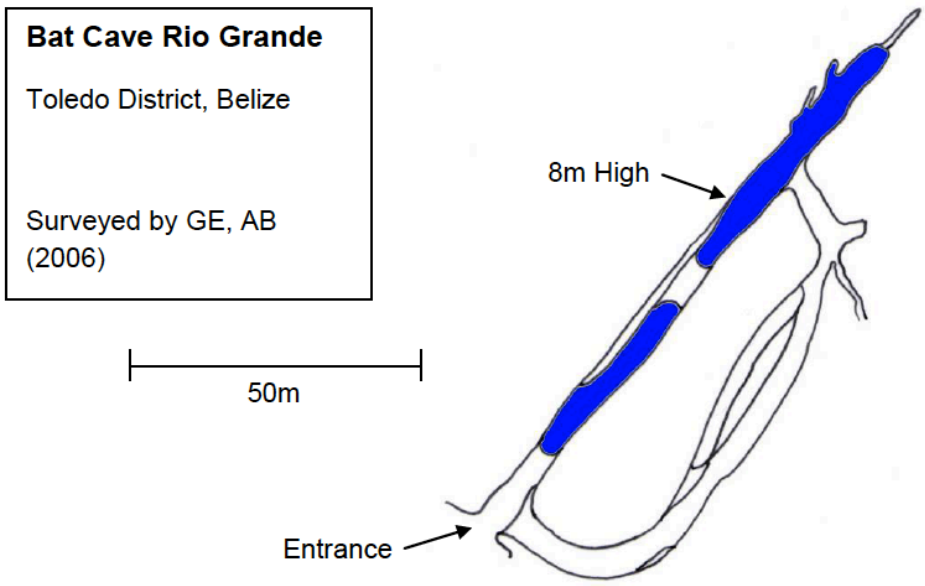

Figure 6. Map of Bat Cave, from a South Wales Caving Club report (SWCC 2006) and website (http://swccbelizecaving.co.uk/).

Figure 7. Researchers recording data and sampling in Bat Cave, with entrance in background. Photo © Mike Slay/SEI.

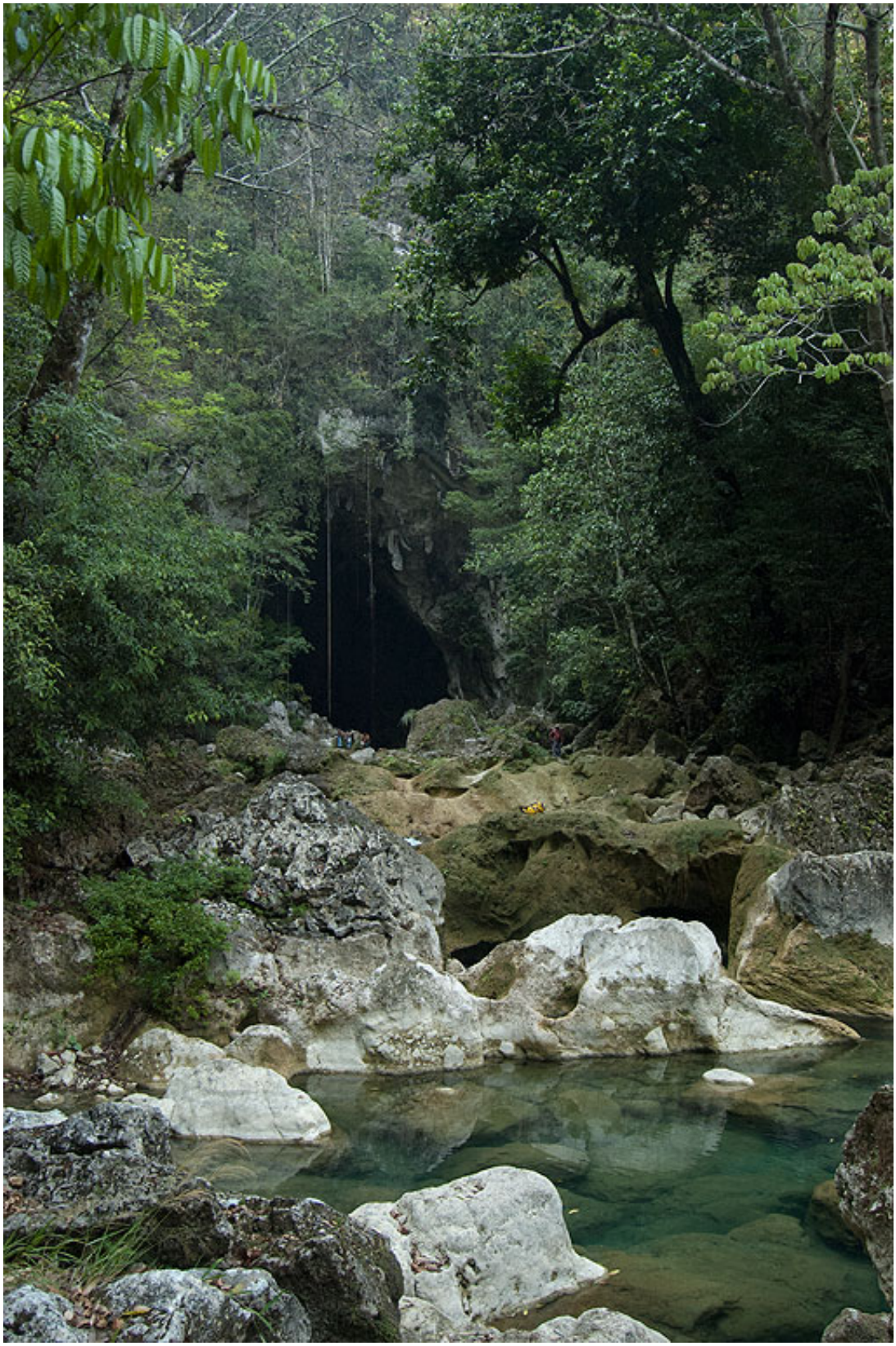

Figure 8. Resurgence entrance of Blue Creek Cave (Toledo District, Belize). Note the people standing in the entrance. Photo © Geoff Hoese/SEI.

Figure 9. Typical passage in the small cave near Okebal Ha (Toldedo District, Belize). Photo © Geoff Hoese/SEI.

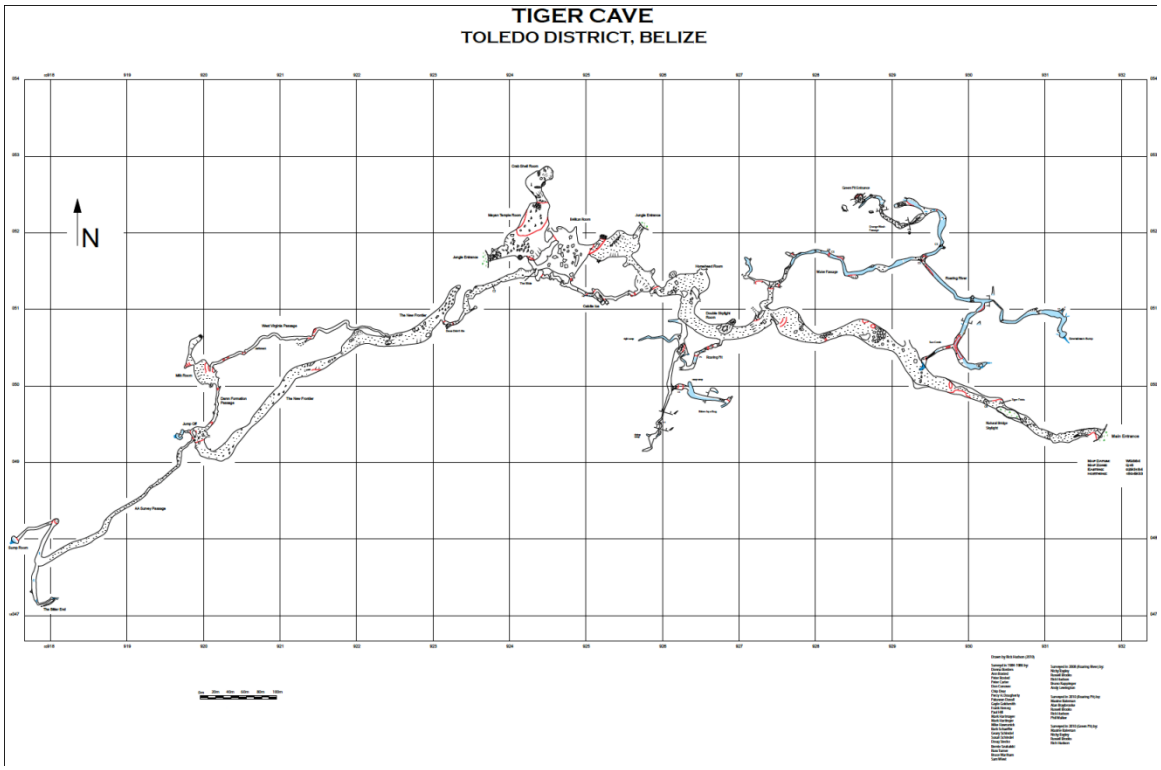

Figure 10. Tiger Cave (Toledo District, Belize). Map by South Wales Caving Club. Length of scale bar is 100 meters. Full map can be found in Walker and Braybrooke (2010), and links on their web pages (http://www.swccbelizecaving.co.uk/).

Figure 11. One of the large skylights in Tiger Cave (Toledo District, Belize). Photo © Christy Slay/SEI.

Cave Biota

More than 1,150 individuals, representing more than 80 unique taxa (Table 2), were recorded from 7 caves in the Toledo District of Belize. Some records are only sight records, but much of the material listed above was collected and is currently being examined by taxonomic experts. We anticipate that, over the next several years, several new species will be described from this material. In the following sections, we review many of the more interesting taxa recorded from the caves, providing tabular data on specimens at their present level of identification.

Phylum Platyhelminthes: Class Turbellaria

Flatworms (Turbellaria) were recorded only from the cave near Pueblo Creek Cave (Table 3). Due to the difficulties in preserving flatworms in a manner that allows species-level identification, it is unlikely that this material will be further identified.

Phylum Annelida: Class Oligochaeta

Aquatic oligochaetes of the family Tubificidae were collected from Tiger Cave (Table 4). Generic identification is pending examination by a taxonomic specialist.

Table 2. Summary of number of taxa and number of specimens recorded from caves in the Toledo District (Belize) during the April 2011 biospeleological expedition.

Cave	Taxa	Specimens
Bat Cave	15	118
Blue Creek Cave	40	294
cave near Pueblo Creek Cave	22	99
Okebal Ha	33	142
small cave near Okebal Ha	13	37
Tiger Cave	37	252
Yok Balum	27	212

Table 3. Turbellaria recorded from caves in the Toledo District (Belize) during the April 2011 biospeleological expedition.

Order	Family	Taxon	Bat Cave	Blue Creek Cave	Cave near Pueblo Creek Cave	Okebal Ha	Small cave near Okebal Ha	Tiger Cave	Yok Balum
Tricladida	Undetermined				9				

Table 4. Oligochaeta recorded from caves in the Toledo District (Belize) during the April 2011 biospeleological expedition.

Order	**Family**	**Taxon**	**Bat Cave**	**Blue Creek Cave**	**Cave near Pueblo Creek Cave**	**Okebal Ha**	**Small cave near Okebal Ha**	**Tiger Cave**	**Yok Balum**
Haplotaxida	Tubificidae	Undetermined						4	

Phylum Mollusca: Class Gastropoda

Snails (Gastropoda) were abundant in the stream resurging from the main entrance to Blue Creek Cave (Table 5), and some of the other snail collections represent terrestrial species, typically found in leaf litter of cave entrances.

Phylum Arthropoda: Class Crustacea

The Crustacea (Table 6) includes several interesting taxa, including shrimp (*Macrobrachium* sp.), probably accidental in the cave, and possibly two species of Philosciid ispods (Figure 12), which show signs of cave adaptation.

Phylum Arthropoda: Class Arachnida

Arachnids comprise one of the most diverse classes of organisms in caves of southern Belize. Eight orders of Arachnida were recorded from our collections (Table 7).

Order Amblypygi

The most evident arachnids in southern Belize caves are the Amblypygids, or tailless whip scorpions. These large, leggy arachnids are easy to find, commonly lingering on bedrock walls, especially in the entrance and twilight zones of the caves. Reddell (1981, p. 130, Fig. 24) lists *Paraphrynus raptator* (Pocock) as occurring in Belize, while Wynne and Pleytez (2005) report "*Paraphrynus* sp. or *Paraphrynus raptator*" from Actun Chapat (Cayo District). Our material includes *Paraphrynus* sp. (Figure 13), possibly undescribed, which is more closely related to *Paraphrynus williamsi* Mullinex 1975, a species described from a cave in Chiapas (Mullinex 1975).

Order Araneae

Spiders (Araneae) (Figure 14) are well represented in caves of the Toledo District by a variety of families, several of which likely contain cave-adapted species. Our material includes as new species of *Tarsonops* (Caponiidae), presently being described as new by authors Bond & Taylor. A trap door spider (*Ummidia* sp., Ctenzidae) was recorded from burrows in Tiger Cave (Figure 15), but no adult, necessary for species level identification, was secured. Several other spiders of interest include *Scytodes* sp. (Scytodidae) from several caves, and several Linyphiidae that may include undescribed material, presently being examined by Bond & Taylor.

Table 5. Gastropoda recorded from caves in the Toledo District (Belize) during the April 2011 biospeleological expedition.

Order	Family	Taxon	Bat Cave	Blue Creek Cave	Cave near Pueblo Creek Cave	Okebal Ha	Small cave near Okebal Ha	Tiger Cave	Yok Balum
Undetermined				11		16	1	11	

Figure 12. A cave-adapted philosciid isopod, possibly *Troglophiloscia* sp., from a cave in the Toledo District, Belize. Photo © Steve Taylor/SEI.

Table 6. Crustacea recorded from caves in the Toledo District (Belize) during the April 2011 biospeleological expedition.

Order	Family	Taxon	Bat Cave	Blue Creek Cave	Cave near Pueblo Creek Cave	Okebal Ha	Small cave near Okebal Ha	Tiger Cave	Yok Balum
Undetermined				4					
Decapoda	Palaemonidae	*Macrobrachium* sp.		6					
Isopoda	Undetermined							1	
	Armadillidiidae	Undetermined						3	
	Philosciidae	Undetermined		5	12	6	2	36	41
Ostracoda	Undetermined	Undetermined	21						

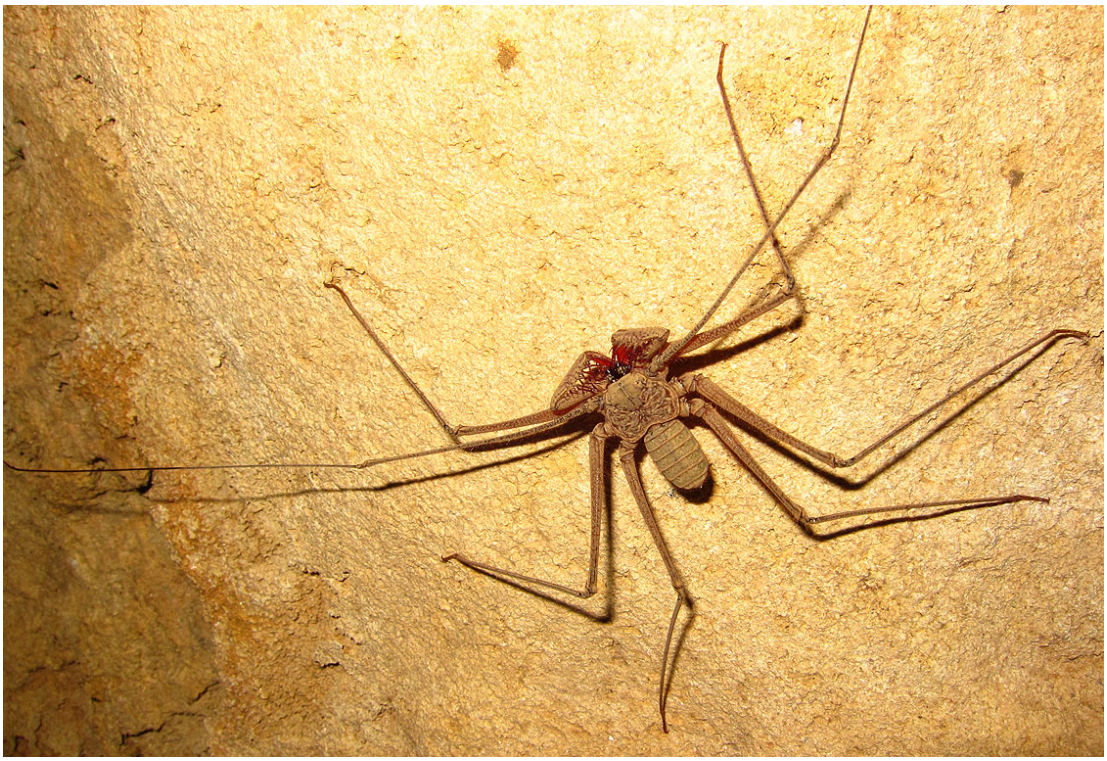

Figure 13. An Amblypygid in a Belizean cave, probably *Paraphrynus* sp. Photo © Jean Krejca/SEI.

Figure 14. A troglomorphic spider from a cave in the Toledo District, Belize. Photo © Jean Krejca/SEI.

A.

B.

Figure 15. A trap door spider (*Ummidia* sp., Ctenzidae) from Tiger Cave (Toledo District, Belize). A. Burrow with door. B. Immature spider. Photos © Jean Krejca/SEI.

Order Opiliones

Harvestmen (Opiliones) are represented in the caves of the Toledo District by some accidental surface forms, as well as two species in the family Phalangodidae, one of which is troglomorphic with markedly reduced eyes (Figure 16). It is likely a new species. Phalangodids of the genera *Cynortina* and *Stygomma* are known from caves of the Cayo District (Reddell 1981).

Order Pseudoscorpiones

Pseudoscorpions were recorded from several caves, and include pale, probably cave adapted forms (Figure 17) perhaps of the family Vachoniidae, as well as, near the cave entrances, members of the family Chernetidae.

Order Schizomida

The Schizomida were represented by a clearly troglomorphic *Schizomus* species (Figure 18), which we anticipate is undescribed. Reddell (1981) and Rowland and Reddell (1977) report an undescribed troglomorphic *Shizomus* from the Cayo District.

Figure 16. A cave adapted harvestman (Opiliones: Phalangodidae) from a cave in the Toledo District, Belize. Photo © Steve Taylor/SEI.

Figure 17. A cave-adapted pseudoscorpion, possibly *Vachonium* sp., from a cave in the Toledo District, Belize. Photo © Steve Taylor/SEI.

Figure 18. An eyeless, cave-adapted *Schizomus* sp. (Schizomida: Schizomidae) from a cave in the Toledo District of Belize. Photo © Steve Taylor/SEI.

Order Scorpiones

Several scorpions were encountered in the caves (Figure 19). These represent at least two species and likely are accidentals, as they exhibit no obvious characteristics associated with cave adaptation.

Phylum Arthropoda: Class Chilopoda

Centipedes (Chilopoda) were rather infrequently encountered (Table 8), but material represents at least three orders. None showed any obvious signs of troglomorphy.

Phylum Arthropoda: Class Diplopoda

Millipeds were not uncommon in the caves (Table 9), and large, white polydesmidan millipeds of the family Chelodesmidae were among the most visually obvious (Figure 20) of the cave-adapted species in the caves of the Toledo District. At least two species in this family were collected, and they are very similar in appearance. Several of the millipeds are new, and are in the process of being described by authors Bond & Taylor.

Figure 19. A scorpion from on of the Toledo District (Belize) cavs, probably an accidental in this environment. Photo © Geoff Hoese/SEI.

Table 7. Arachnida recorded from caves in the Toledo Districct (Belize) during the April 2011 biospeleological expedition.

Order	Family	Taxon	Bat Cave	Blue Creek Cave	Cave near Pueblo Creek Cave	Okebal Ha	Small cave near Okebal Ha	Tiger Cave	Yok Balum
Acari	Undetermined		9	106	4	4		10	1
	Rhagidiidae	Undetermined	8	1					
Amblypygi	Phrynidae	*Paraphrynus* sp.		2	4	2	1	6	
Araneae	Caponiidae	*Tarsonops* n. sp.			1				
	Ctenizidae	*Ummidia* sp.						1	
	Linyphiidae	Species 1		3	7	1			25
	Linyphiidae	Species 2				1			
	Lycosidae	Undetermined						3	
	Pholcidae	Species 1			7	1	4		
	Salticidae	Undetermined		1		1			
	Scytodidae	*Scytodes* sp.	3	2		4		1	
	Sicariidae	Species		3	6				7
	Theridiidae	Species		2	3				
	Theridiosomatidae?	Undtermined	1						
	Undetermined			6	12	6		10	3
Ixodida	Ixodidae	Undetermined				4			1
Opiliones	Undetermined		3	11		1	3	17	1
Pseudoscorpiones	Undetermined			11	3	5	1		4
	Chernetidae	Undetermined							11
Schizomida	Schizomidae	*Schizomus* sp.		6	4	3			2
Scorpiones	Undetermined				1	1		2	

Table 8. Chilopoda recorded from caves in the Toledo District (Belize) during the April 2011 biospeleological expedition.

Order	Family	Taxon	Bat Cave	Blue Creek Cave	Cave near Pueblo Creek Cave	Okebal Ha	Small cave near Okebal Ha	Tiger Cave	Yok Balum
Geophilomorpha	Undetermined							1	
Scolopendromorpha	Undetermined					3	1		
Scutigeromorpha	Undetermined			1		2			
Undetermined						1			

Figure 20. An undescribed cave millipede (Polydesmida: Chelodesmidae) from caves of the Toledo District, Belize. Photo © Steve Taylor/SEI.

Table 9. Diplopoda recorded from caves in the Toledo District (Belize) during the April 2011 biospeleological expedition.

Order	Family	Taxon	Bat Cave	Blue Creek Cave	Cave near Pueblo Creek Cave	Okebal Ha	Small cave near Okebal Ha	Tiger Cave	Yok Balum
Platydesmida	Platydesmidae	*Platydesmus* sp. 1							2
	Platydesmidae	*Platydesmus* sp. 2		1					3
Polydesmida	Chelodesmidae	Undetermined sp. 1				1		8	1
	Chelodesmidae	Undetermined sp. 2		2	3		2		19
	Platyrhacidae	Undetermined sp. 1						1	
	Pyrgodesmidae	Undetermiend sp. 1						11	
Spirostreptida	Spirostreptidae	*Orthoporus*? sp.						14	

Phylum Arthropoda: Class Hexapoda

Eleven orders of insects and other hexapods were recorded through our collections (Table 10).

Collembola

Several species of springtails were collected, including a species of troglomorphic Paronellidae (Entomobryomorpha), which may represent a new species of *Trogolaphysa* (Figure 21).

Diplura

Diplurans were encountered in several caves, and likely represent undescribed, cave-adapted species.

Table 10. Hexapoda recorded from caves in the Toledo District (Belize) during the April 2011 biospeleological expedition.

Order	Family	Taxon	Bat Cave	Blue Creek Cave	Cave near Pueblo Creek Cave	Okebal Ha	Small cave near Okebal Ha	Tiger Cave	Yok Balum
Undetermined				1	1				6
Collembola	Undetermined		34	34	7	23	1	34	16
	Entomobryidae	*Pseudosinella* sp.							7
	Onychiuridae	Undetermined						3	
Diplura	Campodaeidae	Undetermined		4				5	18
Coleoptera	Undetermined			3				2	
	Carabidae	Undetermined	1					15	1
	Carabidae	*Clivina*? sp.						1	
	Cleridae	Undetermined				3			1
	Curculionoidea	Undetermined		1					
	Curculionidae	Undetermined		1					
	Passalidae	Undetermined						1	
	Pselaphidae	Undetermined				2			
	Staphylinidae	Undetermined	7			3		2	
Diptera	Undetermined			2				1	
	Brachycera	Undetermined			1	7		1	
	Nematocera	Undetermined		2		6			
	Culicidae	Undetermined	3						
	Mycetophilidae	Undetermined		2				1	1
	Psychodidae	Undetermined	1						
	Tipulidae	Undetermined	1						
Hemiptera	Undetermined			1		1		7	
	Cercopidae	Undetermined					2		
	Cicadellidae	Undetermined		2					
	Cydnidae	Undetermined	12		3	1		11	3
	Mesoveliidae	Undetermined						2	
	Miridae	Undetermined	1			11			
	Reduviidae	*Triatoma* sp.		4				2	3
	Veliidae	*Microvelia* sp.						8	

concluded on next page

Table 10. Concluded

Order	Family	Taxon	Bat Cave	Blue Creek Cave	Cave near Pueblo Creek Cave	Okebal Ha	Small cave near Okebal Ha	Tiger Cave	Yok Balum
Hymenoptera	Undetermined			2					1
	Formicidae	Undetermined		5	1	5	13	6	2
	Apidae: Euglossini?	Undetermined		1					
Isoptera	Undetermined				3	9			27
Lepidoptera	Undetermined			1					
	Tineidae	Undetermined		4		1	3	1	5
Neuroptera	Myrmeliontidae	Undetermined		1					
Orthoptera	Undetermined				1	1			
	Gryllidae	*Mayagryllus* sp.	13	3	6	6	3	9	
Thysanoptera	Undetermined			35					

Figure 21. A springtail, probably *Trogolaphysa* sp. (Collembola: Entomobryomorpha: Paronellidae) in a Toledo District (Belize) cave. Photo © Steve Taylor/SEI.

Coleoptera

Though beetle collections were fairly diverse (Table 9), most material likely represents accidentals. A ground beetle, probably a species of *Clivna* (Family Carabidae: Subfamily Scaritinae, Tribe Clivinini), was abundant on rich, damp soil floors in Tiger Cave. At least some species of this genus are found in burrows in soft, moist soil in association with water (Peck 2009). The short-winged mold beetles (Pselaphidae) are likely undescribed, and may be cave adapted.

Diptera

Among the flies (Diptera), the fungus gnats (Mycetophilidae) are of interest in that the larvae (Figure 22), which are predatory, form elaborate webs (Figure 23) low on cave walls, or under breakdown, where they trap prey.

Hemiptera

Two species of burrowing bugs (Cydnidae) were abundant on the soft, damp soils of Tiger Cave, and also were encountered in other caves. An assassin bug of the genus *Triatoma* (Figure 24) was encountered in several caves. These bugs are known to transmit the causative agent of Chagas Disease, *Trypanasoma cruzi*.

Figure 22. A larval webworm (Mycetophilidae) in its web in Yok Balum Cave. Photo © Christy Slay/SEI.

Figure 23. Structure of webworm (Mycetophilidae) web. Note flying insect captured on sticky web, near lower middle of image. Photo © Geoff Hoese/SEI.

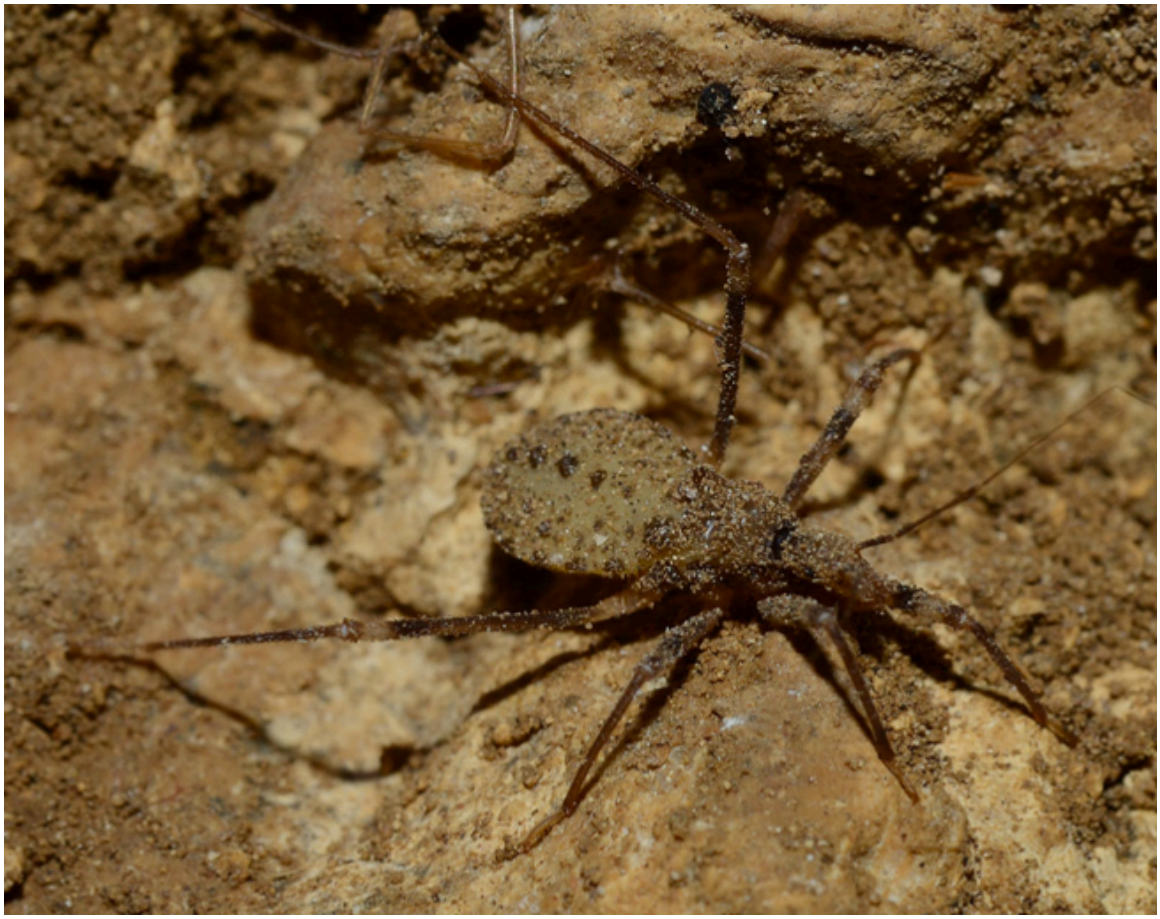

Figure 24. A nymph of *Triatoma* sp. in Yok Balum Cave, Toledo District, Belize. Photo © Christy Slay/SEI.

Hymenoptera

These records are likely accidentals.

Lepidoptera

Guano moths (Tineidae) were encountered in several caves, in one case they were sometimes associated with fruit bat guano (Figure 25).

Orthoptera

Gryllid crickets of the genus *Mayagryllus* were frequently encountered in the entrance and twilight zones of the caves in the Toledo District (Figure 26). These appear to be a new species, and are currently being examined by a taxonomic specialist (Dr. Sam Heads).

Figure 25. A Guano Moth (Tineidae) caterpillar in its case (constructed from fruit bat guano), in Okebal Ha, Toledo District, Belize. Photo © Christy Slay/SEI.

Figure 26. *Mayagryllus* sp. (Family Gryllidae: Subfamily Phalangopsinae: Tribe Luzarini: Subtribe Amphiacustina) from a cave in the Toldedo District, Belize. Photo © Jean Krejca/SEI.

Phylum Chordata: Class Actinopterygii

We were interested in catfish of the genus *Rhamdia*. Few species of fish were observed in the caves (Table 11), and a single *Rhamdia* sp. specimen, apparently the widespread surface species, was taken at Blue Creek Cave. A number of specimens of the River Goby *Awaous banana* (Family Gobiidae: Subfamily Gobionellinae) (Figure 27) were observed in an isolated pool in Bat Cave. An individual was captured, photographed, and released.

Phylum Chordata: Class Mammalia

We saw relatively few bats (Order Chiroptera) (Figure 28), none of which were handled or collected. There are 76 species of bats recorded from Belize (Meerman 2006).

Figure 27. The River Goby *Awaous banana* (Family Gobiidae: Subfamily Gobionellinae) in Bat Cave (Toledo District, Belize). Photo © Geoff Hoese/SEI.

Table 11. Fish recorded from caves in the Toledo District (Belize) during the April 2011 biospeleological expedition.

Order	Family	*Taxon*	Bat Cave	Blue Creek Cave	Cave near Pueblo Creek Cave	Okebal Ha	Small cave near Okebal Ha	Tiger Cave	Yok Balum
Siluriformes	Heptapteridae	*Rhamdia* sp.		1					
Perciformes	Gobiidae	*Awaous banana*	1						

Figure 28. Fruit bats roosting in a cave in the Toledo District, Belize. Photo © Mike Slay/SEI.

Prospects for further scientific study

We have collected more than 10 species which are new to science, including millipedes, spiders, harvestmen, schizomids, and orthopterans. Several of these species were recorded from only one or few sites. These findings point to a high likelihood of collecting additional new species with further effort.

Our success may also be related to the differentiation of karst areas in Belize, with virtually all previous biospeleological work taking place in the Vaca Plateau and Boundary Fault karst areas, whereas our studies have been carried out in the K-T Fault Ridges and southern flank of the Little Quartz Ridge karst areas (Figure 29). These different karst regions are at least partially separated by major river drainages, and it is not difficult to imagine long periods of isolation separating the faunas.

We know relatively little about the distribution of the species within the caves, species co-occurrence, trophic structure, and nutrient sources. In short, many more years of

scientific study of the caves of the Toledo District are needed before we can begin to fully understand these unique ecosystems.

We hope to return soon to continue our work in the Toledo District, perhaps including some sampling of above-ground invertebrates to provide some context for interpretation of the observed subterranean biodiversity.

Relevance

During our fieldwork, we gained a greater appreciation for the role of ecotourism in supporting the local economy of the Toledo District. We believe that there are opportunities for greater interpretation and appreciation of the biological resources of the Toledo District, including the biology of the caves. We hope our work eventually can come to provide local cave guides with a greater depth of knowledge of the natural wonders found in their caves. In addition, we believe that providing local, regional and national decision makers with better information on the interconnectedness of subterranean communities and above ground land use practices will lead to better management of natural resources.

In addition to the socioeconomic relevance of our work, we believe if fits well with Belize's national Environmental and Natural Resources (NRM) Research Agenda (ERI 2010). Specifically, our work addresses several terrestrial research priority needs delineated by ERI (2010), only two of which we will highlight here:

1. *Determine the impacts, including cumulative impacts, of different land-use practices on Belize's natural resources and hydrology.*
    - What could be more relevant to determining impacts than first identifying what resources are present? In our case, identification of new biological resources is spatially located in an environment (caves); strongly influenced by hydrology and dependent upon the land above for nutrients. Clearly, our work needs to be expanded to address this priority need, but we see our current work as laying a baseline for better understanding cave resources.

6. *Determine the ecosystems, and associated species, in Belize that are of national and international conservation concerns and assess their status.*
    - Our work has already identified several undescribed species that are likely narrowly endemic, and thus will rank as globally imperiled upon their description as new species. We hope our current and future work will identify caves as not only being important as archeological sites, but as subterranean ecosystems that are unique, isolated, and sensitive to land use changes.

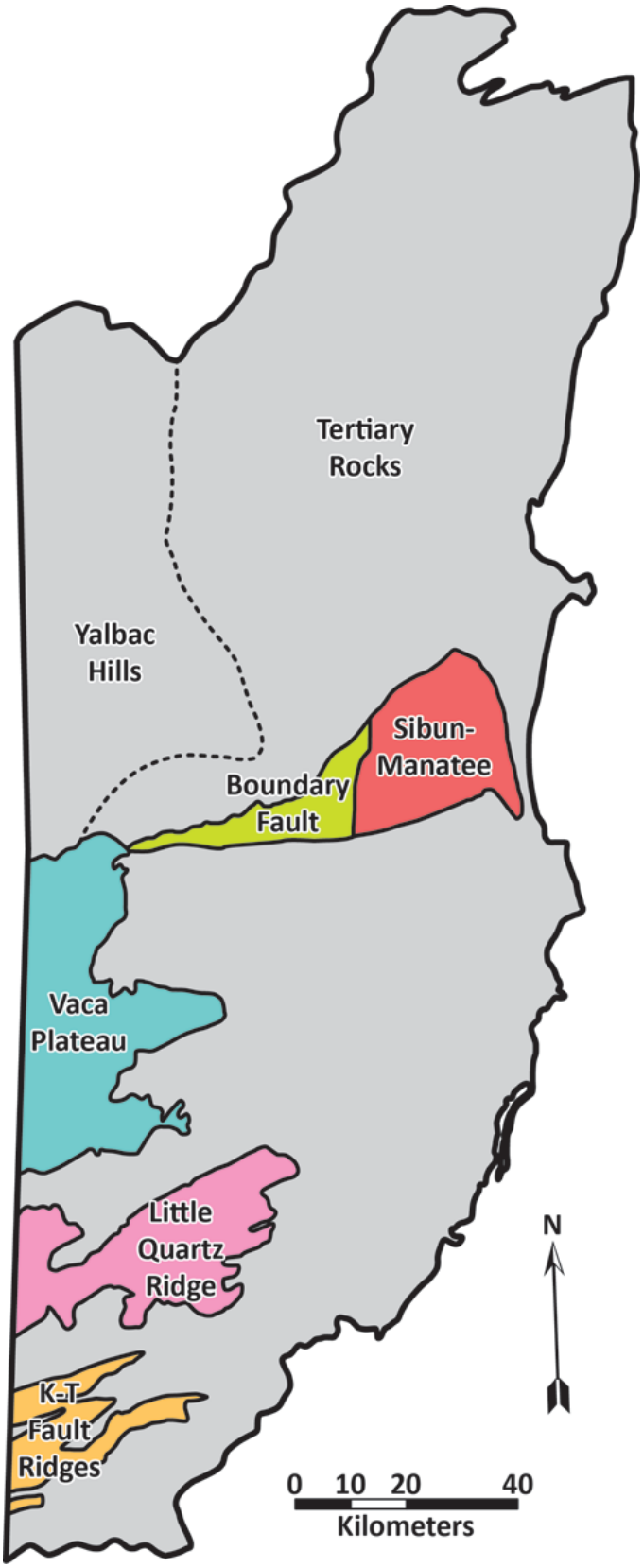

Figure 29. The five primary mainland karst areas of Belize. Map by Steve Taylor, modified after Miller (1996).

Conclusions

This first bioinventory of caves in the Toledo District of Belize has demonstrated the presence of a rich, diverse, and little-understood ecosystem in subterranean environments. Among the material we have collected are a variety of undescribed species, several of which are currently being examined by taxonomic experts. More work is needed to understand these resources, and to provide interpretation of our findings in a manner that can benefit the Belizean people, especially in the areas of ecotourism and land resource management. These findings also speak to the National Environmental & NRM Research Agenda of Belize.

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Literature Cited

Botosaneanu, L., and T. M. Iliffe. 1997. Four new stygobitic cirolanids (Crustacea: Isopoda) from the Caribbean – with remarks on intergeneric limits in some cirolanids. Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Biologie 67: 77-94.

Chamberlin, R. V. and W. Ivie. 1938b. Araneida from Yucatan. Carnegie Int. Washington Publ., 491: 123-136.

Cokendolpher, J. C., and T. Enríquez, 2004. A new species and records of *Pseudocellus* (Arachnida: Ricinulei: Ricinoididae) from caves in Yucatán, Mexico and Belize. Texas Memorial Museum, Speleological Monographs 6: 95-99.

Desutter-Grandcolas & Hubbell *in* Desutter-Grandcolas, L. 1993. The cricket fauna of Chiapanecan caves (Mexico): systematics, phylogeny and the evolution of troglobiotic life (Orthoptera, Grylloidea: Phalangopsidae, Luzarinae). International J. Speleology 22(1-4): 1-82.

Environmental Research Institute (NRI), University of Belize 2010. National Environmental and Natural Resources Management (NRM) Research Agenda. 23 pp.

Gertsch, W. J. 1973b. A report on cave spiders from México and Central America. Association of Mexican Cave Studies Bulletin 5: 141-163.

Gertsch, W. J. 1977b. Report on cavernicole and epigean spiders from the Yucatán Peninsula. Association Mexican Cave Studies Bulletin 6: 103-131.

Gertsch, W. J. 1986. The spider genus *Metagonia* (Araneae: Pholcidae) in North America, Central America, and the West Indies. Texas Memorial Museum, Speleological Monographs, 1: 39-62.

Golovatch, S. I., and R. D. Kime. 2009. Millipede (Diplopoda) distributions: A review. Soil Organisms 81(3): 565-597.

Greenfield, D. W., T. A. Greenfield & R. L. Woods. 1982. A new subspecies of cave-dwelling pimelodid catfish, *Rhamdia laticauda typhla* from Belize, Central America. Brenesia, 19/20: 563-576.

Harvey, M. S. 1990. Catalogue of the Pseudoscorpionida. Manchester University Press, Manchester, UK. 726 pp.

Hobbs, H. H., Jr. 1986. A new troglobitic crab (Crustacea: Decapoda: Pseudothelphusidae) from Belize. Texas Memorial Museum, Speleological Monographs, 1: 1-4.

Hobbs, H. H., III and H. H. Hobbs, Jr. 1995. *Macrobrachium catonium*, a new troglobitic shrimp from the Cayo District of Belize (Crustacea: Decapoda: Palaemonidae). Proceedings of the Biological Society of Washington 108(1): 50-53.

Howarth, F. G. 2003. Cave Insects. Pages 159-163 in Resh, Vincent H. and Ring T. Cardé (eds.). Encyclopedia of Insects. Academic Press, 1266 pp.

Miller, T. E. 1996. Geologic and hydrologic controls on karst and cave development in Belize. Journal of Cave and Karst Studies 58(2): 100-120.

Meerman, Jan C. 2006 (2005). Compilation of information on biodiversity in Belize. Norwegian Ministry of Foreign Affairs. Report to INBio and the Forest Department of the Ministry of Natural Resources and the Environment. 68 pp + Appendicies.

Muchmore, W. B. 1973b. The pseudoscorpion genus *Mexobisium* in Middle America. Association Mexican Cave Studies Bulletin 5: 63-71.

Muchmore, W. B. 1977. Preliminary list of the pseudoscorpions of the Yucatan Peninsula and adjacent regions, with descriptions of some new species (Arachnida: Pseudoscorpionida). Association Mexican Cave Studies Bulletin 6: 63-78.

Muchmore, W. B. 1980. Pseudoscorpions from Florida and the Caribbean area. 10. New *Mexobisium* species from Cuba. Florida Entomologist 63:123-127.

Muchmore, W. B. 1998. Review of the family Bochicidae, with new species and records (Arachnida: Psuedoscorpionida). Insecta Mundi 12(1&2): 117-132.

Mullinex, C. L. 1975. Revision of *Paraphrynus* Moreno (Amblypgida: Phrynidae) for North America and the Antilles. Occasional Papers of the California Academy of Science, 116. 80 pp.

Goodnight, C. J. and M. L. Goodnight. 1977. Laniatores (Opiliones) of the Yucatán Peninsula and Belize (British Honduras). Association Mexican Cave Studies Bulletin 6: 139-166.

Peck, S. B. 1973. A review of the cavernicolous Catopinae (Coleoptera: Leiodidae) of Mexico, Belize, and Guatemala. Association of Mexican Cave Studies Bulletin, 5: 97-106.

Peck, S. B. 1974. Recent studies on the invertebrate fauna and ecology of sub-tropical and tropical American caves. Association for Mexican Cave Studies Newsletter 5(1): 30-38.

Peck, S. B. 2009. The beetles of Barbados, West Indies (Insecta: Coleoptera): diversity, distribution and faunal structure. Insecta Mundi 73: 1-51.

Reddell, J. R. 1977. A preliminary survey of the caves of the Yucatán Peninsula. Association Mexican Cave Studies Bulletin 6: 215-296.

Reddell, J. R. 1981. A Review of the Cavernicole Fauna of Mexico, Guatemala, and Belize. Texas Memorial Museum Bulletin, No. 27. 327 pp.

Reddell, J. R. and G. Veni. 1996. Biology of the Chiquibul Cave System, Belize and Guatemala. Journal of Cave and Karst Studies 58(2): 131-138.

Rodríguez, G. and H. H. Hobbs, Jr. 1989. Freshwater crabs associated with caves in southern Mexico and Belize, with descriptions of three new species (Crustacea: Decapoda). Proceedings of the Biological Society of Washington 102(2): 394-400.

Rowland, J. M. 1975. Classification, phylogeny and zoogeography of the American arachnids of the order Schizomida. Ph.D. Dissertation. Lubbock: Texas Tech Univ. 415 p.

Rowland, J. M., and J. R. Reddell. 1977. A review of the cavernicole Schizomida (Arachnida) of Mexico, Guatemala, and Belize. Association Mexican Cave Studies Bulletin 6: 79-102.

Schultz, G. A. 1984. Three new and five other species of Oniscoidea from Belize, Central America (Crustacea: Isopoda). Journal of Natural History 18:3-14.

Shear, W. A. 1973. *Jarmilka alba*, n. gen., n. sp. (Diplopoda: Spirostreptida: Cambalidae), a new milliped from a cave in Belize. Association Mexican Cave Studies Bulletin 5: 43-45.

Shear, W. A. 1977. Millipeds (Diplopoda) from caves in Mexico, Belize and Guatemala. III. Accademia Nazionale dei Lincei ; problemi attuali di scienza edi cultura 171(3): 235-265, figs. 1-56.

South Wales Caving Club (SWCC). 2006. Belize 2006, Report of the caving expedition to the Toledo District of Belize, Central America. Easter 2006. South Wales Caving Club. 78 pp.

Walker, Phil and Alan Braybrooke. 2010. Belize 2010, Report of the caving expedition to the Toldedo Distric of Belize, Central America, March – April 2010. South Wales Caving Club. 61 pp.

Williams, N. 1996. Bibliography of Belize Caving. Journal of Cave and Karst Studies 58(2): 145-151.

Williams, P. 1976a. The form of *Lutzomyia beltrani* (Vargas & Diaz Nájera) (Diptera, Psychodidae) in Belize, Central America. Bulletin of Entomological Research 65: 595-599.

Williams, P. 1976b. The phlebotomine sandflies (Diptera, Psychodidae) of caves in Belize, Central America. Bulletin of Entomological Research 65: 601-614.

Williams, P. 1976c. Flagellate infections in cave-dwelling sandflies (Diptera, Psychodidae) in Belize, Central America. Bulletin of Entomological Research 65: 615-629.

Wynne, J. J. and W. Pleytez. 2005. Sensitive ecological areas and species inventory of Actun Chapat Cave, Vaca Plateau, Belize. Journal of Cave and Karst Studies 67(3): 148-157.

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