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Associations between Emesinae heteropterans and spiders in limestone caves of Minas Gerais, southeastern Brazil

Associações entre heterópteros Emesinae e aranhas em cavernas calcárias de Minas Gerais, sudeste do Brasil

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Abstract

Emesine bugs, within several genera, are recorded from caves around the world, but have been regarded as uncommon in these habitats. Many emesines have ecological relationships with spiders, as kleptoparasites, predators, or both. However, cave emesines are apparently rarely involved in these arachnophilous relationships, and only two examples have been previously documented. Recent studies in limestone caves at Presidente Olegário in northwestern Minas Gerais, Southeastern Brazil revealed the presence of four emesine species, two of which (*Emesa mourei* Wygodzinsky, 1946 and *Phasmatocoris* sp.) were associated with spiders, probably as kleptoparasites. The spiders recorded in these associations were *Mesabolivar* aff. *tandilicus* (Mello-Leitão, 1940) (Pholcidae) and *Loxosceles similis* Moenkhaus, 1898 (Sicariidae). The only non-emesine reduviid recorded in Presidente Olegário caves was *Zelurus zikani* (Costa Lima, 1940). We discuss these rarely recorded associations between cave emesines and spiders and the importance of protecting Presidente Olegário caves.

Keywords: Arachnophily, Reduviidae, Pholcidae, Sicariidae, subterranean environment.

Resumo

Emesíneos cavernícolas, pertencentes a vários gêneros, são registrados em cavernas ao redor do mundo, porém são considerados menos abundantes nesse habitat. Muitas espécies possuem relações ecológicas com aranhas, como cleptoparasitas, predadores ou ambos. Entretanto, é aparentemente raro esse tipo de associação com aranhas em cavernas e apenas dois exemplos foram documentados anteriormente. Estudos recentes em cavernas calcárias de Presidente Olegário, no noroeste de Minas Gerais, sudeste do Brasil, revelaram a presença de quatro espécies de Emesinae, sendo que duas delas (*Emesa mourei* Wygodzinsky, 1946 e *Phasmatocoris* sp.) estavam associadas com aranhas, provavelmente como cleptoparasitas. As aranhas registradas nessas associações foram *Mesabolivar* aff. *tandilicus* (Mello-Leitão, 1940) (Pholcidae) e *Loxosceles similis* Moenkhaus, 1898 (Sicariidae). O único reduvídeo não Emesinae registrado nas cavernas de Presidente Olegário foi *Zelurus zikani* (Costa Lima, 1940). Discutem-se brevemente essas raras associações entre emesíneos cavernícolas e aranhas e a importância de se proteger as cavernas de Presidente Olegário.

Palavras-chave: Aracnofilia, Reduviidae, Pholcidae, Sicariidae, ambiente subterrâneo.

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Introduction

The Reduviidae is the largest family of predaceous terrestrial Heteroptera, and they occupy many diverse environments (Gil-Santana *et al*., 2015). Vandel (1964) stated that they are commonly found in entrance zones of tropical caves. Among them, emesines, within several genera, are recorded from caves around the world, but have generally been considered uncommon in these habitats (Wygodzinsky, 1966; Pape, 2013). However, emesines have been recorded from caves in several regions of Brazil, including the states of Amazonas, Goiás, Mato Grosso do Sul, Pará and São Paulo (Pinto-da-Rocha, 1995; Gil-Santana *et al.*, 2007; Gil-Santana, 2015).

Associations of emesines with spiders, as kleptoparasites, predators, or even filling both of these niches simultaneously, are relatively common globally in epigean habitats (Wygodzinsky, 1966). However, emesines living in caves seem to only rarely be intimately involved in such arachnophilous associations. Previously, only two examples of such associations occurring inside caves have been published, for *Bagauda cavernicola* Paiva, 1919 in India and Sri Lanka, and for *Phasmatocoris labyrinthicus* Pape, 2013 in Arizona, USA. Both species were found deep in the cave aphotic zones (Wygodzinsky, 1966; Pape, 2013).

These kinds of associations, including those in epigean situations, have rarely been studied. Wygodzinsky (1966), in his monograph, assimilated what was known about such associations at that time. He suggested that specific morphological modifications present in emesines may be adaptations for living in association with spider webs. These include a more or less extended group of serially arranged stiff bristles obliquely inclined on the dorsal surface of the fore tibiae, resembling the calamistrum of cribellate spiders. Cribellate spiders use the calamistrum as a carding apparatus for their silk. The existence of this calamistrum-like structure in the frequently arachnophilous Emesinae is suggestive of a spider silk manipulation function for this structure. Modifications of the tarsal claws in which those of the fore legs are similar to those of many spiders, as described by Wygodzinsky (1966), are also implicated in such associations. The elongation of the legs is another emesine morphological adaptation, which in some groups may have evolved through associations with spiders.

An obvious advantage of long legs when dealing with formidable spider prey (or hosts, for kleptoparasitic associations), is keeping vital body parts of the emesine at a significant distance from the spiders. Additionally, the long legs are thought to facilitate the animals walking on spider webs by distributing the body weight of the animal (Wygodzinsky, 1966). Snoddy *et al.* (1976) reported *Stenolemus lanipes* Wygodzinsky, 1949 feeding exclusively on the spider *Parastetoda tepidariorum* (C. L. Koch, 1841) (Theridiidae) and *Stenolemus* spp. are described as obligate spider predators by Cobben (1978) and Schuh and Slater (1995).

As stated above, Reduviidae bugs, mainly emesines, are found in caves throughout the tropics. Due to a general lack of available nutrients many caves are considered marginal habitats (Juberthie, 2000; Culver and Pipan, 2009). However, for animals with a low tolerance for epigean climatic variability or that have propensities for nocturnal activity, hygrophily or cryptic behavior, the moderated environment within caves could serve as refugia (Culver and Pipan, 2009; Cullingford, 1962).

Karst areas are impacted by a variety of man-made disturbances, including mining, deforestation, urban development, agricultural practices and pollution (Juberthie, 2000; Culver and Pipan, 2014). Even localized effects of these disturbances can adversely affect karst environments, and may lead to extinction of endemic species (Trajano, 2013). Biological surveys are the first step in understanding evolutionary patterns and ecological processes of the subterranean domain (Trajano *et al.*, 2012). In Brazil, Decree 6.640 (Brasil, 2008) reduced the protection for karst areas, which could potentially result in the destruction of entire caves (Trajano, 2013). Thus, cave resource evaluations are essential to the protection of subterranean fauna, their underground environment, and the promotion of public policies to protect biodiversity. According to Trajano (2010), conservation aims to preserve representative samples of biodiversity, its processes and patterns.

This study documents Neotropical emesines in associations with spiders, observed in the caves of Presidente Olegário, state of Minas Gerais, Southeastern Brazil. We discuss the importance of these findings for the preservation of the resources contained within Presidente Olegário caves.

Material and methods

Study area

The study area is located in the municipality of Presidente Olegário, state of Minas Gerais, in Southeastern Brazil (18º25’4”S, 46º25’4’’W) (Figure 1A-B). The caves are developed in a horizontal limestone outcrop of the Bambuí group, which dates to the Upper Proterozoic Era (Grupo Pierre Martin de Espeleologia/GPME, pers. com.).

The elevation of the study area is ca. 900 m and the climate is predominantly tropical sub-warm and semi-humid, with a five month dry season (from April to August) (Nimer, 1989). According to Ab’Saber (1977), Presidente Olegário is situated within the Morphoclimatic Domain of the Cerrado (savannah-like vegetation) (Figure 2A-B).

We examined the following seven caves in the study area:

“Lapa Arco da Lapa” (18º12’31.3’’S, 46º08’53.3’’W): This cave has approximately 500 meters of horizontal development (GPME, pers. com.). The cave is surrounded by

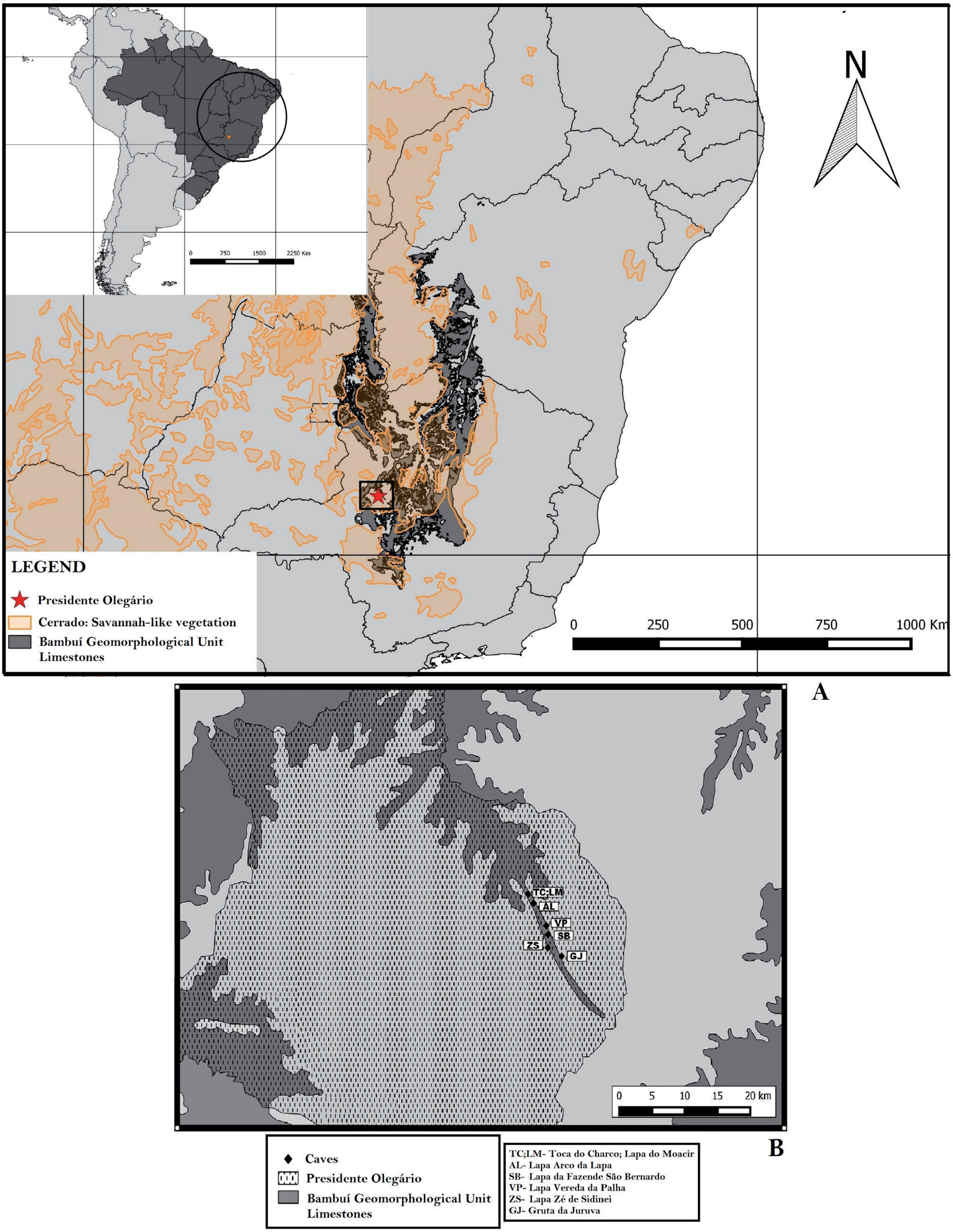

Figure 1. A: Location of Limestone outcrops at Presidente Olegário, state of Minas Gerais, southeastern Brazil. B: Municipality of Presidente Olegário with the location of each studied cave in the limestone outcrop.

Figure 2. Typical limestone outcrops at Presidente Olegário, state of Minas Gerais, southeastern Brazil. A: Outcrop containing Lapa Vereda da Palha Cave with deforestation visible in the area. B: Outcrop with more preserved surroundings. Photos: Resende, L.P.A. and Zepon, T.

an approximately 100-meter radius of fragmented native vegetation. The cave entrance is susceptible to floods in rainy periods and receives input of organic matter during flooding events. There are plant roots that penetrate some chambers and others contain several dry bat guano deposits. This cave has some chambers that have little contact with the epigean environment.

"Lapa da Fazenda São Bernardo": (18º16'36.83"S, 46º06'45.52"W): This cave has approximately 2,000 meters of horizontal development (GPME, pers. com.). The area surrounding the limestone outcrop containing this cave has been severely impacted by removal of native vegetation, planting of grass for cattle grazing, and use of pesticides for agriculture. The cave has an underground stream, plant roots penetrating several of its chambers, and openings in the ceiling that allow the input of much organic matter and light. Because of the openings the majority of the cave chambers are within the twilight zone, but aphotic zones are present in some of the deeper chambers.

"Lapa Vereda da Palha" (18°15'18.77"S, 46º07'33.63"W): This cave has approximately 2,500 meters of horizontal development (GPME, pers. com.). Cattle grazing has heavily impacted native vegetation surrounding the cave. The cave entrance is a silted-in sinkhole that contains some plant roots. An underground stream passes through some areas of the cave, and there are older, drier upper levels in the cave. The cave has few surface connections and, except for the presence of hematophagous bat guano deposits in some of the chambers, contains minimal allochthonous-derived nutrients.

"Lapa Zé de Sidinei" (18º18'05.62"S, 46º05'40.63"W): This cave has approximately 650 meters of horizontal development (GPME, pers. com.). Native vegetation has been removed from the cave area to allow cattle grazing. There is a small underground stream in the cave, but little contact with the surface environment and, therefore, minimal organic matter.

"Toca do Charco" (18º11'05.63"S, 46º09'39.31"W): This cave has approximately 80 meters of horizontal development (GPME, pers. com.) and no aphotic zone. Some of the native vegetation surrounding the cave was removed to permit cattle grazing. The phreatic zone is exposed in the cave interior, which keeps part of cave flooded and muddy all year long. There are plant roots and many dead leaves in the cave.

"Lapa do Moacir" (18º11'09.67"S, 46º09'34.49"W): This cave has approximately 200 meters of horizontal development (GPME, pers. com.) and no aphotic zone. Some of the native vegetation surrounding the cave was removed to permit cattle grazing. There are two large entrances that allow the input of much organic matter and light, in addition to plant roots that penetrate some chambers.

"Gruta da Juruva" (18º19'19.20"S, 46º04'52.90"W): This cave has approximately 1,100 meters of horizontal development (GPME, pers. com.). Despite the presence of some crops planted near the outcrop, some of the native vegetation surrounding the cave has been preserved. The cave has few surface connections, but has a large entrance in an upper level that is very dry. There is a sinkhole in a lower level of the cave.

Observations and collection

Sampling sites were established within the entrance, twilight and aphotic zones of each cave. Since each cave has only a single entrance, selection of those sites could not be randomized. Twilight and aphotic zone sites were randomly selected cave chambers within each of those zones. The chambers selected as sampling sites were surveyed in their entirety.

Each cave was surveyed five times between September 2013 and September 2014, except for "Lapa do Moacir" and "Gruta da Juruva", which were surveyed only four and two times respectively. The location (zone) and behavior of the animals were recorded before they were sampled. Epigean collections were performed near the limestone outcrops for comparison. Specimens were preserved in 70% ethanol for later laboratory identification, Pholcidae spiders were identified by Dr. Everton N. L. Rodrigues, from Universidade do Vale do Rio Sinos, São Leopoldo, state of Rio Grande do Sul; Sicariidae spiders were identified by Dr. Antonio D. Brescovit, from Instituto Butantan, São Paulo, state of São Paulo, and the Reduviidae bugs, by Dr. Hélcio Gil-Santana, from Instituto Oswaldo Cruz, Rio de Janeiro, state of Rio de Janeiro. Voucher specimens are deposited at the collection of the Laboratório de Estudos Subterrâneos in Universidade Federal de São Carlos (LES/UFSCar), São Carlos, state of São Paulo, Instituto Butantan, São Paulo, state of São Paulo, and Laboratório de Diptera, at Instituto Oswaldo Cruz (FIOCRUZ), Rio de Janeiro, state of Rio de Janeiro.

Results and discussion

Five reduviid species were recorded in Presidente Olegário caves, four belonging to the Emesinae and one to the Reduviinae subfamilies. Reduviids are distributed in all cave zones; entrance, twilight and aphotic. In "Gruta da Juruva" and "Lapa do Moacir" caves we only recorded unidentifiable nymphs, and in the other caves, nymphs were more frequently recorded too, but regardless their abundance, we do not consider them on the tables, and in our discussion, we only consider those that were identifiable.

Reduviids found in epigean habitats near the caves included two adult *Emesa mourei* Wygodzinsky, 1946 near "Lapa Vereda da Palha" cave, one *Zelurus* sp. nymph and one emesine nymph near "Lapa Arco da Lapa" cave and one emesine nymph near "Lapa da Fazenda São Bernardo" cave. The presence of emesine adults, nymphs, and exuviae of various instars both inside the caves and in epigean habitats suggests that they may complete their life cycles both inside the caves and in similar epigean habitats, such as the associated epikarst and rock shelters, hence we could classify them as troglophiles (*sensu* Racovitza, 1907). The list of species, with their abundance and location in the caves, are given in Table 1.

The caves "Lapa da Fazenda São Bernardo" and "Lapa Vereda da Palha" contained only one Emesinae species (*Ploiaria* sp.), while "Lapa Arco da Lapa" and "Toca do Charco" caves contained two co-occurring emesines (*Emesa mourei* Wygodzinsky, 1946 and *Ploiaria* sp.; *Ploiaria* aff. *carvalhoi* Wygodzinsky, 1966 and *Phasmatocoris* sp. respectively). Almost all emesines found in the caves occurred on parietal substrates like cave walls, exposed rocks and concretions (Figure 3). Our observations corroborate those of previous authors (Trajano and Bichuette, 2010) in Brazilian caves, where emesines are preferentially parietal. We observed two individuals feeding on cixiid planthoppers (Fulgoroidea) and one on a fly (Diptera: Brachycera).

Emesines living in Presidente Olegário caves

Emesa mourei

Two individuals of *Emesa mourei* were seen in "Lapa Arco da Lapa" cave, one in the entrance and another in the twilight zone (Table 2). The individual observed in the cave entrance is the first record of an interaction between an emesine and a sicariid spider (*Loxosceles similis* Moenkhaus 1898). The emesine was standing on the web in a resting posture, and the spider was resting far from it, at the edge of its web. This is possibly a kleptoparasitic association; however, additional observations are needed in order to confirm this association. The second observation was made in the twilight zone, where a nymph was observed feeding on a fly (Diptera: Brachycera). This observation was near a pholcid web, and may represent a kleptoparasitic association. This supposition is supported by our observation of the presence of vestiges of silk on the body of the fly and in the legs of the emesine (Figure 3). *Emesa mourei* does have the calamistral-like hair

Table 1. Reduviidae species recorded from Presidente Olegário caves, state of Minas Gerais, southeastern Brazil, with abundance and location (zone) of records (only adults and identifiable nymphs were considered). Legend: AL= Lapa Arco da Lapa; AZ= Aphotic Zone; EZ= Entrance Zone; SB= Lapa da Fazenda São Bernardo; TC= Toca do Charco; TZ= Twilight Zone; VP= Lapa Vereda da Palha; ZS= Lapa Zé de Sidinei.

Subfamily	Species Cave	AL			SB			VP			ZS			TC		Total
	Zone	EZ	TZ	AZ	EZ	TZ	AZ	EZ	TZ	AZ	EZ	TZ	AZ	EZ	TZ	
Emesinae	*Emesa mourei* Wygodzinsky, 1945	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2
	Ploiaria sp.	4	2	0	3	3	0	4	3	0	0	0	0	0	0	19
	Ploiaria aff. *carvalhoi* Wygodzinsky, 1966	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	Phasmatocoris sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Reduviinae	*Zelurus zikani* (Costa Lima, 1940)	4	0	0	0	0	1	0	1	4	3	4	2	0	1	20

Figure 3. State Nymph of *Emesa mourei* feeding on a fly (Diptera: Brachycera) near a pholcid web in Lapa Arco da Lapa Cave, state of Minas Gerais, southeastern Brazil. Photo: Resende, L.P.A.

Table 2. Emesinae recorded in association with spiders in caves at Presidente Olegário, state of Minas Gerais, southeastern Brazil, with description of the interactions and zone where the species were recorded.

Species	Lapa Arco da Lapa		Toca do Charco
	Entrance Zone	Twilight Zone	Twilight Zone
Emesa mourei Wygodzinsky, 1945	Adult in association with *Loxosceles similis* web	Nymph in association with *Mesabolivar* aff. *tandilicus* web/ kleptoparasitic	
Phasmatocoris sp.			Nymph occupying a *Mesabolivar* aff. *tandilicus* web

structure of the fore-tibiae, which may be important in its association with spiders (Wygodzinsky, 1966).

Examples of emesine-arachnophilous associations involving pholcid spiders, but not within caves, have been recorded in Puerto Rico for *Emesa tenerrima* (Dohrn, 1860), which lives on the webs of *Modisimus signatus* Banks, 1914 (Santiago-Blay and Maldonado-Capriles, 1988); for the Australian *Stenolemus giraffa* Wygodzinsky, 1956, which feeds on a variety of spiders, but primarily species in the pholcid genus *Trichocyclus* Simon, 1908 (Soley *et al.*, 2011) and for *Stenolemus bituberus* Stål, 1874, also from Australia, which feeds on a variety of spiders, including *Pholcus phalangioides* (Fuesslin, 1775) (Wignall and Taylor, 2008).

Two other species of *Emesa* Fabricius, 1803 have been recorded on epigean spider webs or observed feeding on spiders. *Emesa mantis* (Fabricius, 1794) has been collected from spider webs in Jamaica. One of the observed animals was feeding on a spider, and exuviae of *E. mantis* were often found on the spider webs (Maldonado-Capriles and Farr, 1962). Four adults and a nymph of *Emesa mourei* were collected on webs of the spider *Aglaoctenus castaneus* (Mello-Leitão, 1942) (Lycosidae) in Brazil (Gil-Santana and Jurberg, 2003).

Phasmatocoris sp.

The only *Phasmatocoris* sp., was observed in the twilight zone of "Toca do Charco", on a web of *Mesabolivar* aff. *tandilicus*.

Only four cavernicolous *Phasmatocoris* spp. were previously known: *P. xavieri* Gil-Santana, Alves, Barrett and Costa 2007, from the state of Amazonas, Brazil (Gil-Santana *et al.*, 2007), *P. labyrinthicus* from southern Arizona, USA (Pape, 2013), *P. catarinae* Gil-Santana, 2015 (Gil-Santana, 2015) from the state of Minas Gerais, Brazil and *P. galvaoi* Gil-Santana, 2015 (Gil-Santana, 2015) from the state of Pará, Brazil. We believe the *Phasmatocoris* nymph we found in "Toca do Charco" may also be cavernicolous. All of these species seem to be morphologically adapted for associations with spiders, with each possessing both the stiff, obliquely inclined bristles on the dorsal surface of the fore tibiae and the ventral, subapical auxiliary brushes of the fore tibiae (Pape, 2013; Gil-Santana, 2015). However, only *P. labyrinthicus* has so far been observed actively manipulating spider silk of (abandoned) spider webs (Pape, 2013).

Ploiaria sp. and *Ploiaria* aff. *carvalhoi*

Ploiaria spp. were the most abundant emesines occurring in all of the studied Presidente Olegário caves, except "Lapa Zé de Sidinei" cave. However, no associations with resident spiders were observed for either of the two species.

In the New World, *P. maya* Wygodzinsky, 1966 and *P. umbrarum* McAtee & Malloch, 1925 are known only from caves (Wygodzinsky, 1966). The latter species was recorded as a common predator occurring on guano in several caves in Jamaica by Peck (1997).

Other Reduviids

A non-emesine reduviid regularly found in the studied caves is *Zelurus zikani* (Costa Lima, 1940). This species was recorded in the same caves that the emesines were observed. Species of *Zelurus* Hahn, 1826 are relatively common in caves of the New World tropics, where they are predators of other invertebrates (Ferreira and Martins, 1999 [*Z. variegatus* (Costa Lima, 1940)]; Gnaspini, 1996 [*Z. travassosi* (Costa Lima, 1940)]; Machado, 2002 [*Z. travassosi*]; Machado *et al.*, 2003 [*Zelurus* sp.]; Prous *et al.*, 2015 [*Zelurus* sp.]; Trajano and Bichuette, 2010 [*Z. travassosi* and others]).

Threats and conservation

Studies performed in caves demonstrate the importance of conserving macroinvertebrates, especially predatory arachnids, such as spiders, because they are vulnerable to environmental changes and their decline is indicative of environmental degradation (Trajano, 2010). Understanding the biology and ecology of individual cave invertebrate species, such as emesines and spiders, is essential in unravelling the interspecific associations in cave food chains (van Helsdingen, 2011).

Underground ecosystems are intrinsically fragile due, in part, to their low biological diversity as compared to epigean environments, and their dependence on nutrients imported from the surface. Because of this, they are significantly affected by changes in epigean habitats (Trajano, 2000). In the vicinity of Presidente Olegário, deforestation for agriculture (crop and pasture), and future projects for gas extraction and small hydropower threaten the subterranean environment and its fauna. According to Decree 6.640 (Brasil, 2008), the presence of unique biological values is one of the criteria used for evaluating the significance of cave resources. Thus, this record of rarely documented interactions between spiders and emesines in Presidente Olegário caves is an important factor for promoting the protection of these caves. This record is only the third instance of these interactions in caves in the World and the first in Brazilian caves. The small number of records of emesines interacting with spiders in caves may be due to a generally low abundance of these predatory animals in these habitats (*e.g.*, Pinto da Rocha, 1996; Gnaspini, 1996). It is likely that emesines are important components of the community structure in caves and that their interactions with spiders play an important role in cave communities.

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References

AB'SABER, N.A. 1977. Os domínios morfoclimáticos na América do Sul: Primeira aproximação. *Geomorfologia*, **52**:1-22.

BRASIL. 2008. Decreto no 6.640, de 7 de novembro de 2008. Altera o Decreto no 99.556, de 1º de outubro de 1999, que dispõe sobre a proteção das cavidades naturais subterrâneas e existentes no território Nacional. Available at: http://www.planalto.gov.br/ccivil_03/_Ato2007-2010/2008/Decreto/D6640. Accessed on: 20/12/2014.

COBBEN, R.H. 1978. *Evolutionary trends in Heteroptera. Part II. Mouthpart-structures and feeding strategies.* Wageningen, Mededlingen Landbouwhogeschool, 407 p.

CULLINGFORD, C.H.D. 1962. Cave fauna and flora. *In*: C.H.D. CULLINGFORD (org.), *British Caving, an introduction to speleology*. London, Routledge and Kegan Paul, p. 347-389.
CULVER, D.C.; PIPAN, T. 2009. *The biology of caves and other subterranean habitats*. Oxford, Oxford University Press, 256 p.
CULVER, D.C.; PIPAN, T. 2014. *Shallow subterranean habitats, ecology, evolution and conservation*. Oxford, Oxford University Press, 258 p. https://doi.org/10.1093/acprof:oso/9780199646173.001.0001
FERREIRA, R.L.; MARTINS, R.P. 1999. Trophic structure and natural history of bat guano invertebrate communities, with special reference to Brazilian caves. *Tropical Zoology*, **12**(2):231-252. https://doi.org/10.1080/03946975.1999.10539391
GIL-SANTANA, H.R. 2015. Two new species of *Phasmatocoris* Breddin from Brazil, and description of the male of *Phasmatocoris borgmeieri* (Wygodzinsky) (Hemiptera: Heteroptera: Reduviidae: Emesinae). *Zootaxa*, **4059**(1):51–70. https://doi.org/10.11646/zootaxa.4059.1.3
GIL-SANTANA, H.R.; JURBERG, J. 2003. Sobre a ocorrência de *Emesa mourei* Wygodzinsky, 1945 (Hemiptera, Reduviidae, Emesinae) em teias biológicas. *Entomología y Vectores*, **10**:61-66.
GIL-SANTANA, H.R.; ALVES, V.R.; BARRETT, T.V.; COSTA, L.A.A. 2007. A new species of *Phasmatocoris* Breddin (Hemiptera: Reduviidae: Emesinae) from the Amazon, Brazil. *Zootaxa*, **1642**:43–51.
GIL-SANTANA, H.R.; FORERO, D.; WEIRAUCH, C. 2015. Assassin bugs (Reduviidae excluding Triatominae). *In:* A.R. PANIZZI; J. GRAZIA (org.), *True bugs (Heteroptera) of the Neotropics, Entomology in Focus 2*. Dordrecht, Springer Science+Business Media, p. 307-351.
GNASPINI, P. 1996. Population ecology of *Goniosoma spelaeum*, a cavernicolous harvestman from south-eastern Brazil (Arachnida: Opiliones: Gonyleptidae). *Journal of Zoology*, **239**(3):417-435. https://doi.org/10.1111/j.1469-7998.1996.tb05933.x
JUBERTHIE, C. 2000. Conservation of subterranean habitats and species. *In*: H. WILKENS; D.C. CULVER; W.F. HUMPHREYS (org.), *Ecosystems of the World - Subterranean ecosystems*. Amsterdam, Elsevier, p. 691-700.
MACHADO, G. 2002. Maternal care, defensive behavior, and sociality in Neotropical *Goniosoma* harvestmen (Arachnida, Opiliones). *Insectes Sociaux*, **49**(4):388-393.https://doi.org/10.1007/PL00012663
MACHADO, S.F.; FERREIRA, R.L.; MARTINS, R.P. 2003. Aspects of the population ecology of *Goniosoma* sp. (Arachnida: Opiliones: Gonyleptidae) in limestone caves in southeastern Brazil. *Tropical Zoology*, **16**(1):13-31. https://doi.org/10.1080/03946975.2003.10531181
MALDONADO-CAPRILES, J.; FARR, T.H. 1962. On some Jamaican Triatominae and Emesinae. *Proceedings of Entomological Society of Washington*, **64**:187-194.
NIMER, E. 1989. *Climatologia do Brasil*. Rio de Janeiro, Instituto Brasileiro de Geografia e Estatística, 421 p.
PAPE, R.B. 2013. Description and ecology of a new cavernicolous, arachnophilous thread-legged bug (Hemiptera: Reduviidae: Emesini) from Kartchner Caverns, Cochise County, Arizona. *Zootaxa*, **3670**(2):137–156. https://doi.org/10.11646/zootaxa.3670.2.2
PECK, S. 1997. Jamaican cave invertebrates. *In*: A. FINCHAM (org.). *Jamaica underground: the caves, sinkholes and underground rivers of the island*. Kingston, The Press University of the West Indies, p. 66-73.
PINTO-DA-ROCHA, R. 1995. Sinopse da fauna cavernícola do Brasil (1907-1994). *Papéis Avulsos de Zoologia*, **39**:61-163.
PINTO-DA-ROCHA, R. 1996. Description of the male of *Daguerreia inermis* Soares & Soares, with biological notes on population size in the Gruta da Lancinha, Paraná, Brazil (Arachnida, Opiliones, Gonyleptidae). *Revista Brasileira de Zoologia*, **13**(4):833-842. https://doi.org/10.1590/S0101-81751996000400004
PROUS, X.; FERREIRA, R.L.; JACOBI, C.M. 2015. The entrance as a complex ecotone in a Neotropical cave. *International Journal of Speleology*, **44**(2):177-189. https://doi.org/10.5038/1827-806X.44.2.7
RACOVITZA, E.G. 1907. Essai sur les problèmes biospéologiques. *Archives de Zoologie Experimentale et Génerale Biospelogica*, **14**(4):291-300.
SANTIAGO-BLAY, J.A.; MALDONADO-CAPRILES, J. 1988. Observations on the true bugs *Emesa tenerrima*, a possible spider mimic, and *Ghilianella borincana* (Hemiptera: Reduviidae: Emesinae) from Puerto Rico. *Proceedings of Entomological Society of Washington*, **90**:369-372.
SCHUH, R.T.; SLATER, J.A. 1995. *True bugs of the World (Hemiptera: Heteroptera): classification and natural history*. New York, Cornell University Press, 336 p.
SNODDY, E.L.; HUMPHREYS, W.L.; BLUM, M.S. 1976. Observations on the behavior and morphology of the spider predator *Stenolemus lanipes* (Hemiptera: Reduviidae). *Journal of Georgia Entomological Society*, **11**:55-58.
SOLEY, F.G.; JACKSON, R.R.; TAYLOR, P.W. 2011. Biology of *Stenolemus giraffa* (Hemiptera: Reduviidae), a web invading, araneophagic assassin bug from Australia. *New Zealand Journal of Zoology*, **38**(4):297–316. https://doi.org/10.1080/03014223.2011.604092
TRAJANO, E. 2000. Cave faunas in the Atlantic tropical rain forest: composition, ecology and conservation. *Biotropica*, **32**(4):882-893. https://doi.org/10.1646/0006-3606(2000)032[0882:CFITAT]2.0.CO;2
TRAJANO, E. 2010. Política de conservação e critérios ambientais: princípios, conceitos e protocolos. *Estudos Avançados*, **24**(68):135-146. https://doi.org/10.1590/S0103-40142010000100012
TRAJANO, E. 2013. Variações anuais e infra-anuais em ecossistemas subterrâneos: implicações para estudos ambientais e preservação de cavernas. *Revista da Biologia*, **10**(2):1-7. https://doi.org/10.7594/revbio.10.02.01
TRAJANO, E.; BICHUETTE, M.E. 2010. Diversity of Brazilian subterranean invertebrates, with a list of troglomorphic taxa. *Subterranean Biology*, **7**:1-16.
TRAJANO, E.; BICHUETTE, M.E.; BATALHA, M.A. 2012. Environmental studies in caves: the problems of sampling, identification, inclusion, and indices. *Espeleo-Tema*, **23**(1):13-22.
VANDEL, A. 1964. *Biospéologie. La biologie des animaux souterrains.* Paris, Gauthier-Villars, 619 p.
VAN HELSDINGEN, P.J. 2011. Spiders in a hostile world (Arachnoidea, Araneae). *Arachnologische Mitteilungen*, **40**:55-64. https://doi.org/10.5431/aramit4007
WIGNALL, A.E.; TAYLOR, P.W. 2008. Biology and life history of the araneophagic assassin bug *Stenolemus bituberus* including a morphometric analysis of the instars (Heteroptera, Reduviidae). *Journal of Natural History*, **42**(1-2):59–76. https://doi.org/10.1080/00222930701825150
WYGODZINSKY, P.W. 1966. A Monograph of the Emesinae (Reduviidae, Hemiptera). *Bulletin of American Museum of Natural History*, **133**:1-614.

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