

The first two hotspots of subterranean biodiversity in South America

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Abstract

The term hotspots of subterranean biodiversity has been used to define subterranean habitats with an arbitrary cutoff of twenty or more obligate stygobitic and troglobitic species. Until present, no hotspots of subterranean biodiversity had been identified in South America. Thus, the objective of this work is to present the first two hotspots of subterranean biodiversity in that continent. The two hotspots of subterranean biodiversity are the Toca do Gonçalves cave (22 spp.) and Areias cave systems (28 spp.). The cave species, some of them considered relict species, belong to the Platyhelminthes (1 sp.), Nemertea (1 sp.), Gastropoda (2 spp.), Amphipoda (2), Isopoda (7), Decapoda (1), Collembola (5), Coleoptera (5), Ensifera (1), Sternorrhyncha (1), Zygentoma (1), Diplopoda (6), Chilopoda (5), Araneae (2), Opiliones (1), Palpi-gradi (2), Pseudoscorpiones (4), and Osteichthyes (2). Although both caves, together, have 50 troglobitic species, only 38% of these species are formally described. Both caves have perennial water bodies, but terrestrial obligate cave invertebrates are dominant in number of species in both systems (around 77%). While the Areias system is partially contained in a conservation unit, Toca do Gonçalves cave is currently unprotected, although it certainly deserves protection.

Keywords

Cave conservation, cave diversity, protection strategies

Introduction

The syntagm “biodiversity hotspot”, one of the most important global tools for nature conservation, has been used in different ways, but with the same goal: identifying areas around the world that have high biological diversity (Myers 1988, Reid 1998, Hughes et al. 2002, Brooks et al. 2006). Biodiversity hotspots were defined by Myers et al. (2000) as the biologically richest places with high numbers of species found nowhere else and that have already lost 70% of their original vegetation. Culver and Sket (2000) used the term hotspots of subterranean biodiversity to define subterranean habitats with an arbitrary cutoff of twenty or more obligate stygobitic and troglobitic species, but they did not consider any threats to biodiversity loss. Culver and Pipan (2009) following the concept of the hotspots of subterranean biodiversity, adding another 16 localities to those 20 previously defined by Culver and Sket (2000). Although caves may have a lower diversity when compared to surface habitats, their subterranean fauna have attracted attention because of their biological singularity, high endemism, and evolutionary significance (Culver and Pipan 2009, Chertoprud et al. 2016, Glanville et al. 2016).

Until present, no hotspots of high richness of strictly subterranean species were identified in the Neotropical region (Trajano and Bichuette 2010, Culver and Pipan 2013, Souza-Silva et al. 2015). Since most of the karstic areas of the world are situated in temperate regions, a higher cave biodiversity can be expected in mid-latitudes because caves have served as refugia for many ancestors of obligate cave faunas during strong climate changes in the past (Bar 1968, Romero 2009). However, the high numbers of new species recently discovered in Brazilian caves (Prevorčnik et al. 2012, Ázara and Ferreira 2013 and 2014, Fišer et al. 2013, Iniesta et al. 2012, Iniesta and Ferreira 2013, 2013a, 2013b and 2015, Bastos-Pereira and Ferreira 2015, Vasconcelos and Ferreira 2016) and their high degree of troglomorphism indicate that the events of climatic changes in the Neotropics, even if not so severe as in temperate regions, could have led to the isolation of subterranean lineages. Alternatively, other mechanisms of isolation (e.g. parapatric speciation, oceanic introgressions and regressions) might have led to the evolution of many lineages of subterranean fauna in Brazil (Ferreira et al. 2010, Fišer et al. 2013, Leal-Zanchet et al. 2014). Moreover, most of the caves, particularly in tropical countries, have not been thoroughly explored (Deharveng and Bedos 2000, Lienhard and Ferreira 2015, Souza-Silva and Ferreira 2015).

Despite the fact that South America has the lowest proportions of karstic landscapes of the world, recent studies have shown a high potential for the occurrence of a large number of obligate cave species (Trajano and Bichuette 2010, Deharveng 2005, Deharveng and Bedos 2012, Souza-Silva et al. 2015). The great majority of these recent studies has been developed in Brazil, where the highest proportions of karstic landscapes of South America occur in different rock types (Souza-Silva et al. 2011, CEBS-UFLA 2015, Cordeiro et al. 2014, Gallão and Bichuette 2015).

One of the main tools to predict and avoid future rapid deterioration of subterranean ecosystems may be such studies on endemic cave fauna (Gibert and Deharveng

2002). Thus, researches in critical habitats represent an urgent task for scientists, consultants, and policy-makers regarding conservation. Global assessments of the distribution and changes in biodiversity in spatial and temporal contexts have been playing a crucial role in efficiently allocating limited resources to high-priority areas and species (Amano and Sutherland 2013). In this context, the objective of the present work is to present the first two hotspots of subterranean biodiversity in South America, describing their taxonomic biodiversity, organic resources availability and threats, as well as discussing the potential occurrence of other hotspots or important subterranean ecological sites in order to contribute to their conservation.

Material and methods

Study area

The study was conducted in the Areias Cave System (AS) formed by three caves connected by a stream (UTM 22J, 732863/7279192, 100 km from the sea and at 500 m, asl) and Toca do Gonçalves cave (TG) including a water table level (UTM 24L, 292651/8837465, 460 km from the sea and at 527 m, asl) (Figure 1). The Areias system is a 14 km long cave including all the subterranean stretches of the drainage and it is divided into the upstream Areias de Cima cave (5.5 km long and 43 m elevation difference), Areias de Baixo cave (1.5 km long and 20 m elevation difference), and downstream Resurgência das Areias cave (1.2 km long and 73 elevation differences). The Areias system is a convergent drainage of many autogenic and allogenic drainages, also connected with many closed dolines that receive meteoric water. This cave system has terrestrial humid areas and ponds that receive water from the epikarstic/vadose compartments (Genthner et al. 2003). Between Areias de Cima and Areias de Baixo caves there is a sinkhole with a diameter of 140 m and dense arboreal vegetation. Between Areias de Baixo and Resurgência das Areias caves there is a long passage still not explored and limited by river siphons (approximately 5.6 km - J.A. Ferrari pers. comm.). The Areias cave system is located in the municipality of Iporanga, São Paulo state, Southeastern of Brazil (Figure 1). It is protected inside the conservation unit Parque Estadual Turístico do Alto Ribeira (PETAR) in a humid subtropical zone covered by Atlantic Rain Forest that does not have a dry period (Álvares et al. 2014).

The Toca do Gonçalves cave is smaller and located in a semiarid zone (Caatinga formation) in the municipality of Campo Formoso, Bahia state, Northeast of Brazil (Figure 1), and comprises a maze-cave which totals nearly 500 mapped meters. This cave has a single horizontal lenticular-shaped entrance; the maximum dimensions are approximately 2 m high and 8 m width. After the entrance, a rectilinear conduit descends slightly, reaching some of the lateral conduits. The cave has two main branches: the right branch reaches the lower water table while the left branch has predominantly dry and high galleries without macro-access to the water table level.

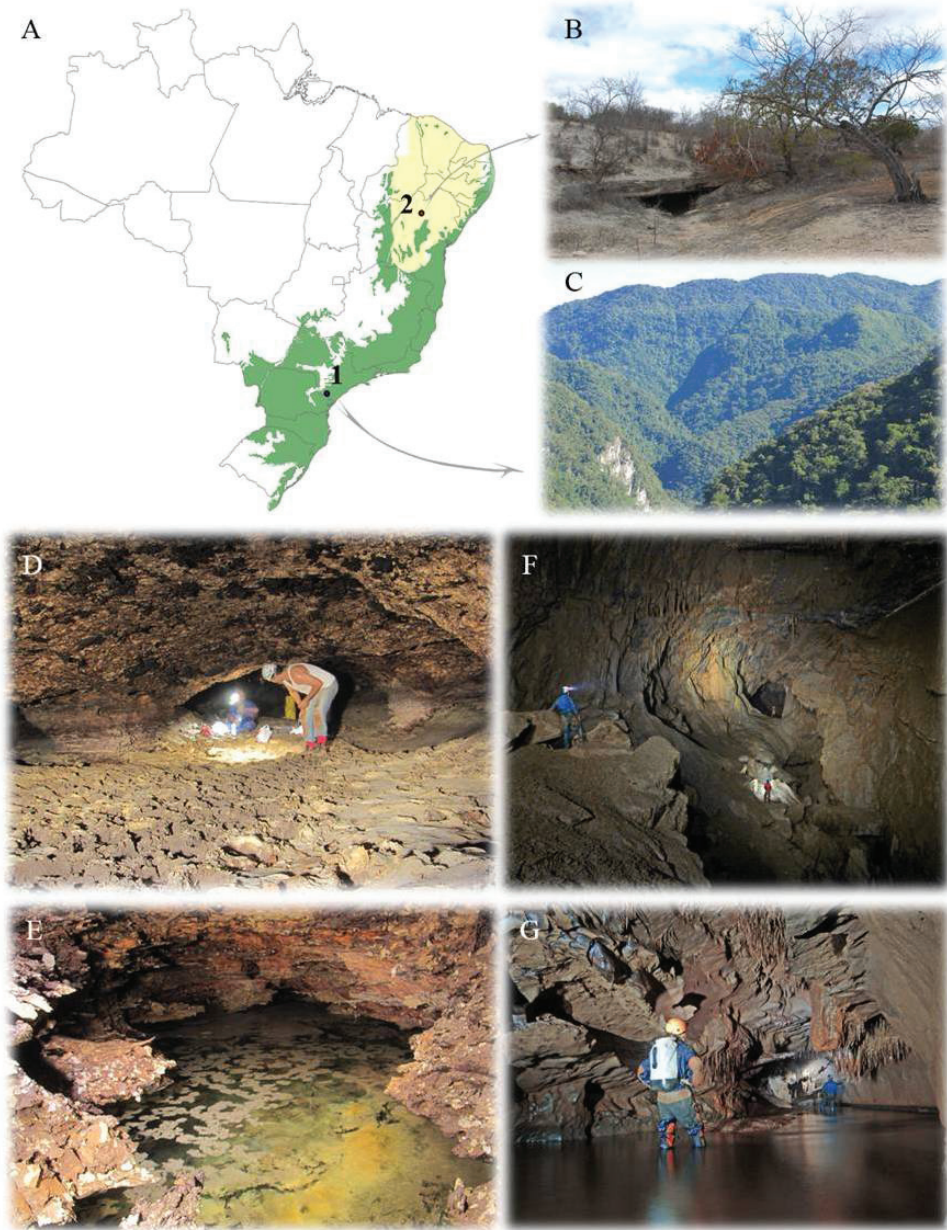


Figure 1. Areias cave system (**F, G**) in the Atlantic Rain Forest (**C**) and Toca do Gonçalves Cave (**A, D, E**) in Caatinga (**B**). Photos **F** and **G** by Daniel Menin.

Laboratory and field procedures to Toca do Gonçalves and Areias cave system

The database of the obligate cave fauna was obtained from published literature (Prates and Drumond 2007, Trajano and Bichuette 2010, Ázara and Ferreira 2013, 2014, Pel-

legrini and Ferreira 2014, Souza-Silva et al. 2015, ISLA 2015) and after conducting five visits (four people/six hours inside the caves in each visit) to AS and eight visits (four people/six hours inside the caves in each visit) to TG to sample the cave fauna in microhabitats and on organic resources. Extensive visual searching and manual collections were made with the aid of soft forceps and brushes. All microhabitats such as root mats, plant debris, guano deposits, spaces under stones, and humid spots were inspected. In the water (both flowing and still) the invertebrates were collected with the aid of tweezers and hand nets (Ferreira 2004, Souza Silva et al. 2011, Simões et al. 2015). The collection team was always composed of four biologists with at least three years of experience in caving and manual collection of invertebrates. Zooplankton nets were not used for sampling fauna from any cave habitat. The epikarst/vadose zone species were collected from travertine pools formed by dripping waters, located in areas not subject to the river flooding (as the case of *Hyaella epikarstica* Rodrigues, Bueno & Ferreira, 2014).

The determination of potentially new troglobitic or stygobitic species was made by identifying “troglomorphisms” in the unknown sampled specimens (when evident), by consulting the specialist researcher of the group or considering those already determined and described in the literature (Tables 1 and 2, Figures 2 and 3).

Pitfall traps were not used because of their low efficiency that has already been demonstrated in some studies conducted in Neotropical caves (Weinstein and Slaney 1995, Sharratt et al. 2000). Moreover, such traps can cause disturbances in cave populations (Ferreira 2004, Souza-Silva et al. 2011).

All collected organisms were fixed in 70% ethanol, identified to an accessible taxonomic level, grouped into morphospecies (Souza-Silva et al. 2011), and deposited in the Subterranean Invertebrate Collection (ISLA) of the Center of Studies on Subterranean Biology in the Biology Department at the Federal University of Lavras (CEBS-UFLA).

Organic debris availability

The organic resources visible in the caves were examined (*in situ*) to describe the possible food resources for the fauna. The information regarding quantification of resources, their access pathways, accumulation, and decomposition were not gathered. The trophic characterization was thus restricted to the qualitative aspects.

Human impacts

During the visits to the caves and using satellite images available on Google Earth 2014, we rated human impacts present inside and around the caves to a maximum distance of 250 m in accordance with the Brazilian legislation (Souza-Silva et al. 2015). Besides, one of the authors (R.L. Ferreira) has often visited the Toca do Gonçalves and its surroundings since 1996.

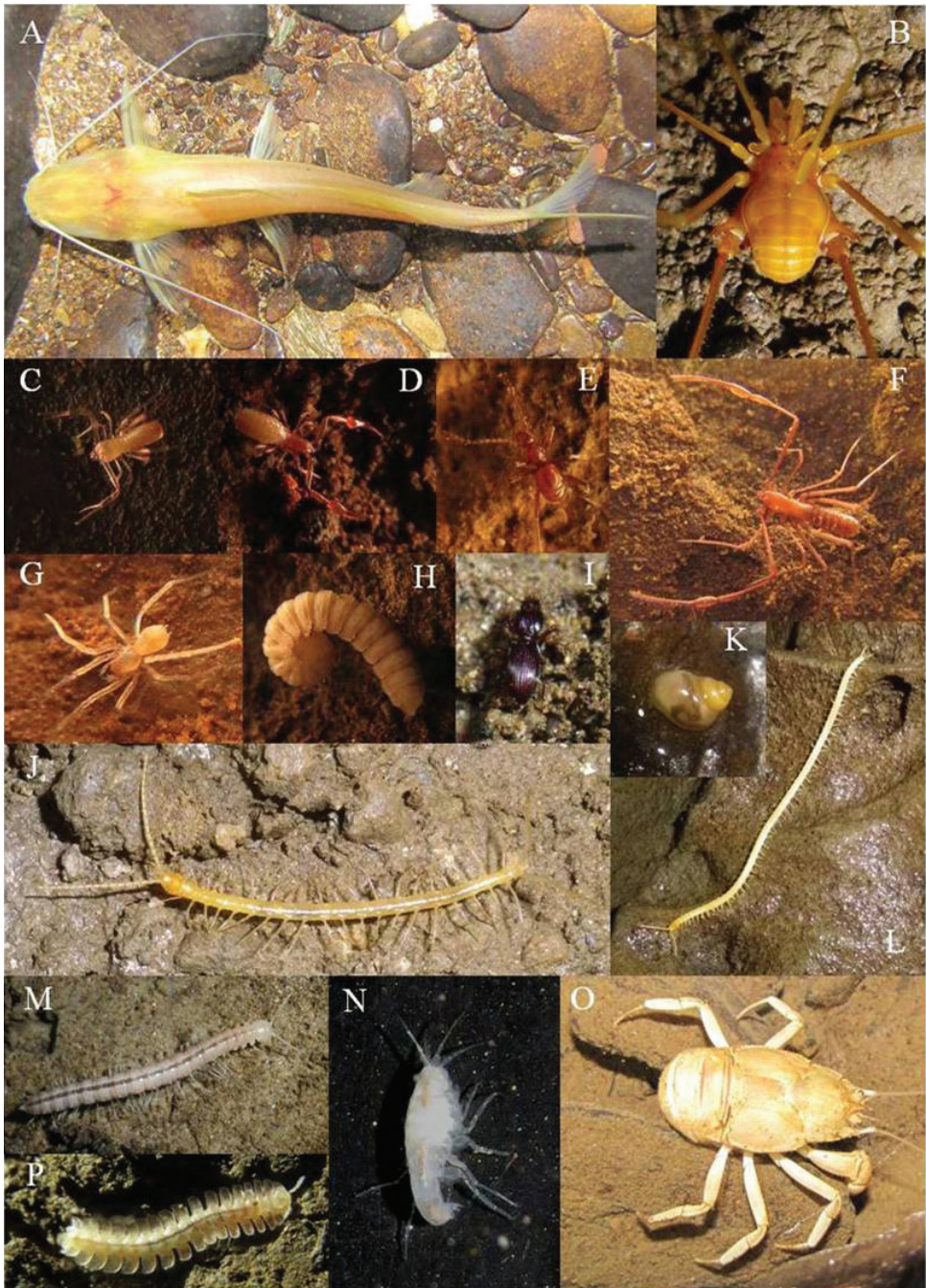


Figure 2. Some of the stygobiotic and troglobitic species in Areias cave system, São Paulo, Brazil. *Pimelodella kronei* (A), *Pachylospeleus strinatii* (B), *Pseudochthonius strinatii* (C), *Ideoroncus cavicola* (D), *Pseudoscorpionidae* sp. n. (E), *Spelaeobochica muchmorei* (F), *Hahniidae* sp. n. (G) *Cryptodesmus* spn (H), *Schizogenius ocelatus* (I), *Cryptops iporangensis* (J), *Potamolithus troglobius* (K), *Crypturodesmus* spn (L), *Leodesmus yporangae* (M), *Hyallella epikarstica* (N), *Aegla cavernicola* (O), *Peridontodesmella* sp. (P).



Figure 3. Some of the stygobiotic and troglobitic species in Toca do Gonçalo. *Rhandiopsis* sp. n. (A), *Spelaeogamarus trajanoae* (B), Phalangopsidae sp. n. (C), *Coarazuphium caatinga* (D), *Lygromma* sp. n. (E), *Scleropactidae* sp. n. (F), *Newportia spelaea* (G), *Clivinina* sp. n. (H), *Pongycarcinia xyphidiorus* (I), *Allokoenenia* sp. n. (J), *Rotadiscus* sp. n. (K), Cthoniidae sp. n. (L), *Geophilomorpha* sp. n. (M), Nicoletiidae sp. n. (N).

Table 1. Composition of invertebrate and vertebrate obligate cave fauna of the Areias cave system in different habitats. Terrestrial habitat (T), aquatic habitat (A), Epikarst/vadose zone (E/V).

Taxon	Taxon	Family	Species/morphospecies	Habitat
Arachnida	Araneae	Hahniidae	Hahniidae spn	T
	Opiliones	Gonyleptidae	<i>Pachylospeleus strinatii</i>	T
	Palpigradi	Eukoeneriidae	<i>Eukoeneria</i> spn	T
	Pseudoscorpiones	Bochicidae	<i>Spelaebochica muchmorei</i>	T
		Chthoniidae	<i>Pseudochthonius strinatii</i>	T
		Ideoroncidae	<i>Ideoroncus cavicola</i>	T
Crustacea	Decapoda	Aegliidae	<i>Aegla cavernicola</i>	A
	Amphipoda	Hyallellidae	<i>Hyallella epikarstica</i>	E/V
	Isopoda	Phylosciidae	<i>Benthana iporangensis</i>	T
		Platyarthridae	<i>Trichorhina</i> sp. n.1	T
			<i>Trichorhina</i> sp. n.2	T
Hexapoda	Coleoptera	Carabidae	<i>Schizogenius ocelatus</i>	T
		Pselaphidae	Pselaphidae sp. n.	T
	Collembola	Cyphoderidae	Cyphoderidae sp. n.	T
		Isotomidae	cf. <i>Folsomia</i> sp. n.	T
		Paronellidae	<i>Trogolaphysa aelleni</i>	T
			Paronellidae sp. n.	T
	Diplura	Campodeidae	<i>Oncinocampa trajanoae</i>	T
Mollusca	Gastropoda	Hydrobiidae	<i>Potamolithus troglolobius</i>	A
Myriapoda	Chilopoda	Cryptopidae	<i>Cryptops iporangensis</i>	T
		Geophilidae	Geophilidae sp. n.	T
		Chelodesmidae	<i>Leodesmus yporangae</i>	T
	Polydesmida	Cryptodesmidae	<i>Cryptodesmus</i> sp. n.	T
			<i>Peridontodesmella</i> sp.	T
		Oniscodesmidae	<i>Crypturodesmus</i> sp. n.	T
Nemertea	Nemertea	-	Nemertea sp. n.	A
Osteichthyes	Siluriformes	Heptapteridae	<i>Pimelodella kronei</i>	A
Platyhelminthes	Turbellaria	Dugesidae	Dugesidae sp. n.	E/V

Data analysis

The taxonomic diversity (Δ) was calculated for both the AS and TG caves. This index reflects the average taxonomic distance between taxa (Pienkowski et al. 1998). The richness was divided by the cave length in Areias de Cima, Areias de Baixo, Ressurgência das Areias, and Toca do Gonçalves in order to obtain a standardized richness (Table 3). Finally, an accumulation curve was performed for each cave. However, since the sampling methods and efforts used to access the fauna were historically quite distinct, the curves are actually graphic representations of the descriptions dates (data from literature) and the records of species sampled in each cave (new records here presented, Figure 4).

Table 2. Composition of invertebrate and vertebrate obligate cave fauna of the Toca do Gonçalves cave, in different habitats. Terrestrial habitat (T), aquatic habitat (A).

Taxon	Taxon	Family	Species/morphospecies	Habitat
Arachnida	Araneae	Prodidomidae	<i>Lygromma</i> sp. n.	T
	Palpigradi	Eukoeneiidae	<i>Allokoenenia</i> sp. n.	T
	Pseudoscorpiones	Cthoniidae	Cthoniidae sp. n.	T
Crustacea	Amphipoda	Artesiidae	<i>Spelaeogamarus trajanoae</i>	A
	Isopoda	Calabozoidae	<i>Pongycarcinia xyphidiorus</i>	A
		Styloniscidae	Styloniscidae sp. n.	A
		Scleropactidae	Scleropactidae sp. n.	T
		Platyarthridae	<i>Trichorbina</i> sp. n.	T
Hexapoda	Coleoptera	Carabidae	Clivinina sp. n.	T
			<i>Coarazuphium caatinga</i>	T
		Ditycidae	Ditycidae sp. n.	A
	Collembola	Arrhopalitidae	<i>Arrhopalites</i> sp. n.	T
	Ensifera	Phalangopsidae	Phalangopsidae sp. n.	T
	Sternorrhyncha	Ortheziidae	Ortheziidae sp. n.	T
Mollusca	Zygentoma	Nicoletiidae	Nicoletiidae sp. n.	T
	Gastropoda	Charopidae	<i>Rotadiscus</i> sp. n.	T
Myriapoda	Chilopoda	Cryptopidae	<i>Cryptops spelaeoraptor</i>	T
		-	Geophilomorpha sp. n.	T
		Scolopocryptopidae	<i>Newportia spelaea</i>	T
	Polydesmida	Oniscodesmidae	Oniscodesmidae sp. n.	T
	Polyxenida	-	Polyxenida sp. n.	T
Osteichthyes	Siluriformes	Heptapteridae	<i>Rhandiopsis</i> sp. n.	A

Table 3. Proportional number of species in Areias caves and Toca do Gonçalves cave in relation to cave extension.

Cave	Extent (m)	Number of Species	Species/m
Areias de cima	5500	19	0.003
Areias de baixo	1500	11	0.007
Ressurgência das areias	1200	7	0.005
Toca do Gonçalves	500	22	0.044

Results

General faunal composition and richness (AS and TG)

A total of 50 troglobitic/stygobitic species was recorded in both systems (28 species in Areias caves system and 22 species in Toca do Gonçalves cave). These taxa belong to the Platyhelminthes (1 sp.), Nemertea (1 sp.), Gastropoda (2 spp.), Amphipoda (3) Isopoda (7), Decapoda (1), Collembola (5), Coleoptera (5), Ensifera (1), Sternorrhyncha (1), Zygentoma (1), Diplopoda (6) Chilopoda (5) Araneae (2), Opiliones (1) Palpigradi (2), Pseudoscorpiones (4), and Osteichthyes (2). Both caves have perennial

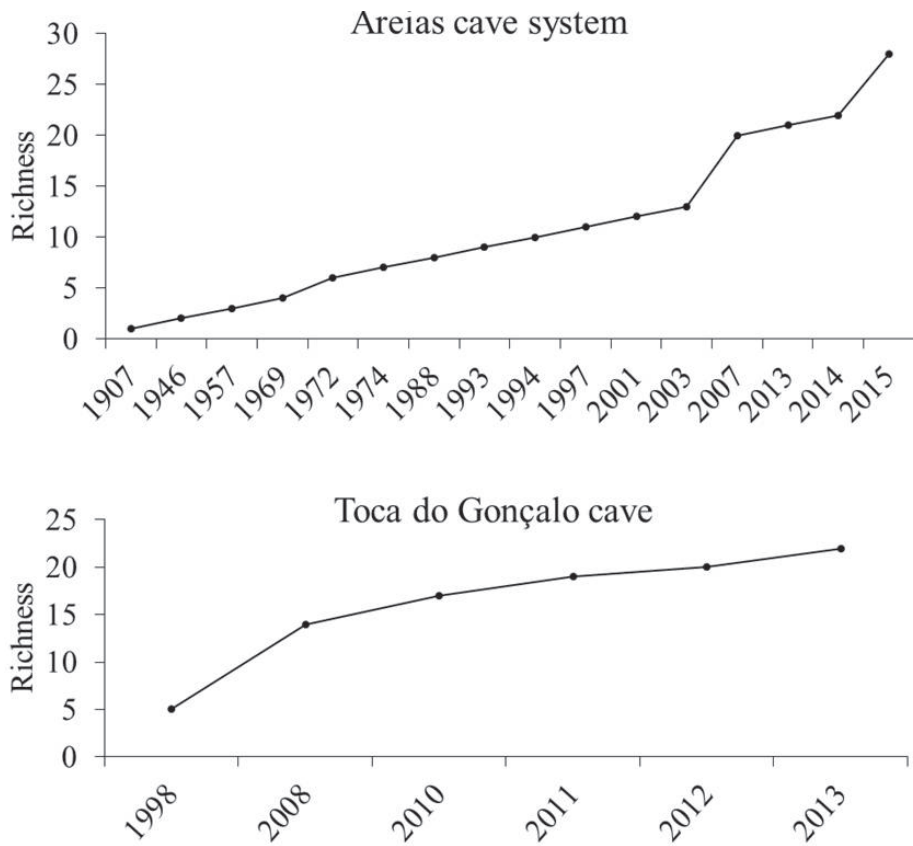


Figure 4. Species accumulation curves for the two Brazilian hotspots. The time-scale do not present regular intervals. Such curves were performed considering both data from literature and the new records here presented.

water bodies, but terrestrial invertebrates are dominant in numbers of taxa for both systems (77%). At least 32 invertebrate families and one vertebrate family (Pisces: Heptapteridae) representing the obligate cave fauna are present in both caves (Tables 1 and 2). Although the two caves have 50 troglobitic species together, only 19 species are described. The taxonomic distinctness of the Areias system was 4.9, and 4.8 in Toca do Gonçalves, with no significant difference between the two systems. The species number accumulation curves for each cave are presented in Figure 4.

Areias cave system

Faunal composition, richness and distribution

The Areias cave system has at least 28 obligate cave species belonging to eight higher taxa and 25 families. The eight higher taxa were Hexapoda (7 spp.), Myriapoda (6),

Arachnida (6), Crustacea (5), Mollusca (1), Nemertea (1), Osteichthyes (1), and Platyhelminthes (1) (Table 1). The richness of the observed obligate cave fauna was Turbellaria (1 sp.), Nemertea (1), Gastropoda (1), Isopoda (3), Amphipoda (1), Decapoda (1), Polydesmida (4), Chilopoda (1), Geophilomorpha (1), Collembola (4 spp.), Coleoptera (2), Diplura (1), Pseudoscorpiones (3), Araneae (1), Opiliones (1), Palpigradi (1), and Siluriformes (1). Only 50% of the obligate cave species from the Areias cave system are previously described as most of them live in terrestrial habitats (77%). They are *Potamolithus troglobius* Simone & Moracchioli, 1994, *Aegla cavernicola* Turkay, 1972, *Hyallolela epikarstica* Rodrigues, Bueno & Ferreira, 2014, *Benthana iporangensis* Lima & Serejo, 1993, *Cryptops iporangensis* Ázara & Ferreira, 2013, *Leodesmus yporangae* (Schubart, 1946), *Pachylospeleus strinatii* Silhavy, 1974, *Spelaeobochica muchmorei* Andrade & Mahnert, 2003, *Pseudochthonius strinatii* Beier, 1969, *Ideoroncus cavicola* Mahnert 2001, *Schizogenius ocelatus* Whitehead, 1972, *Troglolaphysa aelleni* Yoshii, 1988, *Oncinocampa trajanoae* Conde, 1997, and *Pimelodella kronei* (Ribeiro, 1907). The aquatic lotic habitat (4 spp) and epikarst/vadose zone (2 spp.) harbor the remaining species.

Organic debris

The major sources of nutrients for terrestrial and aquatic fauna in lotic habitat seem to be plant debris. However, there are some biofilms covering the rocks in the river that may be used as food by some benthic invertebrates. Dissolved and particulate organic matter is probably derived from the surface forest. Few carcasses were observed during our surveys in the system (frogs, rats, etc.). In all cases, those carcasses were full of invertebrates such as flies (Phoridae), millipedes (*Pseudonannolene strinatii* Mauriès, 1974), and springtails. Finally, some guano deposits also provide nutrition, especially to terrestrial scavenging invertebrates.

Human impacts

Currently the Areias system is partially contained within a state conservation unit (Parque Estadual Turístico do Alto Ribeira - PETAR); however, the caves of the system have been submitted to numerous impacts and currently, conflicts related to tourism, land ownership and use in the region still occur. Sporadic visits to the caves are still conducted in an uncontrolled manner in the Ressurgência das Areias cave. The administrator of the reserve (PETAR) coordinates the activities carried out in the upper and lower Areias cave system. The visitation is allowed only for small groups of researchers with previously registered and authorized activities.

Near the Areias caves system trails, deforested areas, houses, domestic animals, and garbage, among other impacts are visible. All these alterations may affect directly or indirectly the groundwater compartments and the fauna. Another fact to consider is that although Areias system is located inside the PETAR, the springs of all the system drainages are located outside the Park and therefore susceptible to human impacts.

Toca do Gonçalves Cave

Faunal composition, richness, and distribution

The TG cave fauna comprises at least six higher taxa, 22 obligate cave species, and 18 families. The six higher taxa were Mollusca (1 sp.), Crustacea (5 spp.), Myriapoda (5), Hexapoda (7), Arachnida (3), and Osteichthyes (1) (Table 2).

The richness of the observed obligate cave fauna were Gastropoda (1 sp.), Isopoda (3 spp.), Amphipoda (2), Polyxenida (1), Chilopoda (3), Palpigradi (1), Polydesmida (1), Araneae (1), Pseudoscorpiones (1), Coleoptera (3), Collembola (1), Ensifera (1), Zygentoma (1), Sternorrhyncha (1), and Siluriformes (1). Contrary to what was observed for the Areias caves system, only 22% of the obligate species from TG cave are only recently described and most of them live in terrestrial habitats (77%). These are *Spelaeogammarus trajanoae* Koenemann & Holsinger, 2000, *Pongycarcinia xyphidiorus* Messina, Baratti & Benvenuti, 2002, *Cryptops spelaeoraptor* Ázara & Ferreira, 2014, *Newportia spelaea* Ázara & Ferreira, 2014, and *Coarazuphium caatinga* Pellegrini & Ferreira, 2014.

Organic debris

The major sources of nutrients for terrestrial and aquatic fauna seem to be dissolved and particulate organic matter that comes from the epigeal habitats; however, there are some root mats in the water table level that could be used as food. During the rare rainy seasons, the water runoff from epigeal environments can transport coarse and fine particulate organic matter underground. Small guano deposits also occur in the cave and are mainly used by springtails.

Human impacts

The TG cave is facing numerous human impacts, the main one resulting from water extraction. For decades, the villagers of Gonçalves drew from the cave water for their subsistence. This removal was initially done manually but subsequently a diesel pump was placed inside the cave, thus reducing the level of the water table significantly, drying out previously flooded areas of the cave. This pump releases a lot of waste, such as the oil that directly contaminated the soil and the water. Such residues were released for at least 20 years (Prevorčnik et al. 2012, R. L. Ferreira pers. comm.). In 2010 an electric pump was installed in the cave. According to the villagers, this pump was used to remove water from the cave daily. In one of our surveys this pump was working during all the time we were inside the cave. According to the villagers, this water was used by a local farmer for irrigation (tomato and green pepper). The worrisome fact is the pronounced reduction observed in the base level (at least two meters). In 2012 there was neither withdrawal of water or equipments inside the cave because the CECAV (a Federal government agency that deals exclusively with cave matters), intervened and petitioned the municipal government to dig an artesian well for the village of Gonçalves. However, although the water is no longer been extracted from the cave, it is been

extracted from the water table, thus reducing the water level in the whole water table, what is reducing the water level in the cave areas previously flooded. During the visit to the cave in August 2013 a major reduction in the water level was observed (approximately 3 m compared to the “normal” level), but this might be due also to the long drought period in the region (three years without heavy rainfall).

Discussion

The Brazilian cave fauna began to be relatively well studied from 1980 onwards (Desen et al. 1980); however few caves have been intensively studied. Systematic inventories in the presented caves (AS and TG) have revealed a high diversity of troglobitic species and good potential to discover new species. However, in the studies performed to date on the fauna from more than 2,000 Brazilian caves with approximately 800 troglomorphic/troglobitic species, only the Areias and Toca do Gonçalo systems occupy a prominent position in relation to the number of stygobiotic and troglobitic species (Trajano and Bichuette 2010, Souza-Silva et al. 2015, Cordeiro et al. 2014, Gallão and Bichuette 2015). In addition, TG stands out with 22 troglobitic species found in both terrestrial and aquatic habitats because of its reduced extension and depth (Table 3). Until present, only one cave with small extensions and many recorded troglomorphic species is known in Brazil (MP8, an iron ore cave that has 14 obligate cave species) (Souza-Silva et al. 2011). MP8 cave is a 128 m long cave, although it may be longer if we consider the probable sub-surface system of small space (canaliculi) that make up an extensive network of interstitial spaces (meso- and micro-caves) connected to the macro-caves, making for ferruginous subterranean system habitats with great extensions (Ferreira 2005, Souza-Silva et al. 2011, Hoch and Ferreira 2012).

Accessing the subterranean biodiversity

Toca do Gonçalo cave was less studied than other cave systems in Brazil. The Areias system has been studied for more than 100 years, and its most recently discovered troglobitic species were collected and described by Rodrigues et al. in 2014. The importance of systematic studies for an exhaustive faunal characterization of subterranean system has other clear examples in the world (Deharveng and Bedos 2012, White and Culver 2012). Thus, besides the relevance of spatial accuracy of the search and methods used to collect the fauna, the frequency of sample collections can directly influence the observed richness (Gallão and Bichuette 2015). It is difficult to assume that a macro- or meso-subterranean habitat had its species richness exhausted: new searches will almost always be necessary. As indicated in the species accumulation curves, in both systems the curves did not reached an asymptote, indicating that there are more species to be discovered in the future. The difficulty in sampling subterranean environments are related to the inaccessibility of fissures, mesocaverns, and interstitial habitats

(Culver and Pipan 2009, Trontelj et al. 2012, Ortunó et al. 2013). Thus, there is a clear need for successive collections when one intends to effectively document the subterranean biodiversity. However, we must consider that for comparative studies, methods of rapid evaluation may be used successfully (Souza-Silva et al. 2015, Simões et al. 2015), provided a standardized sampling method has been used. In this case, we can expect that caves with many troglobitic species stand out in relation to the others, even with few collection events. As an example, during our first collection in TG, 63% of the total species currently known was obtained, and such a cave stood out from all the other caves that had been inventoried in the same area. The lack of subterranean biodiversity hotspots in South America may be at least partially attributed to the lack of systematic studies in this continent. Furthermore, the lack of standardized sampling methods may also have hampered the establishment of areas requiring priority for conservation. Additionally, the hotspot concept is somewhat restrictive since it considers, at most, interconnected caves and/or cave systems. In Brazil, although some karstic regions (Pains, Carajás, Apodi, etc.) present high richness of obligate cave fauna, any cave could harbor alone more than 20 species (CEBS-UFLA 2015), as suggested by Culver and Sket (2000). Then, in order to attract attention for sites with representative subterranean communities, we should consider not only caves but the whole representative drainage basin, especially with respect to conservation priorities.

Furthermore, when Culver and Sket (2000) classified the hotspots of subterranean biodiversity they did not consider the degree of threat to which these habitats were submitted, according to the hotspot model proposed by Myers et al. (2000). Places prone to economic activities undergo rapid landscape transformations, and in many cases, these are irreversible. Well-conserved landscapes can quickly be reconfigured as pasture areas or to be destroyed by mining activities. In this sense, the strict use of troglobitic species richness might not necessarily indicate the “health” of a given subterranean system, as this will in fact depend on the type of impact that it has received (Souza-Silva et al. 2015). Accordingly, the degree of impacts to which a cave is threatened should also be incorporated in this concept (as proposed by Myers et al. 2000) and reinforced here, especially considering that conservation policies usually act towards investing in priorities. Richer systems are certainly more threatened, thus deserving priority actions for their conservation (Souza-Silva et al. 2015). In the case of the two hotspots of subterranean biodiversity presented in this work, Toca do Gonçalves certainly should have priority in conservation policies, considering the degree of threat to which it is exposed (even though possessing fewer troglobitic species than the Areias cave system, which is already, at least partially, protected).

Global relevance of the two Neotropical hotspots of subterranean biodiversity

Compared to other places in the world, South America stands out with only 5% of the 38 subterranean biodiversity hotspots, similar to southeastern Asia and Australia. The regions with higher densities and more species of aquatic and terrestrial obligate cave fauna are in

Europe (47% of the hotspots), North America, and the Canary Islands (15.7% each). Besides geographic influences on the distribution of subterranean hotspots, the cave extension (caves with more than 5 km of extension) and high productivity (chemoautotrophic production, roots, debris) are also important for determining the biodiversity.

Other explanations for high biodiversity in subterranean habitats are cases of colonization through adaptive shift in dry caves or permanent groundwater, springs, rivers, shallow subterranean habitats or epikarst (Culver and Sket 2000, Culver and Pipan 2009 and 2013). This is not the cause of diversity, but one path of colonization that could also explain the diversity in other subterranean habitats. Deharveng and Bedos (2012) suggested as one emerging biodiversity pattern in the tropics, that the richness of troglobionts or guanobionts is rarely very low and never null as in temperate regions, affected by glaciations. However, in fact, most of the Brazilian caves do not harbor any troglobitic/guanobitic species. According to those authors, the scarcity in troglobitic species is also observed in other countries of tropical America, except for some areas in Guatemala, Belize, and Mexico, for which dozens of troglobitic species are in fact known (Reddell 1981, Reddell and George 1996). However, it is important to highlight the huge contribution of anchialine and aquatic relict fauna to the richness of subterranean fauna in such countries (Iliffe 1993, Alvarez et al. 2015).

The high number of obligate cave species recently described in Brazil, and hundreds of troglobitic species still waiting to be described, also contradict Deharveng and Bedos (2012), who suggested that the terrestrial fauna appears to be more diverse in the Oriental and Australian regions than in the Neotropics or Africa. The fact that many subterranean species have been discovered in the last years in Brazil does not mean that many Brazilian caves harbor obligate cave species. In fact, from the approximately 2,000 sampled caves in Brazil, only a few hundred are inhabited by obligate cave fauna. The recent discoveries of troglobitic species in Brazil are certainly due to an improvement on the sampling efforts in many previously non-prospected areas in Brazil (Prevorčnik et al. 2012, Ázara and Ferreira 2013 and 2014, Fišer et al. 2013, Iniesta et al. 2012, Iniesta and Ferreira 2013, 2013a, 2013b and 2015, Bastos-Pereira and Ferreira 2015, Vasconcelos and Ferreira 2016).

Another situation that was mentioned by Deharveng and Bedos (2012) is the absence of MSS ("Milieu Souterrain Superficiel", Juberthie and Decu 1994) in the tropics. However, in Brazil, the canaliculi systems of ferruginous rocks may well function as an MSS, also influencing the isolation and diversification of the subterranean fauna in the tropics (Ferreira et al. 2015), but these shallow habitats are restricted to ferruginous rocks (Souza-Silva et al. 2011) which represent 0.15 % of the Brazilian territory, nearly 12,000 km² (Vieira et al. 2015).

Conservation and protection of the two Neotropical hotspots

The AS and TG undergo human alterations from past and present activities and deserve special and urgent attention regarding further research and protection.

In 1970 the speleologist Guy Collet installed water tanks within the Ressurgência das Areias Cave in order to construct the first subterranean laboratory in Brazil (Trajano 2007). In addition, G. Collet installed a plastic curtain at the cave entrance to prevent the external light to access the inner portions of the cave, even near the entrance. However, the curtain installation affected the transit of bats in the cave and therefore affected the guano production. To populate the tanks, he collected dozens of blind catfish (*Pimelodella kronei* Ribeiro, 1907) that did not survive. The subterranean laboratory was disabled some years later.

Surrounding the Parque Estadual Turístico do Alto Ribeira (PETAR) there are land occupation and poorly planned land uses, in addition to non-controlled visitation endangering not only the surface land systems, but also the integrity of the associated hydrologic systems, including the subterranean environment (Genthner et al. 2007). Protecting the subterranean fauna also requires the protection of the surface riparian areas, including the upstream cave sources (Ford 2005, Reboleira et al. 2011, Pellegrini et al. 2016). Protection of deep-groundwater species requires protection from both excessive draw further down the system and contamination of the aquifer (Culver and Pipan 2013). Protecting the troglobites that rely on the flow of organic matter via the cave entrance includes the protection of the entrance area and any foraging area of the species responsible for bringing organic matter into the cave (Souza-Silva et al. 2011a, Culver and Pipan 2013, Prous et al. 2015).

Terrestrial habitats of the biodiversity hotspots generally contain large numbers of species with small ranges that are potentially vulnerable to global extinction. In these systems, site-specific conservation efforts are a justifiable priority (Hughes et al. 2002, Reboleira et al. 2011, Souza-Silva et al. 2015).

Final considerations

The tropical region, with both its diversity of rocks and subterranean habitats, has a high potential for finding new biodiversity hotspots. Although only two hotspots have been identified in Brazil until now in this paper, many others may exist and perhaps they are even more threatened or near-threatened in the near future. Besides the lack of researchers and investment in cave studies in Brazil, almost half of the studied subterranean environments were sampled only once and the collection methods were restrict to the terrestrial fauna. Furthermore, there are many karst regions in Brazil with a high richness of obligate cave fauna which desperately deserve attention.

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A new interstitial species of diving beetle from tropical northern Australia provides a scenario for the transition of epigean to stygobitic life (Coleoptera, Dytiscidae, Copelatinae)

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Abstract

Exocelina saltusholmesensis **sp. n.** is described from a single female collected in Holmes Jungle Reserve near Darwin in the Northern Territory, Australia. Phylogenetically, the new species is sister to a clade containing the epigean *E. ferruginea* (Sharp, 1882) and *E. punctipennis* (Lea, 1899) but well characterized by its smaller size, the much smaller eyes, vestigial wings and paler surface. *Exocelina saltusholmesensis* **sp. n.** was collected from a small pool in an intermittent and temporary small creek. The collecting circumstances suggest that this is an interstitial species, with morphological characters interpreted as adaptations to a strongly hidden if not mostly subterranean lifestyle.

Keywords

Beetles, interstitial aquatic fauna, adaptation to subterranean life

Introduction

The diving beetle genus *Exocelina* contains more than 140 described species, most of them in New Guinea and New Caledonia (Toussaint et al. 2014, 2015; Nilsson 2015). The majority of species occur in habitats associated with streams, but there were also four transitions to stagnant water habitats (Toussaint et al. 2015). Two highly derived stygobitic Australian species have been described to date, *Exocelina abdita* Balke et al. 2004 from Newhaven Station, Camel Bore, Northern Territory and *E. rasjadi* Watts & Humphreys, 2009 from Tjukurla calcrete, Lake Hopkins palaeovalley, Western Australia. Both species are blind (Fig. 2B, 3C), have vestigial wings, are depigmented and show a more or less pronounced constriction between base of pronotum and elytra (Fig. 2B) which is linked to reduction of flight muscles (Balke et al. 2004, Watts and Humphreys 2009). Another rarely collected Australian species, *Exocelina australis* (Clark, 1863), has smaller eyes than typical epigeic species and is only lightly pigmented (Fig. 2A). This might indicate a hidden, interstitial lifestyle. The collection of the species from hyporheic environments of a number of localities in the Flinders Range also hints in this direction (Leys et al. 2010).

Here, we describe a new species collected from a small pool in the bed of a slowly flowing wet-season creek near Darwin. Morphological features such as reduced eyes and vestigial wings, light pigmentation and absence of the species from other nearby water bodies suggest this is an interstitial species providing a scenario for the transition from epigeic to stygobitic life. This discovery highlights the hidden diversity of an underexplored habitat.

Methods

Morphological observations were made and measurements were taken with a Leica M205 C stereomicroscope. Specimens were illuminated by a diffuse 13W fluorescent double light tube.

A DNA sequence of the 3' fragment of the mitochondrial cytochrome oxidase 1 gene was generated by Remko Leys at the South Australian Museum in Adelaide, using the oligonucleotide primers Jerry and Pat (TCC AAT GCA CTA ATC TGC CAT ATT A / CAA CAT TTA TTT TGA TTT TTT GG).

Digital images were taken with a Nikon D3X equipped with a bellows or expansion rings and lenses: Mitutoyo 10x ELWD Planapo or Leitz Photar 25/2.8. Illumination came from three compact Nikon flashes, and the instrument was moved on an Isel linear drive (<https://www.isel.com/at/lineareinheiten-les6.html>) or Cognisys Stackshot (for very small steps 1–7 µm) (www.cognisys-inc.com). Image stacks were combined using the method A in Helicon focus software (www.heliconsoft.com).

Results

Family Dytiscidae Leach, 1815

Genus *Exocelina* Broun, 1886

Exocelina saltusholmesensis sp. n.

<http://zoobank.org/90C3C890-B056-4AA3-9A3D-82CB91BA2D0B>

Figs 1, 3

Type locality. Small seasonal creek [-12.400714° 130.931297°], Holmes Jungle Reserve, Darwin, Northern Territory, Australia.

Type material. Holotype, female (South Australian Museum Adelaide, SAMA): “Australia, Northern Territory, Darwin, Holmes Jungle Reserve, -12.400714° 130.931297°, 25. March 2004, C.H.S. Watts (SAMA database no. 25-012926)”. The beetle was originally labelled as “*Copelatus* sp.nov.” by C.H.S. Watts and has now a red, printed holotype label attached in addition.

European nucleotide archive (genbank) accession number for the 3’ end of the mitochondrial cytochrome c oxidase 1 gene: www.ebi.ac.uk/ena/data/view/LN994839

Description. *Size and shape:* Beetle small (length of beetle 3.7 mm, greatest width 1.8 mm, length of pronotum 0.6 mm, width of pronotum at base 1.7 mm), comparably parallel-sided (Fig. 1C).

Coloration. Mainly testaceous and slightly translucent with lighter band on elytral base and darker area in middle basal area of pronotum (Fig. 1C).

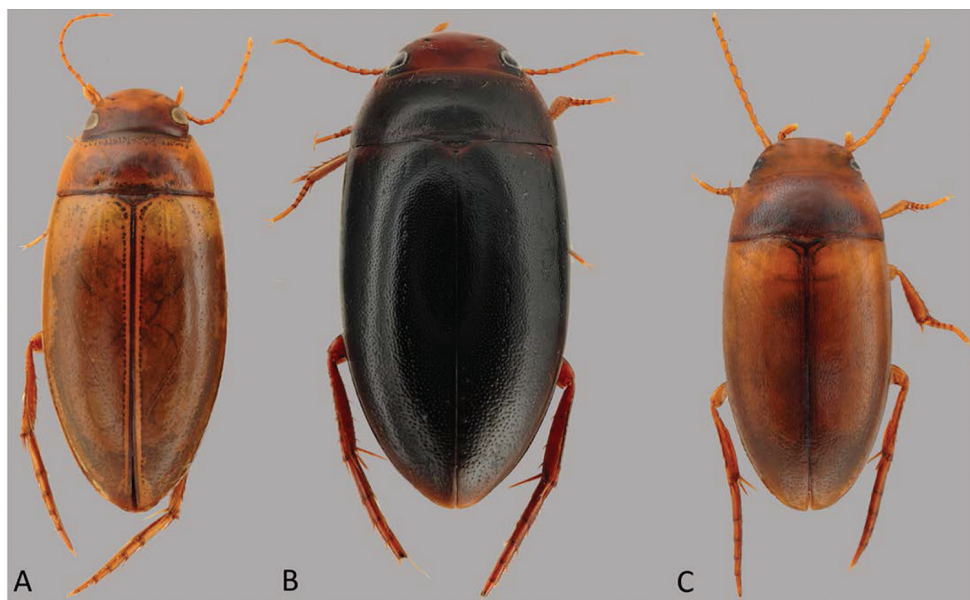


Figure 1. Habitus of *Exocelina* species: *E. ferruginea* (A), *E. punctipennis* (B), *E. saltusholmesensis* sp. n. (C).

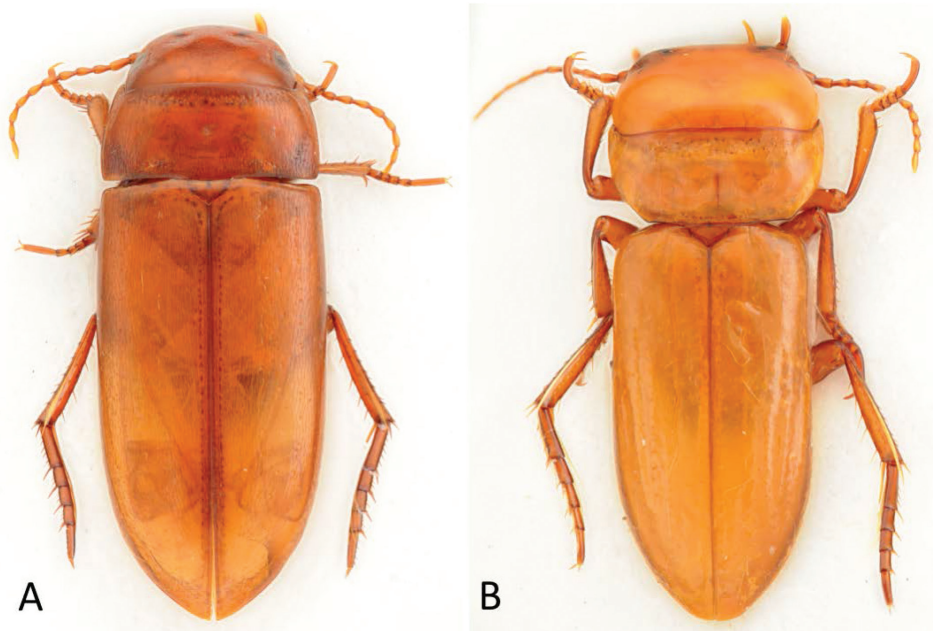


Figure 2. Habitus of *Exocelina* species: *E. australis* (A), *E. abdita* (B).

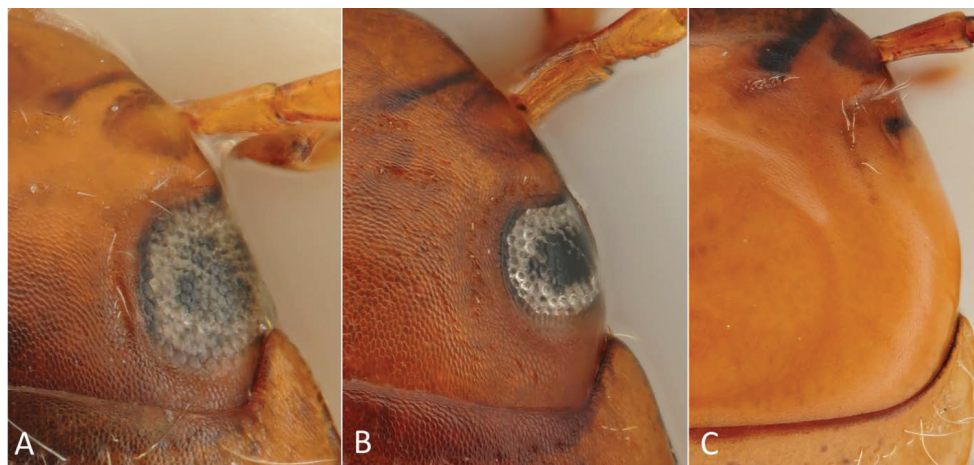


Figure 3. Right lateral aspect of head of *Exocelina* species: *E. ferruginea* (A), *E. saltusholmesensis* sp. n. (B), *E. abdita* (C).

Surface sculpture. Head (frons), pronotum and elytra striolate; with distinct microreticulation and coarser punctation. Metacoxal plates and ventrites 1–4 with few striae, otherwise with fine microreticulation and few punctures. The sixth (apical) ventrite broadly rounded.

Structures. Eyes small in comparison to epigeal *Exocelina*, length of eye *c.* 0.16 mm, distance between eyes *c.* 0.86 mm (Figs 1C, 3B). Pronotum with faint lateral

bead that does not reach anterior corner. Prosternal process lanceolate, gently rounded ventrally; lateral wings of metaventrite narrow. Flight wings vestigial.

Male. Unknown.

Etymology. The name is an adjective is the nominative singular derived from the locality name – Holmes Jungle. Latin: saltus = woodland.

Differential diagnosis. The species is sister to a clade containing *Exocelina punctipennis* (Lea, 1899) and *E. ferruginea* (Sharp, 1882) established based on DNA sequence data (Toussaint et al. 2015), but both these species are larger (> 5 mm), and have larger eyes (Figs 1A–C, 3A, B). Both are epigeal species, distributed along the eastcoast of Queensland (*E. punctipennis*) and the Adelaide Hills in South Australia (*E. ferruginea*) (Hendrich et al. in prep.). They are also fully winged.

Habitat. A small pool in the bed of a small ephemeral creek through eucalypt woodland. A small eyed, wingless Hydraenidae (*Hydraena watti* Perkins, 2007) was collected at the same time (Perkins 2007). During the dry season (June–September) this creek dries out. However, we assume that subsurface water remains in the watercourse during this season providing an interstitial habitat for these flightless, low vagility species.

Discussion

A number of West Palearctic diving beetle species are known from wells or from the interstitial of gravel banks along rivers. These were classified as semi-subterranean or interstitial species. Morphological characters hinting at this include the reduction of eyes, depigmentation, presence of long sensory setae and the reduction of wings (e.g. Fery et al. 2012; Hernando et al. 2012; Manuel 2013).

While the Australian ground water fauna is well studied and is now known to harbour a considerable diversity of diving beetle species (Watts and Humphreys 2009 and previous; Leys et al. 2003; Balke et al. 2004; Watts and Leijes 2005). Interstitial habitats remain much less explored although already known to contain specialised species (e.g. *Limbodessus rivulus* (Larson, 1994), apterous species of *Carabhydrus* Watts, 1978 (Hendrich and Watts 2009), *Limbodessus occidentalis* (Watts & Humphreys, 2004)). Here we add another candidate from interstitial fauna that might document the first steps into fully underground habitats and highlights the need for focused investigations of such habitats in Australia and beyond.

Acknowledgements

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Hymenoptera from caves of Bakony Mountains, Hungary – an overlooked taxon in hypogean research

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Abstract

There are no known troglobiotic hymenopterans, although a few species regularly occur in caves, usually for an inactive phase of their life-cycles. During a recent faunistic survey of the invertebrate fauna of Bakony Mountains' caves (Hungary) several Hymenoptera specimens were collected in hypogean environments. In this paper we report the results of the survey regarding Hymenoptera. Although the Hymenoptera material was small in numbers, they provided valuable faunistic data: very rare or rarely collected species were found, and 5 taxa are first reported from hypogean environment. *Aclastus longicauda* Horstmann (Ichneumonidae: Cryptinae) was found new to the Hungarian fauna, considerably extending the distributional area of this species that has been known only from Northern Europe so far. Our local results clearly indicate that, both at local and world-wide level, research focusing on the usually overlooked Hymenoptera fauna of caves will certainly provide valuable faunistic, distributional and biogeographical data.

Keywords

Aclastus, Ichneumonidae, Braconidae, Proctotrupidae, Embolemidae

Introduction

There are no known troglobiotic hymenopterans, although a relatively few species are known to regularly occur in caves, usually for executing an inactive phase of their life-cycle. From the hundreds of thousands described hymenopteran species only about 200–250 species

have been reported to be associated with hypogean environments (see e.g. Decu et al. 1998, Moldovan 2004). Presumably this number is greatly underestimated due to the following reasons: (i) usually zoologists studying troglobiotic animals are not specialized in Hymenoptera, hence do not consider to collect and/or identify the hymenopterans, as they are not troglobiotic animals; (ii) Hymenoptera specialists usually do not collect in hypogean environments; and (iii) even if there is collected material, there are relatively few specialists who are able to reliably identify the specimens of the most commonly collected, very diverse groups of parasitoid wasps. For these reasons, the literature on Hymenoptera of cave environments is rather scarce and sporadic. The aim of this work is to contribute to the knowledge the Hymenopteran fauna of Middle European caves, and to facilitate future studies by drawing the attention to this poorly discovered topic.

In 2009 the Bakony Museum (BM) of the Hungarian Natural History Museum (HNHM) and the local caver clubs started to investigate the cave fauna of the Bakony Mountains (Veszprém County, Hungary). Some of these caves were never studied before by zoologists. The results have already been reported in some parts (see e.g. Szabó et al. 2013, Disney 2014, Novák and Kutasi 2014). Several Hymenoptera specimens were also collected in these hypogean environments; in this paper we report the results of the survey regarding Hymenoptera.

Methods

Between 2009 and 2012 invertebrates were collected in five caves in the Bakony Mountains. The studied caves belong to the authority of the Balaton-felvidéki National Park, and they are partly open to the public (Fig. 1).

The Csodabogyós Cave (46°47.822'N; 17°21.873'E, ca 400 m, investigated between 17 December 2009–13 January 2011, and 22 July–5 October 2011) is situated at Balatonederics, in the Keszthely Mts. which is part of the Bakony Mts. The cave was formed in the Late Triassic period in Ederics Limestone formation. It is a 5200 m long and 121 m deep cave with a multi-level system of fissures. The cave chambers are decorated with various dripstone formations, therefore it has been strictly protected since 1992 (Kárpát 2003, Anonymous 2012).

The Lóczy Cave (46°58.140'N; 17°52.409'E, ca 250 m, investigated between 25 November 2010–26 March 2012) is near Balatonfüred. It was discovered in 1882. The 154 m long and 15 m deep cave was formed by upwelling thermal water in Füred Limestone in the Late Triassic period, and it is strictly protected since 1982 (Hazslinszky 2003, Anonymous 2012). The Takó Cave (47°11.702'N; 17°54.974'E, ca 350 m, investigated between 6 March 2009–30 January 2010) is near Eplény; it is a 60 m long limestone cave (Anonymous 2012).

The Kőlik Cave (47°06.105'N; 17°44.892'E, ca 370 m, investigated between 25 March 2011–25 October 2012) is situated at Szentgál; it is 420 m long and 39 m deep. This limestone cave is strictly protected since 1993 (Anonymous 2012). The Kapolcsi Pokol Hole (46°56.823'N; 17°35.302'E, ca 270 m, investigated between 28 March

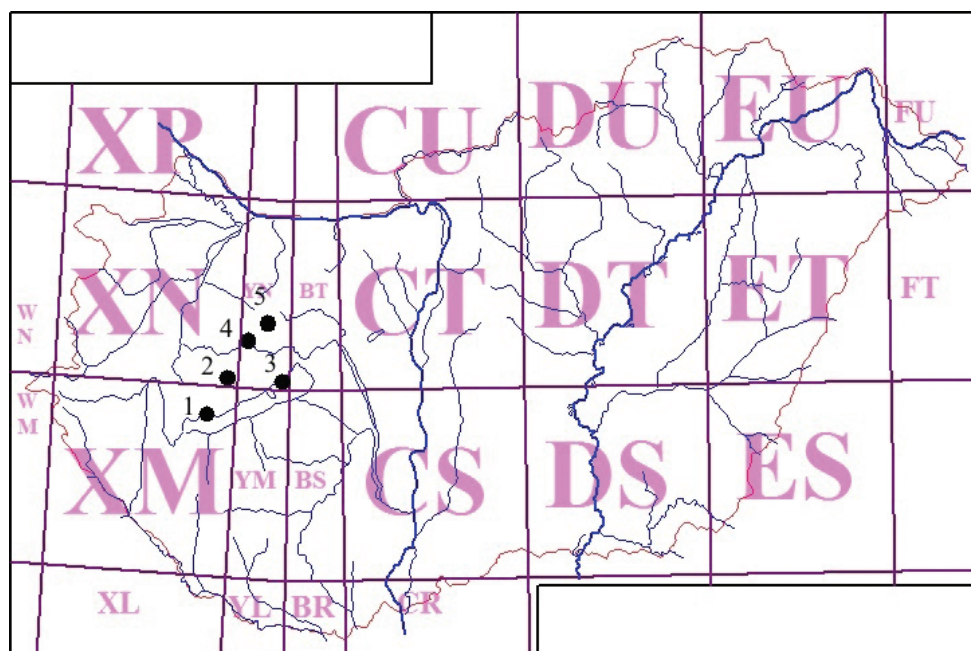


Figure 1. Location on the studied caves in Hungary: **1** Csodabogyós Cave (Balatonederics) **2** Pokol Hole (Kapolcs) **3** Lóczy Cave (Balatonfüred) **4** Kőlik Cave (Szentgál) **5** Takó Cave (Veszprém).

2012–22 May 2013) is a 56 m long tectonic basalt cave. The thick basalt blocks the seeping water, which therefore emerges as a spring.

The invertebrates were collected by 250 cm³ volume pitfall traps filled with ethilenglicol in each cave. Traps were situated from the entrance of the caves till the last approachable parts; average number of traps was 15 per caves, and they were working for a year. Stinking cheese was used as bait material.

The collected Ichneumonidae, Proctotrupidae and Embolemidae material was identified by the first author using a Nikon SMZ645 stereoscopic microscope; a specimen belonging to Braconidae was identified by Dr. Jenő Papp. The identification was based on keys provided by Hellén (1941), Constantineanu (1959), Townes et al. (1965), Townes (1970, 1971), Pschorn-Walcher (1971), Horstmann (1980), Townes and Townes (1981), Wahl (1993), Achterberg and Kats (2000), and Broad (2011). Earlier records of the species in the Hungarian fauna were checked in Mocsáry (1886, 1897), Olmi (1999), Papp (2005), and Yu et al. (2012). The material is deposited in HNHM.

Results and discussion

Below we list the species found in the caves of Bakony Mountains. Taxa are listed in alphabetical order. Distributional and biological and/or taxonomical remarks are

given following the collecting data of each species. English translations of the names of rooms and branches within the caves are given in brackets. Distance of the collecting site from the cave entrance is abbreviated as DFE.

Chrysidoidea: Embolemidae

***Embolemus ruddii* Westwood, 1846**

Material examined. Hungary, Veszprém County, Balatonfüred, Lóczy Cave, Középső-kar [Middle-branch], DFE: 50 m, 29 April 2011–28 June 2011, leg. L.T. Katona & Cs. Kutasi, 1 ♀; same location, 25 September 2011–26 March 2012, leg. Zs. Csermák, L.T. Katona & Cs. Kutasi, 1 ♂; Hungary, Veszprém County, Szentgál, Kőlik Cave, Bagolyvár [Castle of the Owl], DFE: 16 m, 27 November 2011–24 March 2012, leg. Zs. Csermák & L.T. Katona, 1 ♀.

Remarks. Little is known about the biology of this widespread but rare Palaearctic species. Based on rearing data from relatives might be a parasitoid of homopteran larvae (Olmi 1999); however, there are several observations which suggest some relation to ants (Achterberg and Kats 2000). The wingless females regularly occur in mole and ant nests, and under stones; however, this species has also been reported from caves (Sebald and Weber 2013). It is known that females overwinter as adults (Gauld and Bolton 1988); considering collecting dates, they might hibernate in the caves.

Ichneumonoidea: Braconidae

Subfamily: Blacinae

***Blacus longipennis* (Gravenhorst, 1807)**

Material examined. Hungary, Veszprém County, Kapolcs, Pokol Hole, DFE: 4 m, 5 July 2012–13 November 2012, pitfall traps no. 1–3, leg. Cs. Kutasi, 1 ♀.

Remarks. Widespread Palaearctic species, and an endoparasitoid of coleopteran hosts (Anobiidae, Cerambycidae) (Yu et al. 2012). This species is first reported here in association with hypogean environment; some members of this genus are known to overwinter as adults (Johnson 1920); it might be a reason of its presence in caves.

Ichneumonoidea: Ichneumonidae

Subfamily: Cryptinae

***Aclastus longicauda* Horstmann, 1980**

Material examined. Hungary, Veszprém County, Balatonfüred, Lóczy Cave, Felső-terem [Upper-room], DFE: 38 m, 11 June 2011–25 September 2011, leg. Zs. Csermák, 1 ♀.

Remarks. First record in the Hungarian fauna. This species has been described from Sweden (Horstmann, 1980), and besides Sweden it has only been reported from Finland (Jussila, 1989) so far. The presence of this species in Hungary suggests a much more widespread distribution within Europe than it was apparent before. Additionally, this species is first reported here in association with hypogean environment. No particular host of *Aclastus longicauda* is known; however, based on data from close relatives it might be an idiobiont parasitoid of spider egg sacs (e.g. Amaurobiidae, Linyphiidae, Micryphantidae) (Horstmann 1980, Finch 2005, Yu et al. 2012). This phenomenon also could explain its occurrence in caves: it may search for spider eggs sacs there.

Subfamily: Ichneumoninae

Diphyus quadripunctorius (Müller, 1776)

Material examined. Hungary, Veszprém County, Balatonederics, Csodabogyós Cave, Poroltó [Fire Extinguisher], DFE: 6 m, 17 December 2009–27 February 2010, leg. L.T. Katona, 3 ♀♀; same location, 27 February 2010–5 June 2010, leg. L.T. Katona, 1 ♀; same location, 5 June 2010–19 October 2010, leg. L.T. Katona & Zs. Csermák, 3 ♀♀; Hungary, Veszprém County, Szentgál, Kőlik Cave, Felső-terem [Upper-room], DFE: 3 m, 25 March 2011–29 July 2011, leg. L.T. Katona & A. Piri, 1 ♀; same cave, Cseppköves-terem [Dripstones Hall], DFE: 8 m, same date and collectors, 1 ♀; same cave, Nagy-terem [Great Hall], DFE: 9 m, same date and collectors, 1 ♀; same cave, Cseppköves-terem [Dripstones Hall], DFE: 8 m, 27 November 2011–24 March 2012, leg. Zs. Csermák & L.T. Katona, 1 ♀; same cave, Nagy-terem [Great Hall], DFE: 9 m, same date and collectors, 1 ♀.

Remarks. Common and widespread species throughout the Western Palaearctic region (Yu et al. 2012); the most common hymenopteran found in European caves and artificial subterranean environments such as cellars (Novak et al. 2010). This species is a parasitoid of various caterpillar hosts (mainly Noctuidae and Geometridae), and females overwinter as adults (Constantineanu 1959, Yu et al. 2012).

Eutanyacra jucunda (Kriechbaumer, 1882)

Material examined. Hungary, Veszprém County, Kapolcs, Pokol-Hole, DFE: 4 m, 5 July 2012–13 November 2012, pitfall traps no. 1–3., leg. Cs. Kutasi, 1 ♀.

Remarks. A very rare species described and known only from the Carpathian Basin (Kriechbaumer 1882, Mocsáry 1886, Constantineanu 1959). This species is first reported here in association with hypogean habitat. No specific details are known about its biology; however, other *Eutanyacra* species are parasitoids of various caterpillar hosts (mainly Noctuidae), and the females overwinter as adults (Constantineanu 1959, Rasnitsyn 1964, Yu et al. 2012).

Subfamily: Ophioninae***Ophion obscuratus* Fabricius, 1798**

Material examined. Hungary, Veszprém County, Pénzesgyőr, Tilos-erdei Cave, 1 December 2013, leg. S. Tóth, 1 ♀.

Remarks. This specimen has already been reported, however misidentified as *Ophion luteus* (Linnaeus, 1758), by Tóth (2015). Hence, we publish the correction of that record here. *Ophion obscuratus* is a common and widespread species throughout the Western Palearctic region (Yu et al. 2012). This species is a nocturnal koinobiont endoparasitoid of various lepidopteran hosts (e.g. Győrfi 1943, Brock 1982). The autumn generation can be found on the wing in autumn, winter, and early spring. Its presence in caves might be due to overwintering. To our best knowledge this species is first reported here in association with hypogean environment.

Subfamily: Orthocentrinae***Stenomacrus* sp.**

Material examined. Hungary, Veszprém County, Balatonederics, Csodabogyós Cave, Óriás-terem [Giant-hall], DFE: 38 m, 17 December 2009–27 February 2010, leg. L.T. Katona & Cs. Kutasi, 1 ♀; same cave, Függőkert [Hanging Garden], DFE: 60 m, same date and collectors, 1 ♀; same cave, 5-ös terem [5-room], DFE: 58, same date and collectors, 1 ♀; same cave, Bezengő [Sounding], DFE: 50 m, same date and collectors, 1 ♀; same cave, Szív-terem [Heart-hall], DFE: 35 m, 27 February 2010–5 June 2010, leg. L.T. Katona, 1 ♀; same cave, Meseország [Wonderland], DFE: 45 m, same date and collectors, 1 ♀; same cave, Feneketlen hasadék lejárata [Entrance of Bottomless Chasm], DFE: 30 m, 5 June 2010–19 October 2010, leg. L.T. Katona & Zs. Csermák, 1 ♀; same cave, Szív-terem [Heart-hall], DFE: 35 m, 22 July 2011–5 October 2011, leg. L.T. Katona & Cs. Kutasi, 4 ♀♀; same cave, Óriás-terem [Giant-hall], DFE: 38 m, same date and collectors, 1 ♀; same cave, Meseország [Wonderland], DFE: 45 m, same date and collectors, 1 ♀; Hungary, Veszprém County, Szentgál, Kőlik Cave, Felső-terem [Upper-room], DFE: 3 m, 25 March 2011–29 July 2011, leg. L.T. Katona & A. Piri, 1 ♀.

Remarks. Since Aubert (1981)'s revision no comprehensive identification key has been published to the genus, although several new species have been described from Europe (e.g. Kolarov 1986, Jussila 1996). Currently, 50 species of the genus are known from Europe (Yu et al. 2012). By using Aubert (1981)'s key the species found in the caves could not be convincingly identified. They seem to be close to *Stenomacrus laricis* (Haliday, 1838); however, reliable identification might not be possible without a new revision of the Western Palearctic species of the genus. Based on some rearing records

Stenomacrus species seems so be larval and/or pupal endoparasitoids of Sciaridae and Mycetophilidae (Townes 1971, Gauld and Bolton 1988). To our best knowledge this genus is first reported here in association with hypogean environment.

Proctotrupoidea: Proctotrupidae

Exallonyx longicornis (Nees, 1834)

Material examined. Hungary, Veszprém County, Veszprém, Takó Cave, DFE: 8 m, 8 July 2009–18 November 2009, leg. Cs. Kutasi & L.T. Katona, 7 ♀♀; same location, 18 November 2009–5 December 2009, same collectors, 1 ♀.

Remarks. *Exallonyx longicornis* is the most common proctotrupid wasp found in European caves; the females execute there their summer and winter rest in large abundance (Novak et al. 2010). This species is an endoparasitoid of rove beetles (Staphylinidae) (Gauld and Bolton 1988).

Conclusions

Although no troglobiotic hymenopteran species are known, our results suggest that more species are associated with hypogean environment for a shorter or longer phase of their life-cycles than expected. The most probable explanation is that troglobiotic faunistical surveys rarely consider to collect and/or identify the hymenopteran specimens from caves as they are regarded as outsiders of the cave environments. Nevertheless, not only some very rare wasp species (such as *Eutanyacra jucunda*) were found in the caves of Bakony Mts., but this material greatly extended our knowledge of the geographical distribution of an ichneumon wasp species (i.e. *Aclastus longicauda*), and 5 hymenopteran taxa were recorded from cave environment for the first time. Our local results clearly indicate that, both at local and world-wide level, research focusing on the Hymenoptera fauna of caves will certainly provide valuable faunistical, distributional and biogeographical data.

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Predation of *Desmodus rotundus* Geoffroy, 1810 (Phyllostomidae, Chiroptera) by *Epicrates cenchria* (Linnaeus, 1758) (Boidae, Reptilia) in an Ecuadorian Cave

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Abstract

Bats are mammals of the Order Chiroptera. They are highly adaptable to several habitats and their ecology makes them vulnerable to predators. Bats are a common prey of snakes, but description of this kind of predation are rare. This study describes the event of predation of an *Epicrates cenchria* on a *Desmodus rotundus*, in a cave in Tena, Ecuador. Records of *Desmodus rotundus* are known from caves just as *Epicrates cenchria*. Castillo Cave has a total mapped length of 450 meters. The phase of constriction lasted for 10 min 2 s, a duration superior than other studies, due to the size of *Desmodus rotundus*. The terrestrial locomotion behavior of *D. rotundus*, makes it an easy target for *E. cenchria*. The predation event occurred on the floor, a rare case, which has not been described in other events of predation in caves. The cave is located in a disturbed habitat, because it is irrigated by wastewaters. But both species seems to be adapted to the environment. This study confirms that predation of bats in caves by snakes does occur.

Keywords

Bat predation, boids, behavior, attack

Introduction

Bats are mammals of the Order Chiroptera. They are highly adaptable to several habitats: trees (Jachowski et al. 2016), under plantain leaves (Rodríguez-Herrera et al. 2011), caves (Zortea et al. 2015), human settlements (Whitaker et al. 2006, Streicker et al. 2013), etc. Like most animals, they are not predator free. There is a list of enemies mentioned in the literature: monkeys, lorises, mustelids (weasels), minks (Goodpaster and Hoffmeister 1950), raccoons, opossums, cats and even bats themselves. Mikula (2015) recently published a literature review of different fishes (such as salmon, catfishes and sharks) that prey on bats; and amphibians such as Bufonidae, Hylidae and Leptodactylidae, prey on bats too. Giant centipedes were also observed killing bats in a cave in Venezuela (Molinari et al. 2005). Spiders have been recently suggested that their predation on bats is not that uncommon (Nyffeler and Knörnschild 2013). But the most common predators are birds and snakes (Hill and Smith 1984, Mickleburgh et al. 1992). Within birds we can mention raptors such as *Accipiter tachiro*, *Aquila walkbergi*, *Falco subbuteo*, hawks (Lee and Kuo 2001) and owls (Julian and Altringham 1994) such as *Asio stygius* (Motta Junior and Taddei 1992), and *Tyto alba* (Vargas et al. 2002), but there are events of other types of birds such as *Momotus momota* preying on a bat (Chacón-Madrigal and Barrantes 2004). Within snakes we can mention the case reported by Hammer and Arlettaz (1998), another in western Iran by a Colubridae (Sharifi et al. 2014). Esbérard and Vrcibradic (2007) made a review of recorded cases for the neotropical region, but we can also name a more recent case of *Hemorrhhois hippocreps* preying on *Plecotus austriacus* and on *Eptesicus serotinus* (Schreber, 1774) / *Eptesicus isabellinus* (Temminck, 1839) (Garrido-García et al. 2013). Two observations were reported in caves in Mexico where snakes caught bats hanging off the roof (BBC 2014, BBC Earth 2014).

Desmodus rotundus (common vampire) is one of three sanguivorous bat species (Simmons 2005, Kwon and Gardner 2007), that habits mainly in caves but also can be found in tree holes (Pozo and Cueva pers. comm.). Normally they attack their prey flying stealthy and perching on the dorsal face of large mammals like cows, tapirs, deer and peccaries (personal observations). *D. rotundus* is distributed from North of Tamaulipas and Sonora (México) to Uruguay, northern Argentina and central Chile (Greenhall et al. 1983). In Caribbean Islands is found only in Trinidad (Mancina, pers. com.) and Margarita Islands (Wilson and Reeder 2005). Ecuadorian subspecies belong to *Desmodus rotundus rotundus* (Greenhall et al. 1983) which it has been recording in all geographic altitudes zones (Albuja-V et al. 2012). *Desmodus* in the day rests perching on the roof of the caves, but occasionally are found walking on the floor when they are accidentally dropped from roof (Wilmer E. Pozo-Rivera Observations). Over the floor *Desmodus* recently awake, walk helping with their legs and elbows.

Epicrates seems to be a major threat to bats on the neotropics. Half of the records published on the review made by Esbérard and Vrcibradic (2007) involving boid snakes species were *Epicrates* sp. *Epicrates cenchria* is endemic to Central and South America (McDiarmid et al. 1999). Ecuador has the subspecies *Epicrates cenchria gaigei* (Uetz and Hallermann 2016). It is described as a medium sized (Duellman 1978, Ross and Marzec 1990) terrestrial nocturnal snake (Savage 2002). Characterized by having a blue iridescence in sunlight, this viviparous snake was found in primary and secondary forest, on the ground and on the trees (Duellman 1978). But is also very common to find this species close to rivers where food is abundant (Gonzálves 2006). Birds, rodents, and bats (Lemke 1978, Medeiros de Pinho et al. 2009, Pizzatto et al. 2009) are common preys of *Epicrates cenchria*.

We report the first record of predation of *Desmodus rotundus* (Common Vampire Bat) by *Epicrates cenchria* (Rainbow Boa) in a cave in Ecuador.

Methods

The predation event was observed in the late afternoon of the 5th of December 2015 during 25 minutes and mostly filmed during the regular cave monitoring of the Castillo Cave, near the city of Tena, in Napo province (Fig 1).

Geological setting of Castillo Cave

The area around the city of Tena is predominantly covered with deposits (200-700 m) of the Napo Formation, which consists of cyclic sequences of limestones, shales, and sandstones deposited on a low-energy shallow marine platform between the Albian and the Campanian (Estupiñán et al. 2010).

The Napo karst may be considered a shallow one, with direct infiltration of surface streams along lithological contacts such as those between limestones and shales or between different types of limestones. Due to the thinness of the lithological units and their alteration, often “superposed underground streams” are encountered that use different lithological contacts among the same formation. The Castillo Cave has total mapped length of 450 m and three exits-entrances, being a western, a central and an eastern end. The meandering form of the cave is truncated by a river, which flows from north to south. The maximum height in one of the open chambers along the corridors is of approximately three meters. In such chambers rests the highest populations of bats (unidentified species).

One of the entrances of the Castillo Cave is only 60 m in distance of a major paved road in the outside area of Tena city, but the surface karst morphology of the cave is hidden by the dense jungle forest, having the corresponding diverse flora and wildlife. The inner cave fauna include a typical cave fauna: mammals (chiroptera), reptiles, amphibians, arthropods, actinopterygii (Peck 1985, Peck 1994, Romero and Paulson 2001, Hoese G et al. 2015, Toulkeridis et al. 2015).

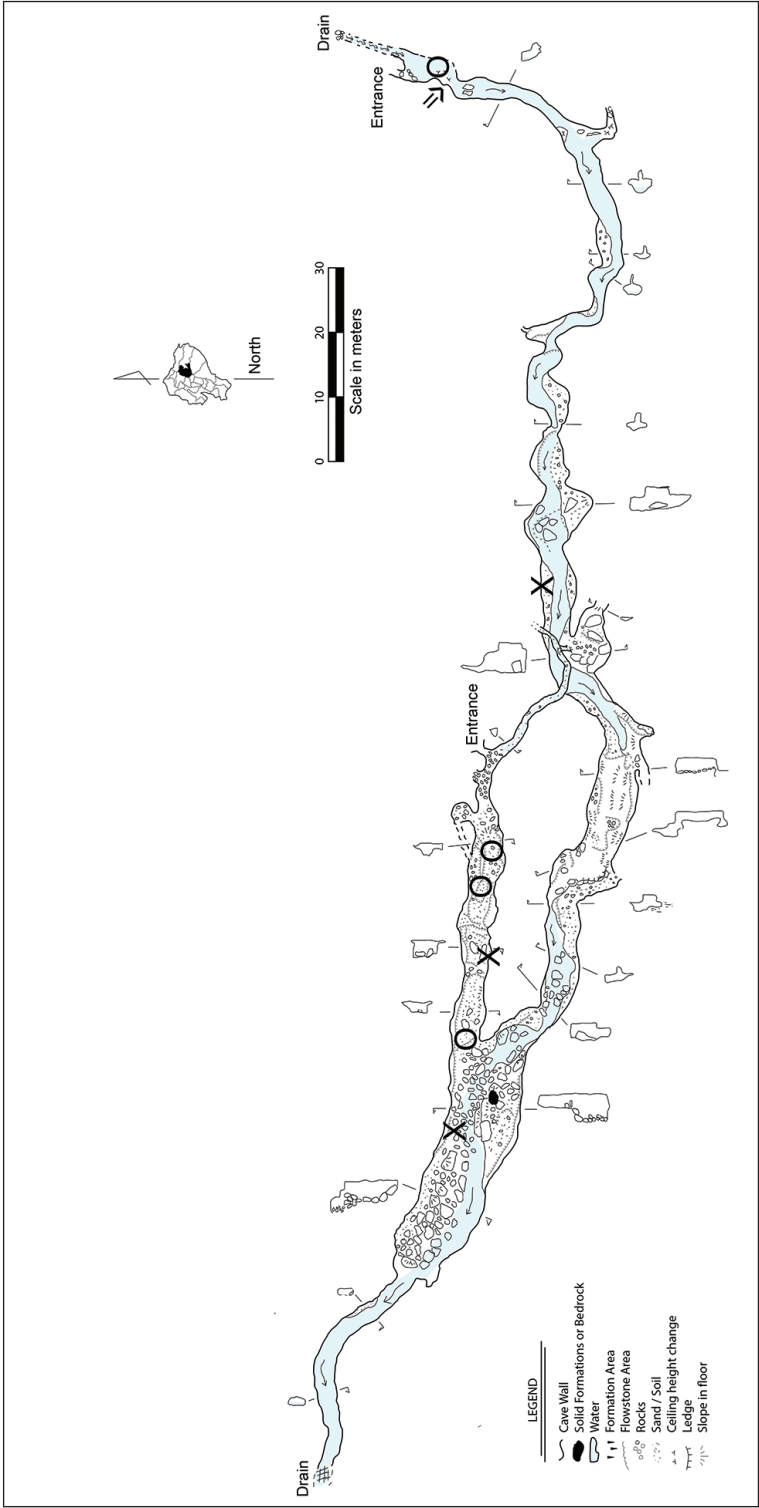


Figure 1. Location of Napo Province and Tena as well as Castillo cave. Map of Castillo Cave in which circles represent sites where boas have been observed in the floor and crosses where boas have been observed close to the roof of the cave. The easternmost site is the one described in the text.

Results

Observation

In the late afternoon of the 5th of December 2015 as part of the regular cave monitoring we entered the Castillo Cave, outside the city of Tena, where we met a first rainbow boa, *Epicrates cenchria*, some 25 meters inside the side entrance. At 4:50 p.m. local time, we observed the catch and recorded most of the predation behavior of a second rainbow boa the *Epicrates cenchria* on a *Desmodus rotundus* adult female in the Castillo Cave close to the northern exit of the cave. The whole event, from the catch until the end of the meal, took approximately 25 minutes. The recorded part in high resolution corresponds to the final act and is as long as some 16 minutes and is summarized and edited in <https://www.youtube.com/watch?v=amtdKGsT7fU>.

The event occurred as follows: A ~140 cm long *E. cenchria* was waiting with its open mouth around a final corner in the eastern exit of the Castillo cave (Fig. 1) for a prey, having just a fourth of its body some 30–35 cm above ground. A *D. rotundus* flying into the cave in a correspondent low height was caught upfront with its head in *E. cenchria*'s mouth. Almost immediately *E. cenchria* brought *D. rotundus* down to the cave floor, where the body of *D. rotundus* got encircled, having *E. cenchria*'s head up, and way above the prey. Resistance of *D. rotundus* ended some two minutes after the catch. Nonetheless, *E. cenchria* remained in that position for some seven more minutes moving just slowly with the whole body (Fig. 2A). Once being assured, that *D. rotundus* had no more life signals, *E. cenchria* left the dead body on the ground (Fig. 2B) and started to open its jaws in the air for some two more minutes, turning around the head some three times. Then *E. cenchria* tried some five times to bite in different parts of the body to see which part would fit in the mouth best (Fig 2C). Every try and exploration took between 30 to 60 seconds. Finally, *E. cenchria* decided to introduce the head of *D. rotundus* first into the mouth and proceeds to bite with intent to swallow *D. rotundus* by some 11 minutes. During these 11 minutes, *E. cenchria* took out the prey of its mouth the fifth time, while at the sixth time, it lift *D. rotundus* slightly off the ground and turned around the body's prey until supine position revealing clearly its age-sex class (Fig. 2D), which belongs to a non-pregnant adult female. There is no evidence of functional mammary gland that warn us that the prey didn't have a suckling infant. This phase lasted for 2 minutes and 17 seconds. Once the prey was covered, *E. cenchria* try swallowing *Desmodus* body by mandibular detachment and using retractable light movements of its teeth, this intention lasted for 2 minutes and 35 seconds.

Viewing that the prey was too difficult to swallow because of the joint stiffness shoulder, *E. cenchria* begins again the process of constriction (Fig. 2E), for which moves their initial proportion of their body and wraps hardly the prey, this process extend by 1 minute and 2 seconds and immediately begins definitive swallow process until swallowing the whole *Desmodus* with a duration of 4 minutes and 50 seconds (Fig. 2F). The last part to be swallowed has been feet and wings. *E. cenchria* remained in that area for some half an hour, swallowing the bat further inside the body, before it moved away (Fig. 2G, H).

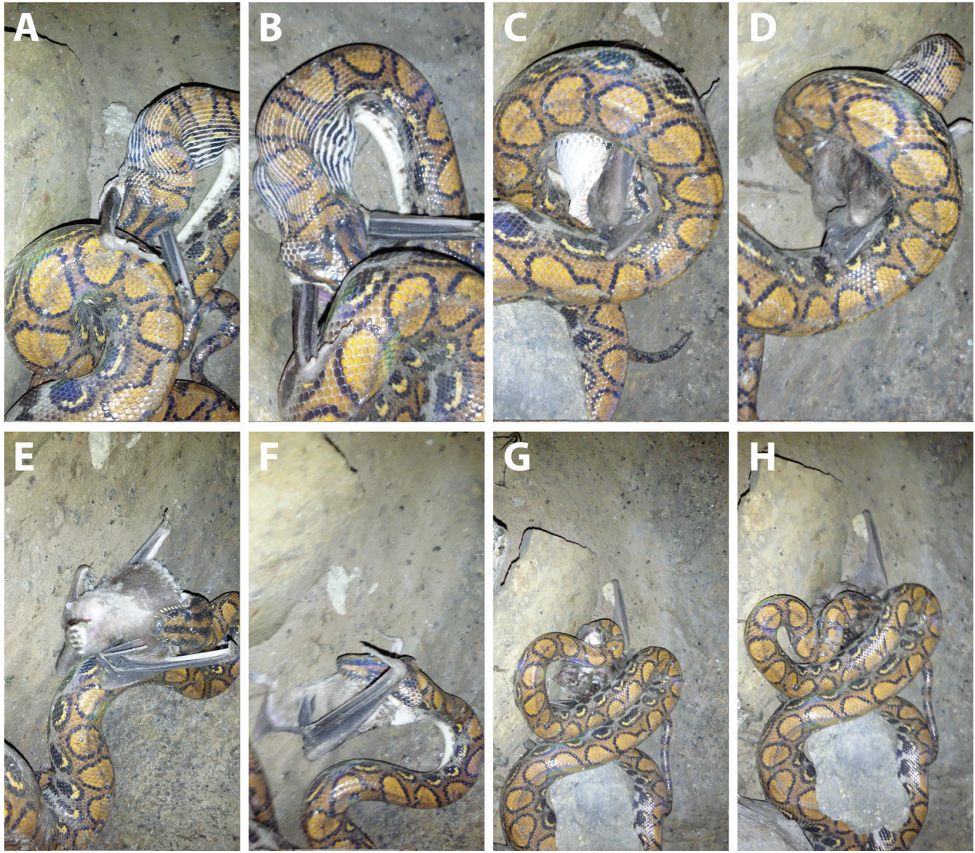


Figure 2. **A** Rainbow Boa (*Epicrates cenchria*) maintains the prey in the mouth with the interest to make sure it is dead, elongated thumb with three typical bearings evidences the species of the Common Vampire Bat (*Desmodus rotundus*) **B** *E. cenchria* releases the dead prey **C** *E. cenchria* turns around *D. rotundus* having the first attempt to swallow prey **D** Evidence of sex-age category of the prey, being a female adult; 2e: Starting the second constriction **F** After the second constriction *E. cenchria* swallows almost entirely *D. rotundus* **G, H** Prey is almost completely eaten except for the wings, but the three typical bearings can be seen on the thumb of *D. rotundus*.

Discussion

Predation of bats by snakes, is not that infrequent (Davis 1951, Steyn 1964, Mankins and Meyer 1965, Thomas 1974, Schatti 1984, Lewis et al. 2009). It is well registered in general websites but few are well documented and published. However reports of *E. cenchria* predating on bats are rare in caves the first record was documented by Lemke (1978), in a cave in Colombia and the second record was registered by Ramos Donato et al. (2012) in a cave in Brazil.

Concerning the prey, they are all, medium sized bats (Greenhall et al. 1983, Lassieur and Wilson 1989, Cloutier and Thomas 1992, Kwon and Gardner 2007).

In Colombia, the bat species was *Carollia perspicillata*, and in Brazil *Lonchorhina aurita*. However, our record is the first to observe the heaviest and largest bat such as *Desmodus rotundus*. In Colombia, there was only one species of bat in the cave, however in Brazil's study they registered also *Desmodus rotundus*, which can implied that *Desmodus rotundus* might belong to their diet too. It is important to notice that *Desmodus rotundus* has a terrestrial locomotion (Riskin et al. 2006) that *E. cenchria* can take advantage because *E. cenchria* was observed several times on the ground (T. T. observations).

The other two studies have not described the process of the event in detail. The predation took place in the three studies during the day but at different moments. In our study, the observation was at 4:50 p.m. For a nocturnal snake and for *D. rotundus*, is almost dusk. And *D. rotundus* can start their foraging activity at different times each day (Wimsatt 1969), and the roost exist can be influenced by human activity or weather. If it is cloudy, the weather during observation, the foraging activity of both individuals can start earlier. The constriction lasted for 4 minutes in Brazil, while in our study it lasted for 10 minutes and 2 seconds. This can be due to the size of *D. rotundus*. Also, in relation to the environment, the caves are located close to rivers which corresponds to the snakes ecology (Gonzálves 2006). Nevertheless, the water of the Castill cave is contaminated with waste water, establishing that the habitat is disturbed. However it appears that both species, *Desmodus rotundus* and *E. cenchria*, are adapted to this environment.

Conclusions

This is the first report for Ecuador, of *Epicrates cenchria* predating on a *Desmodus rotundus*, in a cave, and the third report for Latin America. With such a few reports, we cannot affirm that this kind of predation is common, but we suggest that a detailed study in this population would help us confirmed that this behavior is more than usual.

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Cockroaches (Insecta, Blattodea) from caves of Polillo Island (Philippines), with description of a new species

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Abstract

Cockroaches collected during a protracted series of fieldwork in several limestone caves in Polillo Island, Philippines were taxonomically studied. A new species of *Nocticola* (Nocticolidae), *N. gonzalezi* Lucañas & Lit, **sp. n.**, is described. The male of *Periplaneta banksi* Hanitsch (Blattidae) is described for the first time. Altogether, the present cave cockroach fauna of the island consists of six species.

Keywords

Blaberidae, Blattidae, Burdeos, cave cockroaches, Ectobiidae, Nocticolidae, troglobiont

Introduction

Cockroaches are well represented in cave ecosystems. They are classified as: troglaxene, troglophile, guanobyte or troglobiont depending on their specialization or adaptation to the cave environment (Chopard 1936, Roth and Willis 1960). Juberthie (2000) estimated that there are at least 31 species of troglobiont or obligate cavernicolous cockroaches worldwide but additional species are still waiting to be described.

Unfortunately, very few studies have been conducted regarding the diversity of Philippine cockroaches, maybe because the group includes species that are considered

household pests. Thus, limited information is available on the country's fauna, especially in cave ecosystems. In recent years, the increasing interest in cave studies in the country has provided an opportunity to study the diversity of cockroaches in Philippine limestone caves.

The first documented troglobiont cockroaches in the Philippines were species of Nocticolidae from Rizal Province (Bolívar 1982), a few kilometers to the east of what is now Metro Manila. These were: *Nocticola simoni* Bolívar, 1892 (from a cave in San Mateo town), and *Nocticola caeca* Bolívar, 1892 (from Cueva de Talbac, in what is now Antipolo City). Roth (1988) also noted an unidentified *Nocticola* nymph from a cave in Montalban town (now called Rodriguez), also in Rizal Province, deposited in the Natural History Museum, Geneva, Switzerland.

Unfortunately, due to the limited knowledge on Philippine cockroach diversity, many species have often been misidentified. Encinares and Lit (2014) listed species found in caves in Polillo, including what they initially identified as Cryptocercidae sp. and Blattidae spp. 1, 2, 3 and 4. Lucañas et al. (2015) later clarified their identities to be *Pycnoscelus striatus* (Kirby, 1903) and *Hemithyrsocera* sp.

Mag-usara and Nuñez (2014) reported *Polyzosteria limbata* Burmeister, 1838, *Calolampira irrorata* (Fabricius, 1775), *Methana marginalis* (Saussure, 1864) and *Ellipsoidion* sp. from several caves in Siargao, Surigao del Norte. Although, we were not able to examine the specimens, it is likely that those cockroaches have been misidentified as the mentioned species are all restricted to Australia. Similarly, *Polyzosteria* and *Eublabeus* sp. have been reported from a cave in Lanao del Norte (Macud and Nuñez 2014, Sobrepeña and Nuñez 2014), which are known only from Australia and the neotropics, respectively.

Other than those, there have been very few studies regarding the diversity of cockroaches in caves. This paper provides a list of cockroaches collected from several caves in Polillo Island, Quezon Province in the Philippines.

Materials and methods

All examined specimens were either pinned (for larger specimens) or preserved in vials of 95% ethyl alcohol, unless otherwise indicated as mounted on slide using Canada Balsam. Slide preparations were made starting with cold maceration by soaking in 10% aqueous Potassium Hydroxide (KOH) solution for 24 hours at ambient room temperature. They were then washed in distilled water to remove unwanted undissolved internal contents, and then run through graded alcohol series and then anhydrous clove oil to remove excess ethanol. Finally, they were mounted on microscope slides using Canada Balsam. The following parameters were measured using a calibration micrometer for pinned specimens and calibrated ocular micrometer for slide mounted specimens:

TL (Total length) the length from the tip of the vertex (if exposed) or pronotum up to the tip of the tegmina at rest;

- BL** (Body length) the length from the tip of the vertex (if exposed) or pronotum up to the tip of the subgenital plate (in case of brachypterous/micropterous/apterous species, total length = body length);
- Pn** Pronotum length \times width along the longest axis;
- Tg** Tegmina length along the longest axis.

Standard deviations for each measurement were also noted. Terminologies used for male genitalia follow Klass (1977), and Roth (2003) for other characters such as fore femoral armaments (Type A (robust spines terminating to 2–3 terminal spines), B (several proximal spines followed by row of smaller spinules with 2–3 terminal spines) and C (row of piliform spinules with 1–2 terminal spines)).

Illustrations were made by tracing printed photomicrographs of clear slide-mounted specimens. The degree of sclerotization and pigmentation was made through line thickness and by stippling. All specimens are deposited in the Entomological Collection of the UPLB-MNH.

Taxonomy

Family Nocticolidae Bolívar, 1892

Genus *Nocticola* Bolívar, 1892

Nocticola gonzalezi Lucañas & Lit, sp. n.

<http://zoobank.org/7E3D0AEF-1BED-4DC7-89CC-CD534663BB68>

Figure 1

Material examined. *Holotype*: male, slide-mounted. Original label: “Philippines: Polillo Island (Quezon Province): Cave 5, Sitio Puting Bato, Barangay Aluyon, Burdeos, 13.v.2013 CC Lucañas” “UPLBMNH BLA-00220”, “HOLOTYPE / *Nocticola gonzalezi* Lucañas & Lit [laser printed on red slide label]”

Paratypes: 1 male, 1 female, 5 nymphs, same locality as holotype but 10.x.2013: (CC Lucañas, UPLBMNH BLA-00221, ♀ (slide); -00222, ♂; -00223, nymph (slide); -00224a-d, 4 nymphs). “PARATYPE / *Nocticola gonzalezi* Lucañas & Lit [laser printed on blue slide label or handwritten on blue label]”.

Type locality. Philippines: Polillo Island (Quezon Province): Cave 5, Sitio Puting Bato, Barangay Aluyon, Burdeos, on calcite rubble with insectivorous bat guano.

Diagnosis. Male brachypterous; female apterous. Compound eyes reduced, much smaller in female. Femur Type C_1 . Tarsi simple, symmetrical. Tergal gland absent (*simoni*-species group). Accessory hook-like phallomere (L2d) dagger-like.

Roth (1988) noted the difficulty in separating nocticolid genera. Although Chopard (1945, 1966), being unable to differentiate *Nocticola* from *Alluaudellina* Chopard, 1932 noted the possibility of the two being synonyms, *Nocticola* differs from the latter by the absence of styles. Aside from *Nocticola*, only *Cardacus* Strand, 1928 lacks style in the

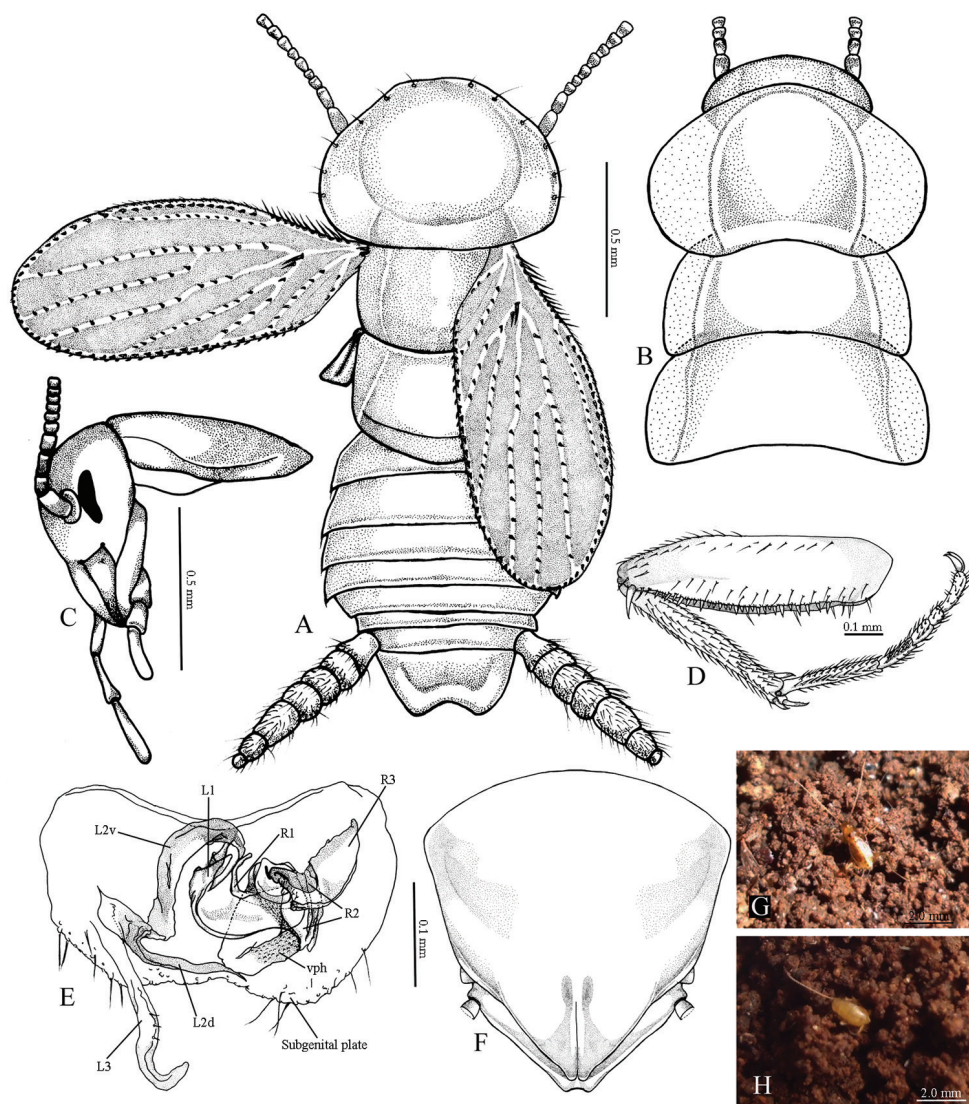


Figure 1. *Nocticola gonzalezi* Lucañas & Lit, sp. n.: **A** Adult male **B** adult female **C** male head, lateral aspect **D** Prothoracic leg **E** male genitalia: (L1-3: sclerites of left phallomere; L2d: L2 dorsal; L2v: L2 ventral; R1-3: sclerites of right phallomere; vph: ventral phallomere) **F** female subgenital plate **G** male and **H** female habitus.

family. The former is distinguished from the latter by the absence of ocelli and exposed vertex. Following such dichotomy, this new species is placed under *Nocticola*.

This species can be distinguished from other troglobiotic *Nocticola* by the presence of an accessory hook-like phallomere which was only reported from two epigeal species, *N. scytala* Andersen & Kjærandsen and *N. clavata* Andersen & Kjærandsen from Ghana, West Africa (Andersen and Kjærandsen 1995).

This species is similar to *N. simoni* and *N. caeca* in terms of coloration but differs in terms of size, *N. gonzalezi* being smaller. Unfortunately, the male genitalia of *N. simoni* and the male of *N. caeca* was not described by Bolivar (1892) and the location of the type specimens are unknown (Paris 1993).

Many *Nocticola* species are narrow endemics even among caves within a contiguous area (e.g. *N. simoni* was collected from a cave in San Mateo, Rizal Province and *N. caeca* from nearby Antipolo, also in Rizal Province). Considering this, as well as the morphological characteristics and the isolation of Cave 5 in Puting Bato, Burdeos, Polillo Island, we iterate the distinctness of *N. gonzalezi*.

Description. Size (mm): ♂, TL: 2.36 ± 0.13 mm; Pn: $0.50 \pm 0.10 \times 0.93 \pm 0.05$ mm; Tg: 1.13 ± 0.2 . ♀ TL: 2.5 mm; Pn: 0.50×0.95 mm.

Male. (Fig. 1A,G). Yellowish brown throughout except for light brown pronotum and tegmina. Vertex of head slightly exposed; eyes reduced but larger than those of female (Fig. 1C); ocelli absent. Pronotum wider than long. Forewing reduced, venation simple indicated by spinules, rounded at apex; hind wing highly reduced, triangular with single vein. Legs very long, forefemur Type C₁ (Fig. 1D); mid- and hind femur with apical spines; mid- and hind tibia with several minute spines on outer aspect; hind metatarsi longer than the rest; pulvilli and arolia absent, tarsal claw simple, symmetrical. Abdominal tergal gland absent (*simoni*-species-group (Roth 1988)). Supra-anal plate symmetrical. Style absent. Genitalia as illustrated (Fig. 1E), genital hook (L3) conspicuous, extending well beyond subgenital plate. Accessory hook-like phallomere (L2d) dagger-like.

Female. (Fig. 1B,H) Larger than male. Opaque yellow throughout except for lateral thoracic margins. Apterus. Supra-anal plate triangular. Subgenital plate broad basally, valvular.

Nymphs. Similar to female. Opaque white. Eyes reduced to 3-4 distinct facets.

Etymology. The species is named after Dr. Juan Carlos T. Gonzalez, the current director of the UPLB-MNH, in recognition of his pioneering efforts toward biodiversity documentation and conservation in the Polillos, a group of islands, east of Luzon and politically a part of Quezon Province.

Distribution. Philippines: Polillo Island.

Ecology. Collected only from a single cave in Burdeos, Polillo Island, Quezon. The cave is deposited with porous calcite rocks and thin guano deposits from periodical roost of insectivorous bats, *Hipposideros coronatus* (Peters, 1871) and *Miniopterus schreibersii* (Kuhl, 1817). The site is relatively dry and rocky compared to the damp and sticky clay that is found throughout the rest of the cave, especially during the rainy season. They are quite fast and usually hide among the holes in the calcite rocks. They are found among and probably serve as prey for nymphs of whipspiders (Arachnida: Amblypygi), whipscorpions (Thelyphonida) and adult short-tailed whipscorpion (Schizomida).

Conservation status. Due to the narrow distribution of this species, it is suggested that the species be considered "Vulnerable" and that the cave from which it was collected be protected from further anthropogenic disturbances.

Remarks. Because of its morphological characteristics, this species can be classified as a true cave-dweller or troglolobitic.

Family Blattidae Stephens, 1829**Genus *Periplaneta* Burmeister, 1838*****Periplaneta banksi* Hanitsch, 1931**

Periplaneta banksi: Hanitsch 1931: 401 (Holotype: ♂, Philippines, The Natural History Museum (BMNH), London); Bruinjing 1948: 110; Princis 1966: 441; Asahina 1980: 113.

Material examined. 8 males, 10 females, 3 nymphs: Philippines: Polillo Island (Quezon Province): Bulalon Cave, Poblacion, Burdeos, 23.ii.2013 (IL Lit, Jr/ OL Eusebio/ AR Larona, UPLBMNH BLA-00232-00234, ♂, -00235 ♀); 25.v.2007 (IL Lit, Jr/ OL Eusebio/ AR Larona, UPLBMNH BLA-00236-00242, ♂, -00243-00245, ♀, -00246-00248, nymphs); 11.vi.2008 (OL Eusebio, UPLBMNH BLA-00528-00531, ♀).

Diagnosis. Reddish-brown throughout. Fore femur A_2 (Fig. 2C). Tegmina well developed (Fig. 2A). Arolia minute. Tarsal claws simple, symmetrical. Male supra-anal plate symmetrical, deeply divided, each lobe rounded and with minute round projection apically (Fig. 2G). Cerci erect, pointed (Fig. 2G). Genital hook (Fig. 2E: L3) angulate, with minute sub-apical process.

Hanitsch (1931) noted the relatively large size of the species compared to other *Periplaneta* species.

Description. *Size* (mm): ♂ TL: 45.71 ± 2.29 ; BL: 37.42 ± 3.69 ; Pn: $11.57 \pm 0.79 \times 14.86 \pm 1.46$; Tg: 35.71 ± 2.29 ; ♀ TL: 48.5 ± 2.01 ; BL: 41 ± 2.53 ; Pn: $11.6 \pm 0.51 \times 15.8 \pm 1.03$; Tg: 37.7 ± 2.41 .

Male. Reddish-brown throughout. Vertex exposed. Ocelli present. Pronotum wider than long, markings indistinct. Tegmina well-developed, extending beyond abdomen. Fore femur A_2 . Pulvilli present on four proximal tarsi. Minute sub-apical spine present on three proximal tarsi. Mid- and hind tibia with several minute spines on outer aspect. Hind basitarsus longer than succeeding tarsi combined. Arolia minute. Tarsal claws simple, symmetrical. Abdominal tergal gland absent. Supraanal plate testaceous, deeply divided, each lobe rounded with minute round projection. Genitalia as illustrated, genital hook angulate, with minute sub-apical process.

Female. Similar to male except that supra-anal plate rounded with deep division. Subgenital plate valvular.

Distribution. Philippines, Taiwan

Ecology. This is the first record of the species inside caves. The species is abundant and most individuals hid among the crevices of the cave walls. They were found from the twilight to the dark zone. Nymphs and mating pairs were often seen, suggesting that the species can complete their life cycle within the cave. Despite that, *P. banksi* is classified as troglophilic because of the lack of distinct troglobiotic characters and the possibility of the species surviving outside cave conditions.

Both nymphs and adults are possibly preyed upon by whipspiders, *Charon* sp., and huntsman spiders, *Heteropoda* sp.

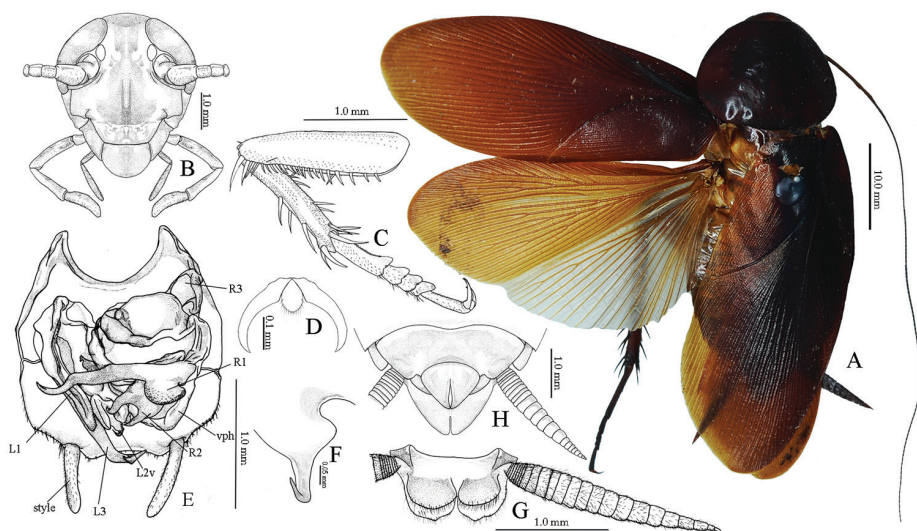


Figure 2. *Periplaneta banksi* Hanitsch, 1931: **A** Adult female **B** head **C** prothoracic leg **D** tarsal claws **E** male genitalia: (L1-3: left phallomere sclerites; L2v: L2 ventral sclerite; R1-3: right phallomere sclerite; vph: ventral phallomere) **F** L2v close-up **G** male supra-anal plate **H** female subgenital plate.

Remarks. Hanitsch (1931) described *P. banksi* from a single female specimen from the Philippines without any further details on its collection locality. Asahinai (1980) later described another female specimen from Taiwan. This is the first time the male of this species is described.

The species resembles *P. lata* (Herbst, 1786), but differs primarily by its larger size. Bruinjing (1948) noted the possibility of the two species being synonyms, but a detailed examination of the male genitalia of *P. lata* is needed to confirm this.

Family Blaberidae Saussure, 1864

Subfamily Pycnoscelinae McKittrick, 1964

Genus *Pycnoscelus* Scudder, 1862

Pycnoscelus striatus (Kirby, 1903)

Figure 3

Leucophaea striata Kirby, 1903: 378 (Lectotype: ♂, Batu Cave, Selangor, Malaysia, BMNH, designated by Princis 1956); 1904: 151; Hanitsch 1915: 122, 163; Chopard 1919: 358; Hanitsch 1923: 445, 466.

Pycnoscelus striatus, Chopard 1924: 82; 1929: 367; Hebard 1929: 14; Hanitsch 1929: 266, 287; Hanitsch 1933: 303, 327; Bruinjing 1948: 41, 145; Princis 1958: 70; 1964: 274; McClure 1965: 55; McClure et al. 1967: 418; Roth 1973: 251; Roth 1980: 103; 1998: 117; Price 2004: 314; Lucañas et al. 2015: 2.

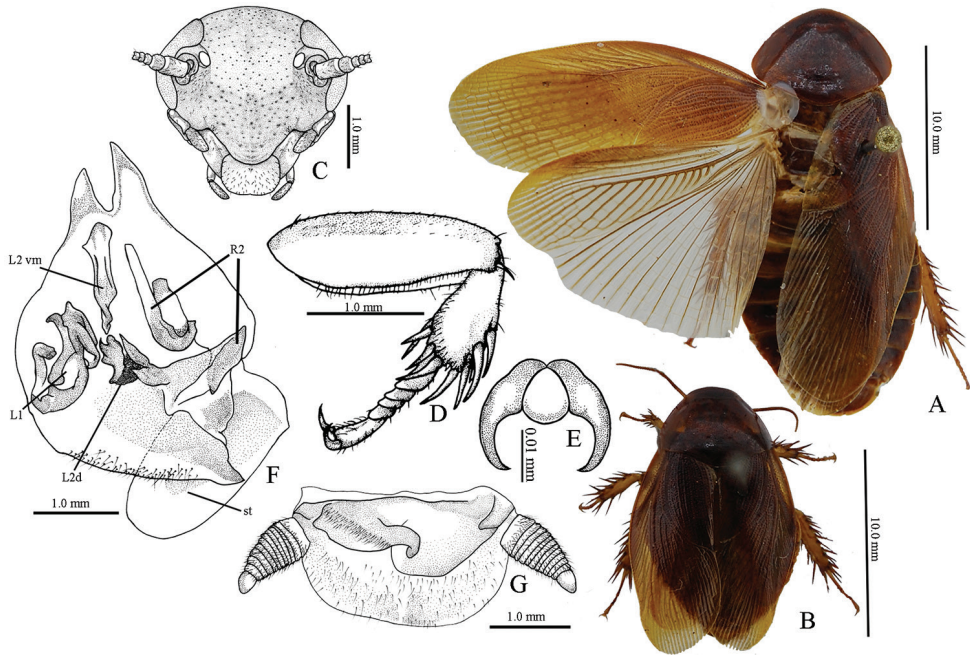


Figure 3. *Pycnoscelus striatus* (Kirby, 1903): **A** Adult female **B** adult male **C** head **D** prothoracic leg **E** tarsal claws **F** male genitalia (st: right style; L1-2: left phallomere sclerites; L2d: L2 dorsal; L2vm: L2 ventromedial/ median sclerite; R2: right phallomere sclerite) **G** male supraanal plate.

Material examined. 22 males, 15 females, 38 nymphs: Philippines: Polillo Island (Quezon Province): Bulalon Cave, Poblacion, Burdeos, v.2010 (JMA Encinares, UPLBMNH BLA-00443-00455 and -00500-00505, ♂; -00456-00466, ♀; -00467-00497, nymphs), 24-27.ii.2007 (IL Lit, Jr/ OL Eusebio, UPLBMNH BLA-00507-00509, ♀); Cave 2, Sitio Puting Bato, Barangay Aluyon, Burdeos, 23.ii.2013 (CC Lucañas, UPLBMNH BLA-00517, ♂; -00518, ♀), 23.v.2013 (CC Lucañas, UPLBMNH BLA-00524 ♂; -00522-00523, nymphs); Cave 3-4, Sitio Puting Bato, Barangay Aluyon, Burdeos, 23.ii.2013 (CC Lucañas, UPLBMNH BLA-00511, -00515, ♂; -00512, -00516, ♀; -00513-00514, nymphs); Cave 5, Sitio Puting Bato, Barangay Aluyon, Burdeos, 24.ii.2013 (CC Lucañas, UPLBMNH BLA-00519-00521, nymphs).

Description. *Size* (mm): ♂ TL: 14.25 ± 1.32 ; BL: 13.59 ± 1.15 ; Pn: $4.57 \pm 0.42 \times 5.91 \pm 0.65$; Tg: 9.68 ± 1.56 ; ♀ TL: 21.39 ± 1.91 ; BL: 17.67 ± 1.97 ; Pn: $5.97 \pm 0.40 \times 7.42 \pm 0.43$; Tg: 16.67 ± 1.91 .

Male. Often less than half the size of females. Vertex exposed. Ocelli present. Pronotum rhomboid, almost as long as wide, reddish-brown, densely punctured. Tegmina variable, reaching slightly beyond abdomen or reaching only up to 7th abdominal tergite. Fore femur C₁. Mid- and hind femur unarmed. Pulvilli present on four proximal tarsomeres. Hind metatarsomere slightly longer than succeeding tarsomeres combined. Tarsal claws simple, symmetrical. Arolia minute. Abdominal tergites un-

specialized. Supraanal plate entire, testaceous. Genitalia as illustrated. Left style absent. Right style ovoid, rounded apically. Genital hook on right side.

Female. Almost similar to males except larger and robust. Wing size highly variable. Subgenital plate entire.

Distribution. Malaysia (Malacca), Indonesia (Sumatra, Kalimantan), Philippines.

Ecology. McClure (1965) noted that *P. striatus* reaches very high population density, reaching up to 3000/m² of guano on Batu Caves, Malaysia. Similarly, individuals from Cave 3-4 form dense populations in thick guano from the fruit bat *Rousettus amplexicaudatus* (Geoffroy, 1810), but are also found in small population on dark zone with thin guano from insectivorous bats. They classified as guanobytes as they burrow beneath layers of guano. They are found together with and may serve as prey to *Phlogiellus kwebaburdeos* Barrion-Dupo et al., 2014 (Barrion-Dupo et al. 2014, Rasalan et al. 2015), scutigerid centipedes, *Scutigera* sp. and some whipspiders, *Charon* sp.

Remarks. Roth (1998) reported a female specimen collected from bat guano in Manhuyod or Negros. Roth temporarily assigned it as *Pycnoscelus* sp. C. due to the absence of a male specimen, but stated that it closely resembles *P. striatus*. The specimen is deposited in the Zoological Institute, Department of Systematics, Lund, Sweden. Several specimens collected from Burdeos have the same interocular width as *Pycnoscelus* sp. C (2.3mm), while some fit with *P. striatus* (1.5-1.7mm). Therefore, it is possible that *Pycnoscelus* sp. C is a variation of *P. striatus*. Additional specimens, particularly from the same collection locality of *Pycnoscelus* sp. C, are needed to confirm this.

The foregoing description of the right style (*i.e.* rounded apically) differs from that of Roth (1998), which he illustrated as acute apically.

Pycnoscelus sp. D

Figure 4A

Material examined. 3 females: Philippines; Polillo Island (Quezon Province): Cave 2, Sitio Puting Bato, Barangay Aluyon, Burdeos, 23.v.2013 (CC Lucañas, UPLBMNH BLA-00525-00526), v.2010 (JMA Encinares, UPLBMNH BLA-00527).

Description. *Size* (mm): ♀ TL: 21.5 ± 0.71; BL: 18.5 ± 0.71; Pn: 6.5 ± 0.71 × 8.5 ± 0.71; Tg: 17.5 ± 0.71.

Male: Unknown

Female: Body generally convex. Vertex concealed. Ocelli present. Pronotum medially wider than long, black throughout except for yellow anterolateral markings, minutely punctate. Tegmina well-developed extending beyond abdomen, hyaline black-brown. Fore femur C₁. Hind basitarsus longer than succeeding tarsal segments combined. Pulvilli present on four proximal tarsomeres. Arolium large. Tarsal claws symmetrical. Abdomen medially brown, darkening distally.

Ecology. The species was collected on thick guano piles of mix bat populations in Cave 2. In contrast with *P. striatus*, the species was present only on the top layer of the guano and does not burrow much even if disturbed.

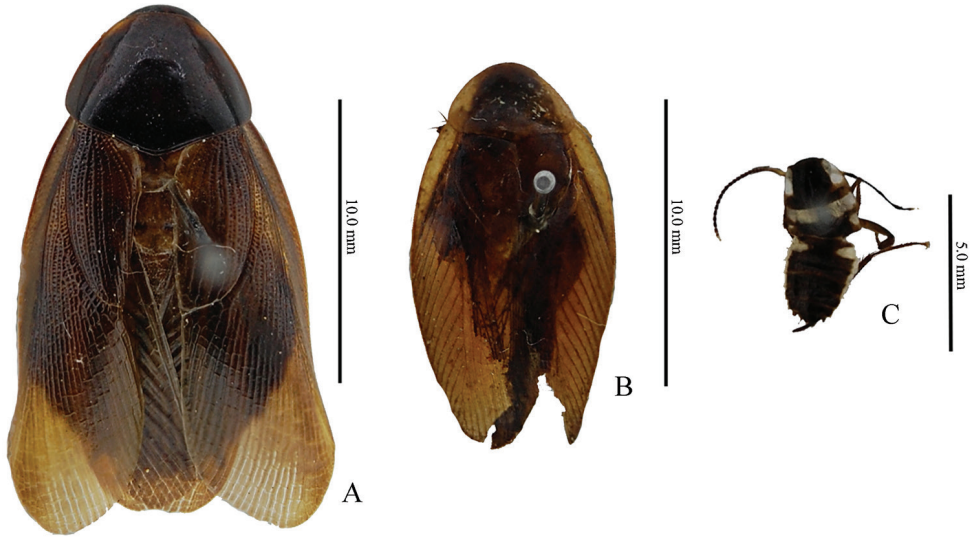


Figure 4. Other cave cockroaches from Polillo Island, Quezon: **A** Blaberidae: *Pycnoscelus* sp. **D** adult female **B** Ectobiidae: *Shelfordina* sp., adult female **C** *Hemithysocera* sp., early instar nymph.

Remarks. This species or form is closely similar to *P. striatus* and may prove to be only a variation. For now, it is treated separately because of its darker coloration, robust abdomen, rather convex body, large arolia and the presence of narrow anterolateral band on its pronotum. The absence of a male specimen hinders further identification.

Roth (1998) described unverified species of *Pycnoscelus* and temporarily assigned them as spp. A, B and C. In order to avoid confusion, this specimen is temporarily named as *Pycnoscelus* sp. D.

Family Ectobiidae Brunner von Wattenwyl, 1865

Subfamily Pseudophyllodromiinae (temporary name)

Genus *Shelfordina* Hebard, 1929

Shelfordina sp.

Figure 4B

Material examined. 1 female: Philippines: Polillo Island (Quezon Province): Cave 3-4, Sitio Puting Bato, Barangay Aluyon, Burdeos, 01.iii.2013 (CC Lucañas, UPL-BMNH BLA-00533).

Description. *Size* (mm): TL: 13.50; Pn: 3.00 × 4.00; Tg: 10.00.

Male: Unknown.

Female: Vertex of head slightly exposed. Ocelli minute. Pronotum anteriorly ellipsoid, wider than long, with brown central maculae, anterior and lateral areas hyaline. Fore femur type A2. Mid femora armed with row of spines on outer aspect. Hind

femora missing from specimen. All tarsomeres with pulvilli, 1-3 spined. Tarsal claws symmetrical with minute dentations. Arolium present. Tegmina well-developed.

Remarks. Accidentals. Since only one female specimen was collected and troglomorphic characters are absent, it can be said that its presence in the cave was accidental.

Roth (1990) described *Shelfordina philippensis* from Camarines Sur, but later transferred it to the genus *Margattea* (Roth 1996). Both genera are morphologically similar except for the armature of the fore femora, i.e., type A for *Shelfordina* and B for *Margattea*, and the presence of tergal gland on the eighth abdominal segment in males of *Margattea*.

Subfamily Blattellinae Karny, 1908

Genus *Hemithyrsocera* Saussure, 1893

Hemithyrsocera sp.

Figure 4C

Material examined. 3 nymphs: Philippines: Polillo Island (Quezon Province): Bulalon Cave, Burdeos (v.2010 JMA Encinares, UPLBMNH BLA-00441-00442, nymphs); Cave 3-4 (v.2011 JMA Encinares, UPLBMNH BLA-00532, nymph).

Description. Front femur A2, pulvilli on 4 proximal tarsomeres, tarsal claw simple and symmetric, arolium present. Quite similar to nymphs of *H. silbergliedi* except for the broad lateral white margin of the pronotum and completely black abdomen.

Remarks. Accidentals. This species has been previously recorded only from Bulalon Cave (Lucañas et al. 2015) with only a few early instar nymphs collected inside the cave. Even though *H. silbergliedi* (Roth, 1985) is abundant outside the caves, the slight differences in pronotal coloration and the absence of adult specimens hinders further identification.

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23rd International Conference on Subterranean Biology

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The 23rd biennial International Conference on Subterranean Biology was held on the campus of the University of Arkansas in Fayetteville from June 13 to June 17, 2016. As is usual for these meetings, there was a strong international representation, with 125 participants from 17 countries, including for the first time, a strong group from the People's Republic of China. It was the first meeting held in the United States and only the third meeting in the Americas (previous meetings were in Brazil and Mexico). It was also the first meeting covered by a reporter from *Science* (Pennisi 2016). It was also the most digital of meetings – the abstracts were available in a digital version and the conference itself was documented in social media, including Facebook and Shutterfly. The talks were organized into two broad themes – the ecological theater and the evolutionary play – taken from the book with the same name, written by the famous ecologist, G. Evelyn Hutchinson.

The results of the evolutionary play are of course species, and the description of new species has long been a strength in the research reported at these meetings, and given the high endemism of the subterranean fauna, it has long been the primary activity of speleobiologists. This meeting was no exception, with reports of new species descriptions and diversity patterns from around the world, including Australia (Cooper, Harms, Perina), Brazil (Ferreira, Soares, Souza) and China (Tian), all are areas of high, but largely undescribed, subterranean species richness. Phylogeography, a strong

theme in the past several conferences, continues to be a prominent research topic, with an entire session devoted to it. Both the number of genes sequenced and the breadth of the taxa analyzed continues to grow. This was especially noteworthy in Trontelj's presentation on the evolutionary history of the very large amphipod genus *Niphargus*. Also noteworthy is the diminished role of the Pleistocene as an agent forcing animals into caves and isolating them there. This is a big change in thinking that has occurred over the past several decades. According to by Delić, climate changes in the Pleistocene act more as selective agents, promoting thermal adaptation. But, we have probably not heard the last of the Pleistocene.

One of the newer approaches to research on evolution of cave animals is that of evolutionary developmental biologists, who analyze particular pathways of development of troglomorphic features, such as eye and pigment loss, and identify individual genes responsible for the changes. A theme of these talks was that there is often a trade-off between a reduced feature, such as eyes, and elaborated features, such as tastebuds (Jeffery, Ma). While the debate between the relative roles of selection and genetic drift continues, there are more and more examples of selection, even in unlikely systems such a melanin loss. Bilandžija showed that blockage of melanin production can lead to adaptive behavior changes resulting from increased levels of catecholamine. Many of the talks about the Mexican cavefish *Astyanax mexicanus* highlighted its potential use as a biomedical model. At a least a superficial sense, we learned that the Mexican cavefish is eyeless (Gross), has a deformed skull (O'Quinn) without pigment (Ma), fat (Rohner), and neurotic (Yoshizawa), and for these reasons may be a good model of some human diseases. It was this possibility that was the subject of Pennisi's *Science* article.

Just as our understanding of the evolutionary play in the subterranean world has grown by leaps and bounds, so has our understanding of the ecological theater. The scope of the theater itself was subject of a number of talks, including the presence of troglobionts and stygobionts in wetlands (Gottstein), sinkholes (Lewis), wells (Hahn, Siemensmeyer), calcrete (Cooper, Harms, Humphreys), scree slopes (Rendoš), canga (Soares), and deep caves (Borko). As usual, efficient sampling of the subterranean fauna remains elusive, but the technique of environmental DNA analysis has proved very useful in locating new sites of the black *Proteus* (Gorički) as well as fish and crayfish (Gabriel).

The mapping of subterranean biodiversity continues to be a hot topic, with several presenters (Ferreira, Reboleira) identifying caves with ten or more troglobionts and/stygobionts, the number ten being used by Culver and Sket (2000) to identify cave biodiversity hotspots. Several presenters (Lukić, Malard, Niemiller) discussed geographic patterns based on literally thousands of georeferenced data points, and this scale of analysis promises to be the wave of the future. While the forefront on analysis of the evolutionary play relies heavily on advances in molecular genetics and development, advances in understanding subterranean biodiversity rely on advances in data manipulation and statistical analysis.

There is perhaps no more fundamental question about the ecological theater of subterranean organisms than what subterranean organisms eat. Several talks (Hutchins, Engel) pointed to the growing recognition of the importance of chemoautotrophy.

The subterranean ecological theater is, by definition, dark. Yet, many, but not all, cave organisms avoid light; a few are indifferent to it. The response to light among different groups is perplexing but interesting, and not just due to differences in time since isolation in the dark. A surprising number of talks focused on this topic (Fišer, Fong, Worsham).

Conservation of the subterranean fauna was an overarching theme as well. Not only were there several sessions devoted explicitly to conservation, including an update on White-nose Syndrome, which affects many North American cave dwelling bats (Watson), many speakers in other sessions pointed to the vulnerability and rarity of the subterranean cave fauna. The most eloquent plea for speleobiologists to redouble their efforts at protection was that of Dante Fenolio, when he introduced his new book, *Life in the Dark*.

One of G. Evelyn Hutchinson's favorite sayings was that everything was relevant to an ecologist except perhaps the irregular Greek verbs. The meeting seemed to cover almost everything except the irregular Greek verbs, and one person's summary only weakly conveys the richness and diversity of the presentations. A list of oral presentations given at the meeting follows and abstracts of these and the posters can be found at www.speleobiology.com/icsb2016/conference-info/program/2016-icsb-abstracts/

A number of participants remarked positively about the large number of students and post-doctoral fellows in attendance. This was made possible by the generosity of several donors, which, on behalf of the Steering Committee, I wish to acknowledge:

- Den and Sheila Roenfeldt family
- Cave Conservancy of the Virginias
- Cave Conservancy Foundation
- Crustacean Society
- International Society of Subterranean Biology.

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- Pennisi E (2016) Blind cave fish may provide insights into human health. *Science* 352: 1502–1503. doi: 10.1126/science.352.6293.1502

Oral presentations

Microbial indicators of air and water quality in a tropical cave.

Abris, Mattheus Imcon¹; Palanca, Mishael Grace¹; De Leon, Marian P.²;
Banaay, Charina Gracia B.*^{1,3}

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***Astyanax mexicanus* as a natural model for metabolic adaptation.**

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²Stowers Institute for Medical Research, Kansas City, Missouri, United States

Character systems and criteria for species diagnosis in *Plutomurus* (Collembola, Tomoceridae), with description of two new species from Georgian caves (Caucasus).

Barjadze, Shalva^{*1}; Baquero, Enrique²; Soto-Adames, Felipe³; Giordano, Rosanna³; Jordana, Rafael²

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²Department of Environmental Biology, University of Navarra, Pamplona, Navarra, Spain

³Department of Entomology, University of Illinois at Urbana-Champaign, Champaign, Illinois, United States

Brazilian subterranean amphipods with notes on their ecology and conservation.

Bastos-Pereira, Rafaela^{*}; Ferreira, Rodrigo Lopes

Study Center on Subterranean Biology, Biology Department, Federal University of Lavras. Lavras, Minas Gerais, Brazil

Microbiological monitoring in Romanian show caves.

Bercea, Silviu¹; Nastase-Bucur, Ruxandra¹; Kenesz, Marius¹;

Constantin, Silviu²; Moldovan, Oana Teodora^{*1}

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²Department of Geospeology and Palentology, Emil Racovitza Institute of Speleology, Bucuresti, Romania

Evolution of melanin pigment regression in cave animals.

Bilandžija, Helena

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United States; Department of Molecular Biology, Ruđer Bošković Institute, Zagreb,
Croatia; Croatian Biospeleological Society, Zagreb, Croatia

Deep cave fauna – fact or fiction?

Borko, Špela*; Delić, Teo; Trontelj, Peter

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Slovenia

Geographically structured genetic diversity in the cave beetle *Darlingtonia kentuckensis* Valentine 1952 (Coleoptera: Carabidae: Trechinae).

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United States

²Department of Biology, Western Kentucky University, Bowling Green, Kentucky,
United States

Speleotranscriptome profiling casts light on differential expression and polymorphism in cave and surface populations of the amphipod *Gammarus minus*.

Carlini, David B.

Department of Biology, American University, Washington, District of Columbia,
United States

A working relationship between the Missouri Department of Conservation and caving organizations.

Colatskie, Shelly*; Elliott, Anthony

Missouri Department of Conservation, Powder Valley Conservation Nature
Center, 11715 Cragwood Road, Kirkwood, Missouri 63122, United States

Regressive evolution of beetles from the subterranean archipelago of Western Australia: insights from comparative transcriptomics.

Cooper, Steven John Baynard^{*1,2}; Tierney, Simon Martin¹; Hyde, Josephine Charlotte Anne¹; Saint, Kathleen Margaret²; Bertozzi, Terry^{1,2}; Austin, Andrew Donald¹; Humphreys, William Frank³

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Australia

**Predicting the occurrence of cave-inhabiting fauna based on features of the
surface environment.**

Culver, David C.¹; Christman, Mary C.²; Doctor, Daniel H.³; Niemiller, Matthew
L.^{*4}; Weary, David J.³; Young, John A.⁵; Zigler, Kirk S.⁶

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**Phylogeography, haplotype diversity and niche differentiation among fresh-
water crab *Sundathelphusa* species (Decapoda: Brachyura: Gecarcinucidae) in
the subterranean habitat of Quezon, Philippines.**

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and Sciences, University of the Philippines Los Baños, College, Laguna, Philippines

**Thermal adaptation, a new driver of ecological speciation in subterranean
fauna.**

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Distribution and diversity of stygobionts in Poland.

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Traits of terrestrial subterranean biota of the Western Carpathians (Central Europe) are affected by productivity of above ground ecosystems.

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A macroecological take on European groundwater biodiversity patterns.

Eme, David^{1,2}; Zagmajster, Maja³; Delić, Teo³; Douady, Christophe¹; Fišer, Cene³; Flot, Jean-François⁴; Galassi, Diana M.P.⁵; Konecny-Dupré, Lara¹; Marmोनier, Pierre¹; Stoch, Fabio⁵; Zakšek, Valerija³; Malard, Florian^{*1}

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Prevalence of microbial taxonomic groups to specific subterranean habitats may shed light on ubiquity of microbial function in cave ecosystems.

Engel, Annette Summers

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Threats to the conservation of stygobionts.

Fenolio, Danté

Conservation & Research, San Antonio Zoo, San Antonio, Texas, United States

Iron ore plateaus in the Amazon forest: hotspots of subterranean biodiversity?

Ferreira, Rodrigo Lopes

Study Center on Subterranean Biology, Biology Department, Federal University of Lavras. Lavras, Minas Gerais, Brazil

Brazilian troglomorphic fauna: besides raising the knowledge, are we contributing to their conservation?

Ferreira, Rodrigo Lopes*; Souza-Silva, Marconi

Study Center on Subterranean Biology, Biology Department, Federal University of Lavras. Lavras, Minas Gerais, Brazil.

Brazilian vs. Slovenian aquatic subterranean biodiversity: the case of Arcias and Postojna-Planina cave systemsFerreira, Rodrigo Lopes¹; Souza-Silva, Marconi^{1*}; Fišer, Cene²; Zagmajster, Maja²; Prevorčnik, Simona²; Sket, Boris²¹Center of studies on Subterranean Biology, General Zoology sector, Department of Biology, Federal University of Lavras, Minas Gerais, Brazil²Department of Biology, Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, 1000 Ljubljana, Slovenia.**Searching for reproductive barriers between sympatric surface and subterranean ecomorphs of *Asellus aquaticus*.**

Fišer, Žiga*; Trontelj, Peter

Department of Biology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia

Variation in phototactic behavior among surface and subterranean gammarid and crangonyctid amphipod species from different habitats.Fong, Daniel Wu^{*1}; Wanner, Maria J.²¹Department of Biology, American University, Washington, District of Columbia, United States²Department of Biology, Gettysburg College, Gettysburg, Pennsylvania, United States

Adult lens cuticle deposition in a microphthalmic cave beetle.

Friedrich, Markus^{*1,2}; Kulacic, Jasmina¹

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Cave animals at the dawn of speleogenomics.

Friedrich, Markus

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Environmental DNA for monitoring and detection of rare and endangered cavefish and cave crayfish in the Ozark Highlands.

Gabriel, Ana E.^{*1}; Van Den Bussche, Ronald A.¹; Brewer, Shannon K.²; Stark, Richard³; Niemiller, Matthew L.⁴; Fenolio, Dante B.⁵

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Long term population trends of biota in White Cave, Mammoth Cave National Park (2003-2016).

Gilmore, Terrence¹; Lavoie, Kathleen^{*1}; Helf, Kurt²; Poulson, Thomas³

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Searching for black *Proteus* (*Proteus anguinus parkelj*) in karst groundwater with the help of eDNA.

Gorički, Špela^{*1}; Stanković, David^{1,2}; Năpăruș-Aljančič, Magdalena¹; Snoj, Aleš³; Aljančič, Gregor¹

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Microhabitat selection of subterranean amphipods in the Western Balkan peat bog.

Gottstein, Sanja^{*1}; Brigić, Andreja¹; Kerovec, Mladen¹; Ternjej, Ivančica¹

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Genetic analysis of craniofacial changes in blind Mexican Cavefish, *Astyanax mexicanus*.

Gross, Joshua

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Challenges and rewards of subterranean fauna environmental impact assessment.

Halse, Stuart

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Biodiversity in complex subterranean systems: a tale of arachnids in arid Western Australia.

Harms, Danilo^{*}; Halse, Stuart; McRae, Jane; Scanlon, Michael; Curran, Michael
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Shape variation within the Southern Cavefish, *Typhlichthys subterraneus* (Percopsiformes: Amblyopsidae).

Hart, Pamela^{*}; Burress, Edward; Armbruster, Jonathan.

Department of Biological Sciences, Auburn University, Auburn, Alabama, United States

Patterns on patterns: The rise and rise of Australian subterranean biodiversity.

Humphreys, William F.

Department of Terrestrial Zoology, Western Australian Museum, Locked Bag 49, Welshpool DC, Western Australia 6986, Australia; School of Animal Biology, University of Western Australia, Crawley, Western Australia 6009, Australia.

Conservation of subterranean species and habitats in Australia.

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Phylogeography of crab genus *Sundathelphusa*: history of extensive migration, cave colonization and refugia in the Philippines.

Husana, Daniel Edison^{*1}; Haga, Takuma²; Kase, Tomoki³

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Biodiversity, stability, and trophic complexity in the Edwards Aquifer, United States:

The influence of chemolithoautotrophy on stygobiont community structure.

Hutchins, Benjamin T.^{*1,2}; Engel, Annette Summers³; Nowlin, Weston H.²; Schwartz, Benjamin F.^{3,4}

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Conservation status of stygobionts in Texas, United States.

Hutchins, Benjamin T.

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Homocystinuria in Cavefish: Molecular analysis of an *Astyanax* eye QTL reveals the role of cystathionine β -synthase in eye degeneration.

Jeffery, William

Department of Biology, University of Maryland, College Park, Maryland,
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Investigating the physico-chemical niche of obligate subterranean amphipods in shallow subterranean waters of the DC metro area.

Keany, Jenna^{*1}; Culver, David¹; Knee, Karen¹; Fong, Daniel²

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As above, so below? Testing for gene flow between cave and surface-dwelling populations of *Garra barreimiae*.

Kirchner, Sandra^{*1,2}; Sattmann, Helmut³; Plan, Lukas⁴; Krenn, Harald¹;
Victor, Reginald⁵; Haring, Elisabeth^{1,2}; Kruckenhauser, Luise²

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Synchronous ceiling-floor pitfall trapping allows study of microdistribution and habitat preferences of terrestrial subterranean fauna in caves.

Kozel, Peter^{*1,3}; Pipan, Tanja¹; Culver, David²; Šajna, Nina³; Polak, Slavko⁴; Novak,
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Long-term cave adaptation and diversification in the *Ptomaphagus hirtus*-group (Coleoptera: Leiodidae: Cholevinae).

Leray, Vincent L.¹; Zigler, Kirk S.*²; Friedrich, Markus³

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Improving outcomes and modifying policies with evidence-based research on the karst of the Hoosier National Forest.

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Disjunct distribution of terrestrial troglobiotic species in Europe: the case of Collembola.

Lukić, Marko*^{1,2,3}; Delić, Teo³; Zigmajster, Maja³; Bedos, Anne⁴; Deharveng, Louis⁴

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Molecular analysis of melanophore lineage genes in cavefish depigmentation.

Ma, Li*¹; Stahl, Bethany^{1,2}; Adams, Hannah¹; Gross, Joshua¹

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Home range and habitat use of foraging *Myotis grisescens* from five maternity sites in northern Arkansas using aerial tracking.

Moore, Patrick Ryan*; Morris, Keith; Rolland, Virginie; Risch, Thomas Stephen
Department of Biological Sciences, Arkansas State University, Jonesboro, Arkansas 72467, United States

Estimating the trophic ecology of aquatic invertebrate using stable isotopes.

Nair, Parvathi*¹; Nowlin, Weston¹; Diaz, Pete²

¹Department of Biology, Texas State University, San Marcos, Texas, United States

²US Fish and Wildlife Service, San Marcos, Texas, United States

Conservation of amblyopsid cavefishes (Percopsiformes: Amblyopsidae) of the Ozark Highlands and Interior Low Plateau karst regions, USA.

Niemiller, Matthew L.

Illinois Natural History Survey, Prairie Research Institute, University of Illinois
Urbana-Champaign, Champaign, Illinois, United States

Ecological and consumer-driven nutrient recycling in a subterranean aquatic community.

Nowlin, Weston H.^{*1}; Loney, Lauren¹; Hutchins, Benjamin²; Schwartz, Benjamin F.³

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Texas, United States

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University, San Marcos, Texas, United States

Are cave sampling methods effective to assess subterranean fauna richness?

Oliveira, Marcus Paulo Alves^{*}; Ferreira, Rodrigo Lopes

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Brazil

The evolution of scleral ossification in the Mexican Cavefish

(Astyanax mexicanus).

O'Quin, Kelly E.^{*1}; Doshi, Pooja²; Lyon, Anastasia¹; Hoenemeyer, Emma¹;
Yoshizawa, Masato³; Jeffery, William R.²

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United States

Conserving cave invertebrate fauna in Virginia (USA).

Orndorff, William David

Virginia Department of Conservation and Recreation, Natural Heritage Program,
Richmond, Virginia, United States

Niche bacterial and archaeal community compositions as indicators of ecosystem processes and health in Bahamian and Mexican anchialine caves.

Paterson, Audrey T.^{*1}; Iliffe, Thomas M.²; Bracken-Grissom, Heather³; Pérez-Moreno, Jorge L.³; Porter, Megan⁴; Gonzalez, Brett C.⁴; Engel, Annette Summers¹

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³Department of Biological Sciences, Florida International University-Biscayne Bay, North Miami, Florida, United States

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Remarkable biodiversity of a neglected group of stygofauna: Bathynellidae (Bathynellacea, Crustacea) in the north of Western Australia.

Perina, Giulia^{*1,2}; Huey, Joel²; Camacho, Ana³; Horwitz, Pierre¹; Koenders, Annette¹

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Uncovering divergent lineages and phylogeographic structure in an obligate cave-dwelling Salamander (*Eurycea spelaea*).

Phillips, John G.^{*1}; Fenolio, Dante B.²; Emel, Sarah L.^{1,3}; Bonnett, Ronald M.¹

¹Department of Biological Sciences, University of Tulsa, 800 South Tucker Drive, Tulsa, Oklahoma, United States

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³Department of Biology, Temple University, Philadelphia, Pennsylvania, United States

Phylogeny and systematic of the enigmatic Anthroherponina (Leptodirini, Cholevinae, Leiodontidae, Coleoptera).

Polak, Slavko^{*1}; Delić, Teo²; Trontelj, Peter²

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Cuticular hydrocarbon analysis of cave versus surface Hawaiian planthoppers.Porter, Megan Linnay^{*1}; Yew, Joanne ²¹Department of Biology, University of Hawai'i at Mānoa, Honolulu, Hawaii, United States²Pacific Bioscience Research Center, University of Hawai'i at Mānoa, Honolulu, Hawaii, United States**Food limitation is necessary to explain elaborated troglomorphy in some species.**

Poulson, Thomas L.

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The evolution of craniofacial shape change in the blind Mexican Cavefish.

Powers, Amanda*; Davis, Erin; Kaplan, Shane; Gross, Joshua

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Developmental and genetic analysis of eye and pigment loss in the cave isopod *Asellus aquaticus*.Mojaddidi, Hafasa¹; Klein, Emily²; Trontelj, Peter³; Protas, Meredith^{1*}¹Department of Natural Sciences and Mathematics, Dominican University of California, San Rafael, California, United States²Department of Biology, Whitman College, Walla Walla, Washington, United States³Department of Biology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia**Portugal - the emergence of a new hotspot of subterranean biodiversity in Europe.**

Reboleira, Ana Sofia P. S.

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“Troglobiário” – a cave lab building bridges between citizens and science.Reboleira, Ana Sofia P. S.^{*1,2}; Fernandes, Maria Jesus³; Martins, Olímpio³¹Natural History Museum of Denmark, University of Copenhagen, Universitetsparken 15, DK-2100 Copenhagen, Denmark

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³Parque Natural das Serras de Aire e Candeeiros, Instituto de Conservação da Natureza e das Florestas, I.P., Portugal

Unsafe sex – interesting interactions between cave inhabitants.

Reboleira, Ana Sofia P. S.*; Enghoff, Henrik

Natural History Museum of Denmark (Zoological Museum), University of Copenhagen, Universitetsparken 15, DK-2100 København Ø, Denmark

Organic carbon content as substantial factor affecting diversity and vertical distribution of Collembola on forested scree slopes.

Rendoš, Michal *¹; Raschmanová, Natália ¹; Miklisová, Dana ²; Mock, Andrej¹; Euptáčík, Peter¹; Kováč, Lubomír¹

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Physiochemical differences in water sources within De Leon Springs, Florida, and their potential effect on cave biota.

Sawicki, Thomas R.*¹; Stine, Michael²; Long, Richard A.³

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²Department of Mathematics, Physics, and Biological Sciences, North Florida Community College, Madison, Florida, United States

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Molecular and morphological analysis of *Stygobromus* sp. near San Marcos, Texas.

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The effects of well type and quality on sampling of stygofaunal communities.Siemensmeyer, Tobias^{*1,2}; Schwenk, Klaus²; Hahn, Hans Jürgen¹¹Institute for Groundwater Ecology IGE GmbH, University of Koblenz Landau,
Fortstr. 7, 76829 Landau, Rheinland-Pfalz, Germany²Institute for Environmental Sciences, University of Koblenz Landau, Fortstr. 7,
76829 Landau, Rheinland-Pfalz, Germany**Building a constituency for karst conservation.**Simon, Scott^{*}; Slay, Michael E.Arkansas Field Office, The Nature Conservancy, 601 North University Avenue,
Little Rock, Arkansas, United States**Trogloformic fauna sampling methods in canga formations, Minas Gerais State, Brazil.**Soares, Gustavo^{*}; Andrade, Renata; Perroni, Gustavo
Instituto do Carste, Belo Horizonte, Minas Gerais, Brazil**Updated records of troglomorphic palpigrades in Brazil.**Souza, Maysa Fernanda Villela Rezende^{*}; Ferreira, Rodrigo Lopes
Study Center on Subterranean Biology, Biology Department, Federal University
of Lavras, Lavras, Minas Gerais, Brazil**Global warming – where are the refugia for cold-stenothermous stygofauna?**Spengler, Cornelia; Hahn, Hans Jürgen^{*}University of Koblenz Landau, Institute for Environmental Sciences, Fortstr. 7,
76829 Landau, Rheinland-Pfalz, Germany**Species delimitation and phylogeography of *Hesperocheernes* (Pseudoscorpiones: Chernetidae) from karst regions of the southeastern United States.**Stephen, Charles Donald Robert^{*1}; Niemiller, Matthew Lance²; Bond, Jason Edward¹¹Department of Biological Sciences, Auburn University, Auburn, Alabama,
United States²Illinois Natural History Survey, Prairie Research Institute, University of Illinois
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Documenting Missouri cave biology – from Ruth Hoppin to Missouri Cave Database.

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Integrative taxonomy of cryptic subterranean Amphipods (Niphargidae: *Niphargus*) from Dinaric Karst.

Švara, Vid*¹; Delić, Teo¹; Coleman, Charles Oliver²; Fišer, Cene¹

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²Museum für Naturkunde, Leibniz Institute for Evolution and Biodiversity Science, Berlin, Germany

Cave-dwelling terrestrial isopods (Crustacea, Oniscidea) from Southeast Asia: a review.

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Current status and habitat use of the Foushee cavesnail, *Amnicola cora* (Hydrobiidae) in Foushee Cave, Independence County, Arkansas.

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Diversity and distribution of cavernicolous ground beetles (Insecta: Coleoptera: Carabidae) in China.

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Crossing to the dark side: the South Central Texas *Eurycea* clade as a novel subterranean model system for the study of evolutionary developmental biology.

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The origin of niphargids revisited and tested at the continental scale.

Trontelj, Peter*; Moškrič, Ajda; Verovnik, Rudi; Fišer, Cene

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StygoTracing - a biological tracing method for underground waters.

van den Berg-Stein, Susanne¹; Schwenk, Klaus²; Hahn, Hans Jürgen¹

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Geomicrobiology study in Heshang Cave, central China.

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Managing the spread of *Pseudogymnoascus destructans* and conserving bats threatened by White-nose Syndrome in North America.

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²U.S. Fish and Wildlife Service, Bloomington, Indiana, United States

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How the Endangered Species Act protects subterranean fauna in central Texas.

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The effect of selection on the phenotype of response to light in subterranean, epigeal, and interstitial Crangonyctidae.

Worsham, McLean^{*}; Nair, Parvathi¹; Nowlin, Weston¹; Gibson, Randy²; Schwartz, Benjamin¹

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Adaptation through changes of behavioral and morphological traits in Mexican Cavefish.

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The neglected subterranean biodiversity hotspot under threat: can we protect the aquatic interstitial fauna of the Sava River in the Balkans (Europe)?

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A tribute to Gheorge Racoviță (1940–2015)

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Gheorge Racoviță, grandson of the great Romanian naturalist, Emil Racoviță, the founder of biospeleology (1907) and of the world's first Institute of Speleology (Cluj, 1920), decided to continue the work and research of his grandfather by joining the Institute in 1963. He was a true mentor for several generations of Institute's cave researchers.

As a biologist, Gheorge Racoviță worked and published in various scientific fields: subterranean ecology, climatology and glaciology, karst geomorphology and protection. He dedicated much of his time to taxonomy, ecology, origin and evolution of cave fauna, mathematical modeling of climatic processes and the ice of Scărișoara Glacier, or to the concept of environmental protection of caves and karst. His publishing record comprises 196 titles in 12 volumes, 20 chapters in collective books, 136 scientific papers, 8 research reports and 20 science articles for the larger public. In his last working years, before retiring, he was deeply captivated by the history of science, focusing on the life and work of his grandfather, Emil Racoviță. In his great generosity, he donated the entire familial records (original documents, letters, photographs etc) to the Romanian Academy Library in Cluj-Napoca.

Gheorghe Racoviță always polarized the scientific discussions; he was an acknowledged personality, very sober and of great dignity. He was of an extreme modesty (a feature of his illustrious family), so he has been constantly “overshadowed” by those with fewer scientific and human qualities, but eager to affirm themselves. Even between 1970 and 1990, a period when research funds were almost non-existent, he managed to initiate and conduct high-level research. He considerably contributed to the development of cave science in Romania, by always approaching new fields. He very often accompanied us, his younger colleagues, in cave field trips, where we shared shelter, thoughts and provisions with the same magnanimousness with which we discussed in his office on Clinicilor street number 5.

With a fragile health, he retired from the institute in 2009 and passed away on 1st of December 2015.

Gheorghe Racoviță lived for speleology, as we, his followers, do. He constantly fought for a decision-making position of the Institute of Speleology in issues of protection and conservation of caves in Romania, as Emil Racoviță always advocated, and as required by the law for the establishment of the Institute of Speleology (April 26, 1920). With the disappearance of Gheorghe Racoviță, the Institute of Speleology, with its departments in Cluj and Bucharest, lost a remarkable researcher, a true model of professional ethics, a mentor and an authentic leader.

Selected publications

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