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Distribution of cave-dwelling pseudoscorpions (Arachnida) in Brazil

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Abstract. Pseudoscorpions are among the most diverse of the smaller arachnid orders, but there is relatively little information about the distribution of these tiny animals, especially in Neotropical caves. Here, we map the distribution of the pseudoscorpions in Brazilian caves and record 12 families and 22 genera based on collections analyzed over several years, totaling 239 caves from 13 states in Brazil. Among them, two families (Atemnidae and Geogarypidae) with three genera (*Brazilatemnus* Muchmore, 1975, *Paratemnoides* Harvey, 1991 and *Geogarypus* Chamberlin, 1930) are recorded for the first time in cave habitats as, well as seven other genera previously unknown for Brazilian caves (*Olpiolum* Beier, 1931, *Pachyolpium* Beier 1931, *Tyrannochthonius* Chamberlin, 1929, *Lagynochthonius* Beier, 1951, *Neocheiridium* Beier 1932, *Ideoblothrus* Balzan, 1892 and *Heterolophus* Tömösváry, 1884). These genera are from families already recorded in this habitat, which have their distributional ranges expanded for all other previously recorded genera. Additionally, we summarize records of Pseudoscorpiones based on previously published literature and our data for 314 caves. We present these data in maps, considering the Brazilian biogeographical provinces. For the genus *Spelaeochernes* Mahnert, 2001, we reevaluate its *Schiner-Racovitza* status and propose that all species represent troglobites. Finally, we discuss the ranges of the pseudoscorpion families/genera.

Keywords: Biogeographical provinces, cave fauna, Neotropical, Pseudoscorpiones

The arachnid order Pseudoscorpiones includes 26 recent families, with 454 genera (Harvey 2013a). Among these, there are about 20 families with over 400 species (in at least 100 genera) that are frequently recorded in subterranean habitats around the world (Beier 1963; Reddell 1981, 2012; Heurtault 1994; Harvey 2013b; Moulds & Bannink 2012; Harvey et al. 2016a). Nevertheless, there is scant information about the distribution of this fauna in the Neotropical region, particularly concerning subterranean habitats, such as caves.

In Brazil, 173 described species have been recorded in 16 families and 66 genera (Table 1) (Ratton et al. 2012; Harvey 2013a; Von Schimonsky et al. 2014; Harvey et al. 2016b; Viana et al. 2018). Of these, 30 species in 12 genera of 10 families include subterranean populations (Beier 1969; Mahnert 2001; Andrade & Mahnert 2003; Ratton et al. 2012; Von Schimonsky et al. 2014; Viana et al. 2018), which have been recorded in 106 caves of eight Brazilian states (Bahia, Goiás, Minas Gerais, Mato Grosso do Sul, Pará, Paraná, Santa Catarina and São Paulo). The family Chernetidae is the most speciose of these, with about 39 percent of the described Brazilian species, followed by Chthoniidae with about 11% of species and Olpiidae with 8% (Harvey 2013b).

The genus *Spelaeochernes* Mahnert, 2001 (Chernetidae), which is endemic to Brazil, is notable for having eight described species occurring in caves around the country (Mahnert 2001), making it the genus with the highest number of Brazilian cave-dwelling species. On the other hand, for the family Chthoniidae, *Pseudochthonius* Balzan, 1892 occurs in other countries in South America and Africa, with 29 described species (Harvey 2013b), but it is more diverse in Brazil, with nine described species.

According to Trajano (2012), subterranean fauna can be classified using the *Schiner-Racovitza* system and the concepts of sink and source populations in three categories: troglobites (exclusively and obligatory cave-dwelling source population), troglophiles (cave-dwelling and epigean source populations with gene flow between them), and trogloxenes (epigean source populations, regularly found in subterranean habitat with the need to frequently move between both to complete their life cycle) (Trajano & Carvalho 2017). Troglobites frequently have troglomorphic traits, that is, apomorphic character states related to the hypogean life such as pallid coloration, elongate appendages, and loss or reduction of eyes (Christiansen 1962; Harvey et al. 2000; Reddell 2012; Trajano 2012; Trajano & Carvalho 2017), which may or may not be an adaptive feature.

Regarding pseudoscorpions, some authors have stated that troglobites always show troglomorphic traits; if such characteristics are not present, then they should be classified as troglophiles (e.g., Heurtault 1994; Andrade 2004). This correlation is not necessarily the rule, because the classification relies on the occurrence or not of established populations in subterranean habitats and implies that only the more modified organisms are included into the troglobite category. Besides that, the presence of troglomorphisms is not exclusive to subterranean organisms, being found in endogean organisms and deep-sea animals (Poulson 2001; Christiansen 2012; Culver & Pipan 2014).

Mahnert (2001) considered three species of Brazilian pseudoscorpions as troglobites: *Pseudochthonius strinatii* Beier, 1969, *P. biseriatus* Mahnert, 2001 (Chthoniidae) and *Ideoroncus cavicola* Mahnert, 2001 (Ideoroncidae). Additionally, *Spelaeobochica muchmorei* Andrade & Mahnert, 2003, *S.*

Table 1.—Brazilian pseudoscorpion families with number of genera and described species. The underlined families are those occurring in caves.

Families	Genera number	Species number	Families	Genera number	Species number
Atemnidae	3	4	Geogarypidae	1	4
Bochicidae	1	4	Ideoroncidae	2	11
Cheiridiidae	2	4	Lechytiidae	1	1
Cheliferidae	4	5	Olpiidae	5	14
Chernetidae	24	65	Pseudochiridiidae	1	1
Chthoniidae	4	19	Syarinidae	4	10
Feaellidae	1	1	Tridenchthoniidae	6	9
Garypinidae	1	1	Withiidae	6	17

iuiu Ratton, Mahnert & Ferreira, 2012 and *S. goliath* Viana, Souza & Ferreira, 2018 (Bochicidae) were also classified as troglobites, bringing the current total to six exclusively subterranean species.

In this work, we present an overview of the distribution of pseudoscorpion families and genera, with the new occurrences and the new records based on literature data and collections. For the presentation of the maps, we consider the state political divisions of Brazil, the biogeographical provinces (Morrone 2006, 2014), and the karstic/non-karstic areas. Furthermore, we discuss the *Schiner-Racovitza* classification status for species of *Spelaeochernes*.

METHODS

Material examined.—The material examined for this study is deposited in the zoological reference collection of Laboratório de Estudos Subterrâneos (LES) of Universidade Federal de São Carlos and has the following catalogue numbers: LES000001–6, LES000014, LES000333–338, LES000421–476, LES000523–572, LES001617, LES002616–2645, LES005693–5702, LES005705–5720, LES005724–5736, LES005740–5751, LES005755–5756, LES005758–5759, LES007655–7692, and LES009331–9867. Other material we examined is deposited in Museu de Zoologia da Universidade de São Paulo (MZUSP) and has the following catalogue numbers: MZUSP3835, MZUSP10283–284, MZUSP10298, MZUSP10300, MZUSP10305, MZUSP13782, MZUSP13785, MZUSP13846, MZUSP16589, MZUSP16592, MSUSP16596, MZUSP20125, MZUSP20726–727, MZUSP20947, MZUSP21287, MZUSP21291–295, MZUSP21299–302, MZUSP21355–356, MZUSP71759–764, and MZUSP71766.

Table 2.—Number of caves positively sampled in different Brazilian States, karstic/non-karstic areas and biogeographic regions. Abbreviations of states: BA – Bahia, CE – Ceará, GO – Goiás, MG – Minas Gerais, MS – Mato Grosso do Sul, MT – Mato Grosso, PA – Pará, PR – Paraná, RS – Rio Grande do Sul, SE – Sergipe, SP – São Paulo, TO – Tocantins.

No. of caves	Karstic/ non-karstic areas	Biogeographic region	States
48	Bambuí Group	Cerrado Province	BA
		Parana forest Province	
	Una-Irecê Group	Caatinga Province	
	Tombador	Caatinga Province	
4	Exu Group	Caatinga Province	CE
14	Bambuí Group	Cerrado Province	GO
101	Bambuí Group	Cerrado Province	MG
		Parana forest Province	
	Iron Quadrangle	Parana forest Province	
17	Corumbá Group	Cerrado Province	MS
6	Araras Group	Cerrado Province	MT
5	Altamira-Itaituba Group	Xingu-tapajós Province	PA
1	Brusque Group	Araucária forest Province	PR
1	Botucatu Group	Pampean Province	RS
3	Canudos Supergroup	Atlantic Province	SE
37	Açungui Group	Parana forest Province	SP
		Atlantic Province	
	Serra do Mar region	Atlantic Province	
	Botucatu Group	Cerrado Province	
2	Bambuí Group	Cerrado Province	TO

Methods.—The majority of specimens have been collected in various field trips for projects conducted by staff from LES under the coordination of MEB and are preserved in 70 percent ethanol. The material is from 13 Brazilian states: Bahia, Ceará, Goiás, Minas Gerais, Mato Grosso, Mato Grosso do Sul, Pará, Piauí, Paraná, Rio Grande do Sul, Sergipe, São Paulo and Tocantins.

Pseudoscorpions were hand collected through qualitative active searching in all kinds of substrates inside caves. We also collected leaf litter for extraction in a Winkler apparatus and combined our searches with the use of a quadrat sample method (Bichuette et al. 2015) which allows us to concentrate sampling efforts in smaller areas. Other researchers also donated some additional material. We sampled epigean habitats in the surroundings of the caves and made qualitative active searches under trunks, rocks, and accumulations of organic matter.

The pseudoscorpions were studied with stereo- and compound microscopes, verifying the diagnostic characters using various identification keys for families (Harvey 1992; Mahnert 2001; Mahnert & Adis 2002) and publications for genera and species (e.g., Balzan 1890; With 1908; Chamberlin 1929, 1932; Chamberlin & Chamberlin 1945; Hoff 1945; Beier 1970b, 1974; Muchmore 1970, 1975a, 1975b, 1982; Mahnert 1979, 1985, 2001, 2016; Mahnert & Aguiar 1986; Mahnert et al. 1986; van den Tooren 2002; Harvey & Muchmore 2013) and by comparison with the material on loan from MZUSP.

Images were taken with a Leica DFC 295 video camera attached to a Leica M205C with a Planapo 1.0x objective. The figures were produced from stacks of images using Leica Application Suite v3.7.

Study areas.—The caves are located in different karstic/non-karstic areas and biogeographical provinces of Brazil, presented in accord with Karman & Sánchez (1986) and

Figure 1.—Pseudoscorpion specimens. (A) *Spelaeochernes* sp. (Chernetidae) from Bahia/Sergipe state; (B) *Neocheiridium* sp. (Cheiridiidae) from São Paulo state; (C) *Geogarypus* sp. (Geogarypidae) from São Paulo state; (D) *Pseudochthonius biseriatus* (Chthoniidae) from Minas Gerais state. Scale bars (A, C 1.0 mm; B, D 0.5 mm) (Photos by Luciana Bueno dos Reis Fernandes)

Auler et al. (2001), and Morrone (2006, 2014), respectively (Table 2). The maps were created in *QGis* Las Palmas 2.18 (QGIS Development Team 2016) with shapefiles of biogeographical provinces (Löwenberg-Neto 2014), geopolitical divisions (state), and the coordinates of sampled caves.

RESULTS

We analyzed 781 lots comprising 1,518 individuals (Figs. 1 & 2) from 239 caves (Fig. 3), of which only 31 caves already had published records of pseudoscorpion. Of these, 697 lots with 1,316 individuals were collected inside caves, of which 549 lots (984 individuals) were collected between 2010 and 2015. We summarized the distribution of the Brazilian cave-dwelling pseudoscorpion fauna for 314 caves across seven biogeographical regions and 13 states. Most of the material came from scientific research projects in different areas, and some material was from consulting works for different projects, like mining or hydroelectrical power plants.

Distribution of pseudoscorpion families/genera in Brazilian caves.—In addition to the new records of some families and genera for Brazilian caves, we expanded the distribution range for all other families and genera (Table 3), with the exception of Pseudochiridiidae (*Pseudochiridium* With, 1906), which was only recorded from one cave (Von Schimonsky et al. 2014). The number of recorded caves in which each family/genus occurs is presented in Table 4.

The families Chernetidae, Olpiidae and Chthoniidae showed the highest number of records and are more widespread than the others. Of these three families, Chernetidae is the one with the widest distribution, occurring in all states and biogeographical provinces sampled (Fig. 4), of which *Spelaeochernes* occurs in 12 states and six biogeographical provinces. The genus *Maxchernes* Feio, 1960 appears to be restricted to the Vale do Ribeira area, occurring in two caves. Unidentified genera were recorded from six different states, one of which is the only record of pseudoscorpions for one cave in Rio Grande do Sul state, in the extreme south of Brazil.

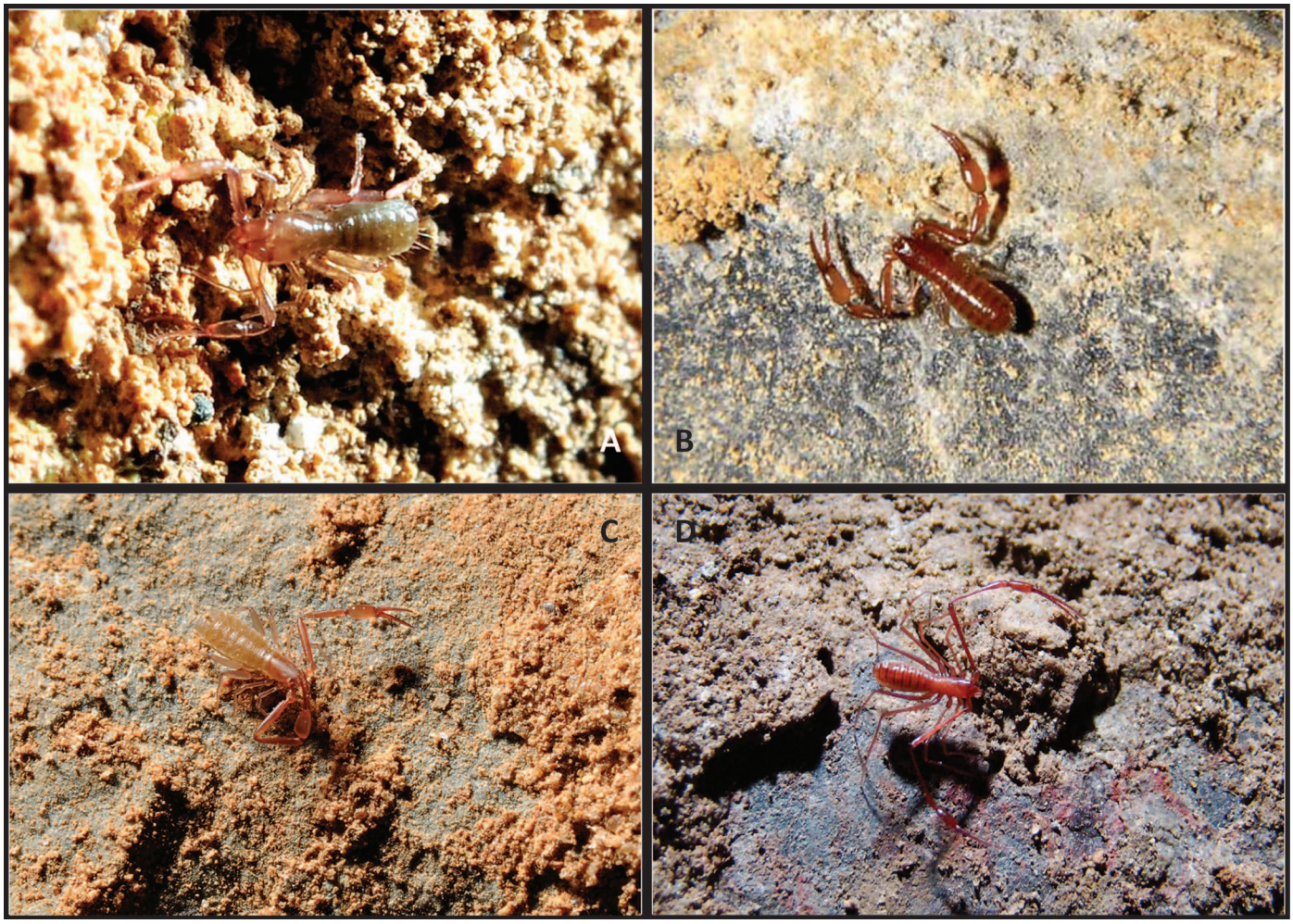

Figure 2.—Pseudoscorpion specimens in vivo. (A) *Pseudochthonius* sp. (Chthoniidae) from Bahia state; (B) *Spelaeobochica* sp. (Bochicidae) from Bahia state; (C) *Progarypus setifer* (Olpiidae) from Minas Gerais state; (D) *Spelaeobochica muchmorei* (Bochicidae) from São Paulo state. (Photos A–C by Adriano Gambarini; D by Cristiano de Carvalho)

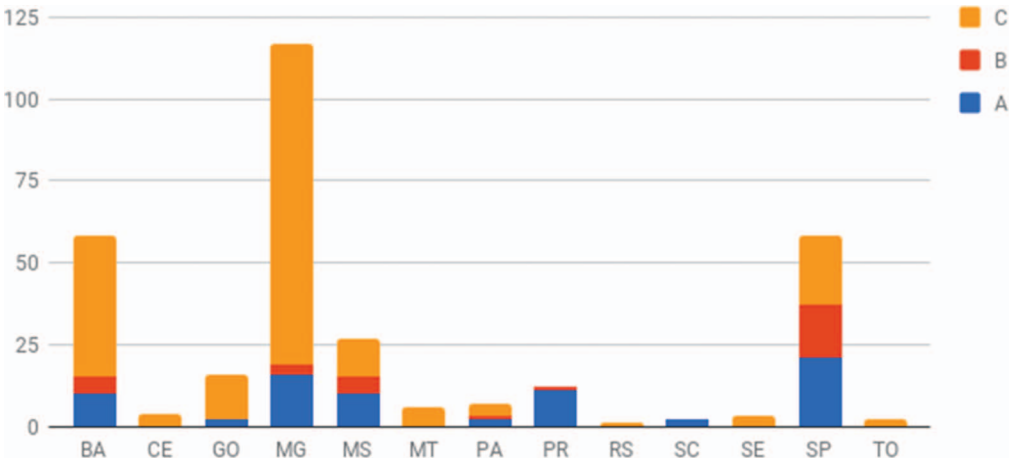

Figure 3.—Brazilian States with the number of sampled caves with pseudoscorpions: (A) Mahnert 2001 and not resampled; (B) caves with known pseudoscorpion occurrence, but resampled and records of Andrade & Mahnert 2003, Ratton et al. 2012, Von Schimonsky et al. 2014 and Vieira, Souza & Ferreira 2018; (C) new records from the present work. State abbreviations: BA – Bahia, CE – Ceará, GO – Goiás, MG – Minas Gerais, MS – Mato Grosso do Sul, MT – Mato Grosso, PA – Pará, PR – Paraná, RS – Rio Grande do Sul, SE – Sergipe, SP – São Paulo, TO – Tocantins.

Table 3.—Brazilian cave-dwelling pseudoscorpion families/genera that occur in each State sampled, with biogeographic regions in parenthesis. Open circles (○) indicate the literature register summarized in Mahnert (2001), supplemented by Andrade & Mahnert (2003), Ratton et al. (2012), Von Schimonsky *et al*. (2014) and Vieira, Souza & Ferreira (2018). Closed circles (•) indicate new occurrences of previously recorded pseudoscorpion families/genera in caves. Open diamonds (◇) indicate all unprecedented records. States abbreviations: BA – Bahia, CE – Ceará, GO – Goiás, MG – Minas Gerais, MS – Mato Grosso do Sul, MT – Mato Grosso, PA – Pará, PR – Paraná, RS – Rio Grande do Sul, SE – Sergipe, SP – São Paulo, TO – Tocantins. Biogeographic regions abbreviations: AFP – Araucária Forest Province, ATP – Atlantic Province, CAP – Caatinga Province, CEP – Cerrado Province, PAP – Pampean Province, PFP – Parana Forest Province, XTP – Xingu-Tapajós Province.

Families - Genera (Biogeographic provinces)	BA	CE	GO	MG	MS	MT	PA	PR	RS	SC	SE	SP	TO
Atemnidae - *Brazilatemnus* sp. (PFP)												◇	
Atemnidae - *Paratemnoides* sp. (CEP)			◇	◇									
Bochicidae - *Spelaeobochica* sp. (ATP, CAP, PFP)	•			○								○	
Cheiridiidae - *Cheiridium* sp. (CAP, CEP, PFP)	•		◇	◇		◇						◇	
Cheiridiidae - *Neocheiridium* sp. (ATP, CEP, PFP)			◇	◇								◇	
Chernetidae - *Maxchernes* sp. (ATP)												•	
Chernetidae - *Spelaeochernes* sp. (AFP, ATP, CAP, CEP, PFP, XTP)	•	◇	•	•	•	◇	•	○		○	◇	•	◇
Chernetidae - *Zaona* sp. (CEP)					○								
Chernetidae - Other genera (CEP, PAP, PFP)	◇		◇	◇			◇		◇			◇	
Chthoniidae - *Lagynochthonius* sp. (PFP)				◇									
Chthoniidae - *Pseudochthonius* sp. (ATP, CAP, CEP, PFP)	•		◇	•	◇			○				•	
Chthoniidae - *Tyrannochthonius* sp. (CEP)				◇	◇								
Geogarypidae - *Geogarypus* sp. (CAP, CEP, PFP)	◇		◇	◇									
Ideoroncidae - *Ideoroncus* sp. (AFP, ATP, CAP, CEP, PFP)	◇			◇				○				•	
Lechytiidae - *Lechytia* sp. (CAP, CEP)	◇				○								
Olpiidae - *Olpiolum* sp. (CAP, CEP, PFP, XTP)	◇	◇	◇				◇						
Olpiidae - *Pachyolpium* sp. (ATP, CAP, CEP, PFP)	◇	◇	◇	◇								◇	
Olpiidae - *Progarypus* sp. (ATP, CAP, CEP, PFP)	•		◇	•		◇						•	
Pseudochiridiidae - *Pseudocheiridium* sp. (CEP)	○												
Syarinidae - *Ideoblothrus* sp. (CAP)	◇												
Syarinidae - *Nannobisium* sp. (CAP, XTP)	◇						•						
Tridenchthoniidae - *Cryptoditha* sp. (CEP, PFP)				•								◇	

Table 4.—Numbers of caves in which each pseudoscorpion family/genus occurs in Brazil, according to the literature (Mahnert (2001), Andrade & Mahnert (2003), Ratton et al. (2012), Von Schimonsky et al. (2014) and Vieira, Souza & Ferreira (2018)) (A), the present work (B) and the total, without duplicates (C). In (B) the numbers in parenthesis are the duplicates, that is, those families/genera sampled from the same cave before in the literature.

Families – Genera	A	B	C
Atemnidae - *Brazilatemnus* sp.	0	1	1
Atemnidae - *Paratemnoides* sp.	0	5	5
Bochicidae - *Spelaeobochica* sp.	4	5(1)	7
Cheiridiidae - *Cheiridium* sp.	1	7	8
Cheiridiidae - *Neocheiridium* sp.	0	11	11
Chernetidae - *Maxchernes* sp.	1	2(1)	2
Chernetidae - *Spelaeochernes* sp.	84	152(15)	221
Chernetidae - *Zaona* sp.	1	0	1
Chernetidae - Unidentified genera	0	10	10
Chthoniidae - *Lagynochthonius* sp.	0	3	3
Chthoniidae - *Pseudochthonius* sp.	12	47 (4)	55
Chthoniidae - *Tyrannochthonius* sp.	0	2	2
Geogarypidae - *Geogarypus* sp.	0	5	5
Ideoroncidae - *Ideoroncus* sp.	4	18 (1)	21
Lechytiidae - *Lechytia* sp.	1	2	3
Olpiidae - *Olpiolum* sp.	0	9	9
Olpiidae - *Pachyolpium* sp.	0	17	17
Olpiidae - *Progarypus* sp.	9	30(4)	35
Pseudochiridiidae - *Pseudocheiridium* sp.	1	0	1
Syarinidae - *Ideoblothrus* sp.	0	2	2
Syarinidae - *Nannobisium* sp.	1	2	3
Tridenchthoniidae - *Cryptoditha* sp.	2	7	9
Tridenchthoniidae - *Heterolophus* sp.	0	1	1

Olpiidae is present in seven states and in five biogeographical provinces, with the first records of *Olpiolum* Beier, 1931 and *Pachyolpium* Beier, 1931 from Brazilian caves. *Progarypus* Beier, 1931 seems to be more common in the cave environment (Fig. 5).

Chthoniidae occurs in five states and four biogeographical provinces, with *Pseudochthonius* more widespread than *Lagynochthonius* Beier, 1951 and *Tyrannochthonius* Chamberlin, 1929, which are recorded from caves in Brazil for the first time (Fig. 6).

The families Atemnidae and Geogarypidae are newly recorded from Brazilian caves. We recorded the first from three states and two biogeographical provinces with the occurrence of *Brazilatemnus* Muchmore, 1975 and *Paratemnoides* Harvey, 1991. The second was represented by species of *Geogarypus* Chamberlin, 1930 from three states and three biogeographical provinces (Fig. 7).

The family Cheiridiidae was recorded infrequently, but we extended the distribution of *Cheiridium* Menge, 1855, and recorded *Neocheiridium* Beier, 1932 in caves for the first time in Brazil (Fig. 8). Ideoroncidae, represented by *Ideoroncus* Balzan, 1887, is present in three states and five biogeographical provinces (Fig. 9).

The remaining five families and seven genera have short-range distributions and a low number of records, such as Pseudochiridiidae, with a single record of *Pseudochiridium* in Bahia state in a single biogeographical province. The genus *Spelaeobochica* Mahnert, 2001 (Bochicidae) occurs in three states and three biogeographical provinces, and *Lechytia* Balzan, 1892 (Lechytiidae) is present in two states and two

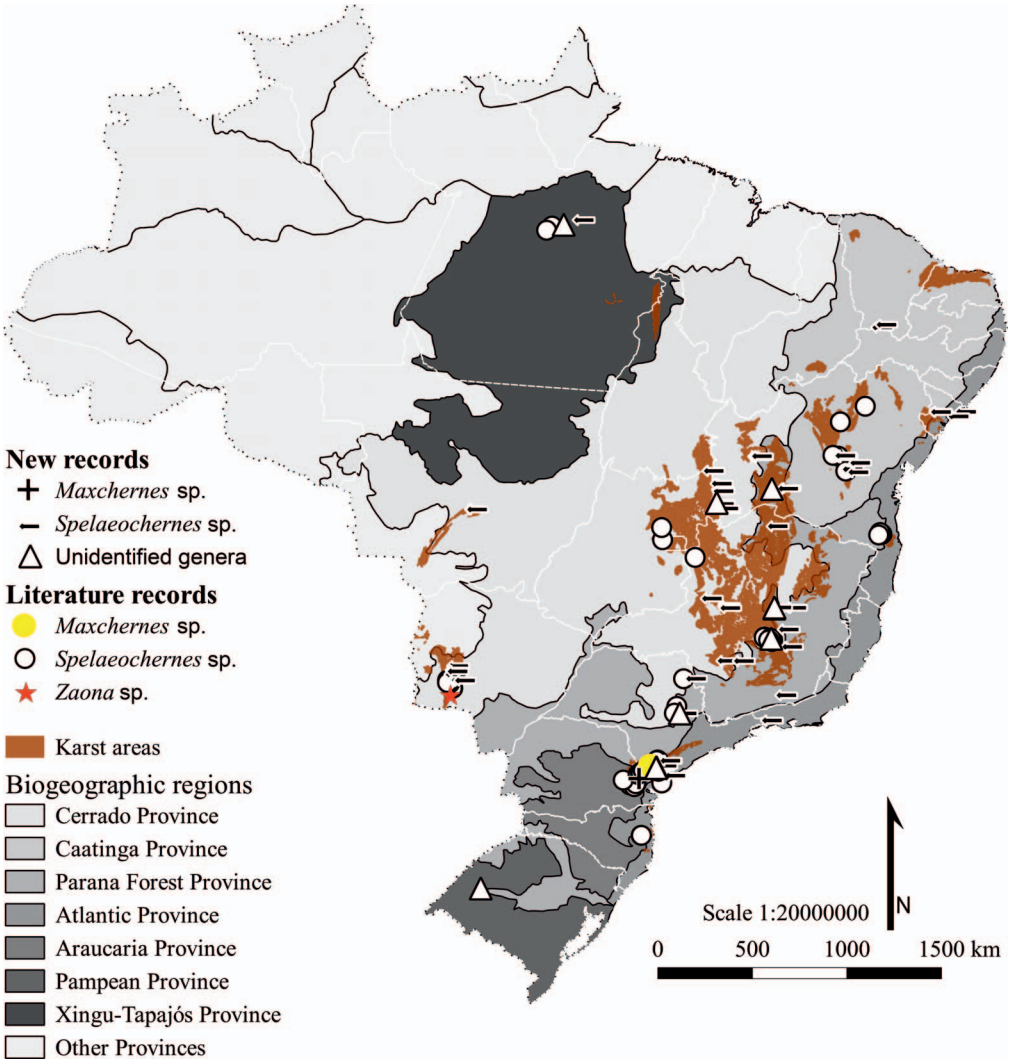

Figure 4.—Map showing the distribution of Chernetidae genera sampled in Brazilian caves. Previous records from the literature: *Maxchernes* (yellow circle), *Spelaeochernes* (white circle) and *Zaona* (red star); new records: *Maxchernes* (black cross), *Spelaeochernes* (black arrow) and unidentified genera (white triangle). The Brazilian biogeographical provinces in which these specimens occur are indicated by grey shading, the Brazilian karst regions are indicated by brown shading, and Brazilian States are outlined in white.

biogeographical provinces. Syarinidae and Tridenchthoniidae were each represented by two genera: *Ideoblothrus* Balzan, 1892 and *Nannobisium* Beier, 1931, and *Cryptoditha* Chamberlin & Chamberlin 1945 and *Heterolophus* Tömösváry 1884, respectively. Both are present in two states and two biogeographical provinces (Fig. 10).

DISCUSSION

The Catalogue of the Pseudoscorpionida (Harvey 1991) presented the known data of this order from 1758 until 1998, with 3,064 named species. Later, a digital catalogue presented 3,498 species with published data up to the end of 2010 (Harvey 2011a). In the last update of this catalogue (which included data until the end of 2011), there were about 3,799 described species of pseudoscorpions (Harvey 2013b) with the addition of 300 described species in a few years. However, for Brazilian fauna, only three new species were added to these numbers: *Spelaeobochica iuiu*, *S. goliath* Viana, Souza & Ferreira, 2018 and *Iporangella orchama* Harvey, Andrade & Pinto-da-Rocha, 2016 (Feaellidae), as well as a new record of *Pseudochiridium* aff. *insulae* Hoff, 1964 (Von Schimonsky et al. 2014), increasing the Brazilian pseudoscorpion fauna to 173 species.

Although the Brazilian pseudoscorpion fauna is the fifth-most diverse in the world, after the United States of America, Italy, Spain, and Australia (Harvey 2011b, 2013b), the number of species described can be considered relatively low for a mega-diverse country. The difficulty of collecting these organisms, due to their tiny size and cryptobiotic habits, can explain this apparently low richness, combined with the taxonomic impediment and many areas in Brazil without comprehensive sampling (Carvalho et al. 2007).

It is noteworthy that since 2001, only 29 species, of which 22 are new species, have been recorded from Brazilian caves (Mahnert 2001; Andrade & Mahnert 2003; Ratton et al. 2012; Von Schimonsky et al. 2014; Viana et al. 2018). Despite these

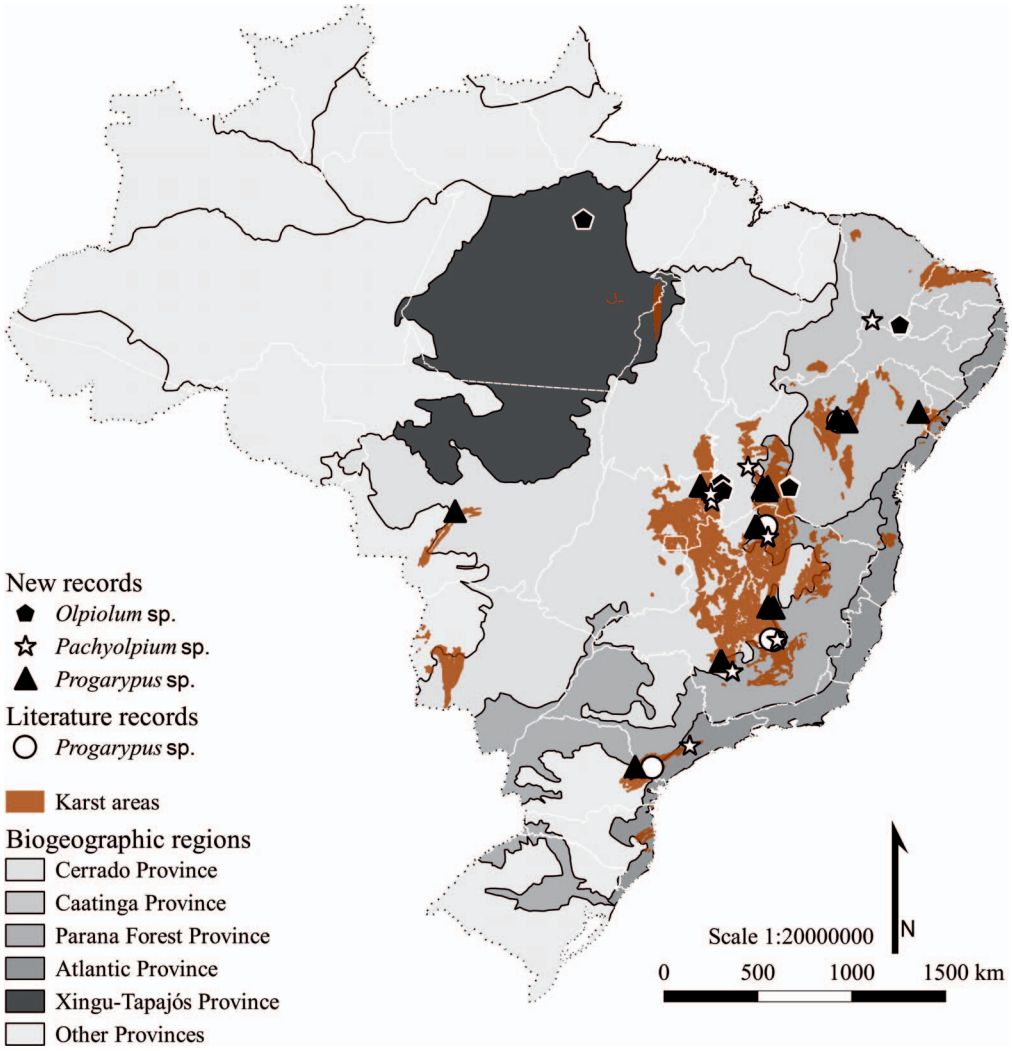

Figure 5.—Map showing the distribution of Olpiidae sampled in Brazilian caves. Previous record from the literature: *Progarypus* (white circle); new records of three genera: *Olpiolum* (black pentangle), *Pachyolpium* (white star), and *Progarypus* (black triangle). The Brazilian biogeographical provinces in which these specimens occur are indicated by grey shading, the Brazilian karst regions are indicated by brown shading, and Brazilian States are outlined in white.

records, two other epigean species were described for Brazil: *Attaleachernes thaleri* Mahnert 2009 for Pantanal region from central west Brazil, and *I. orchama,* found in a karst area from southeastern Brazil (Harvey et al. 2016b). Caves are a promising environment to look for new taxon records. This habitat offers favorable conditions for pseudoscorpions, with its lower abiotic variation (Trajano & Bichuette 2010; Reddell 2012).

Among the 16 families that occur in Brazil, 13 have been found in caves; 12 were recorded in this work. Feaellidae, Garypinidae and Withiidae only have epigean records in Brazil, although these families occur in caves in Southeast Asia (Cambodia, Malaysia and Vietnam), Afghanistan, and Venezuela and Kenya, respectively (Mahnert 1988; Heurtault 1994; Harvey 2013b; Harvey et al. 2016b), which may indicate a possibility of finding these families in Brazilian caves. Although there are no Brazilian karstic regions near or adjacent to Venezuela, the species that occur in caves there (*Ceratochernes guanophilus* Mahnert, 1994, *C. granulatus* Mahnert, 1994, *Lustrochernes argentinus* (Thorell, 1877), *Pachyolpium furculiferum* (Balzan, 1892), *Ideobisium chapmani* Muchmore, 1982 (Mahnert 1994; Galán & Herrera 2006) are not found in Brazil, except *L. argentinus* and *P. furculiferum*, both in epigean habitats (Feio 1945).

Most specimens of family Chernetidae in Brazilian caves belong to the genus *Spelaeochernes*, which currently includes eight named species (Mahnert 2001), none of which shows obvious troglomorphisms. Even with no records in epigean habitats, Mahnert (2001) did not consider it as a troglobitic genus. *Spelaeochernes* is morphologically and ecologically close to *Austrochernes* Beier, 1932, an Australasian genus (Harvey 2018). *Spelaeochernes* occurs in cave habitats and *Austrochernes* has some species that are found in caves, with a highly troglomorphic species (*A. imitans* (Beier, 1969)), considered to be a troglobite (Harvey & Volschenk 2007). Species of *Spelaeochernes* do not show any evident troglomorphisms, but according to the ecological classification of cave organisms (Trajano 2012; Trajano & Carvalho 2017), it

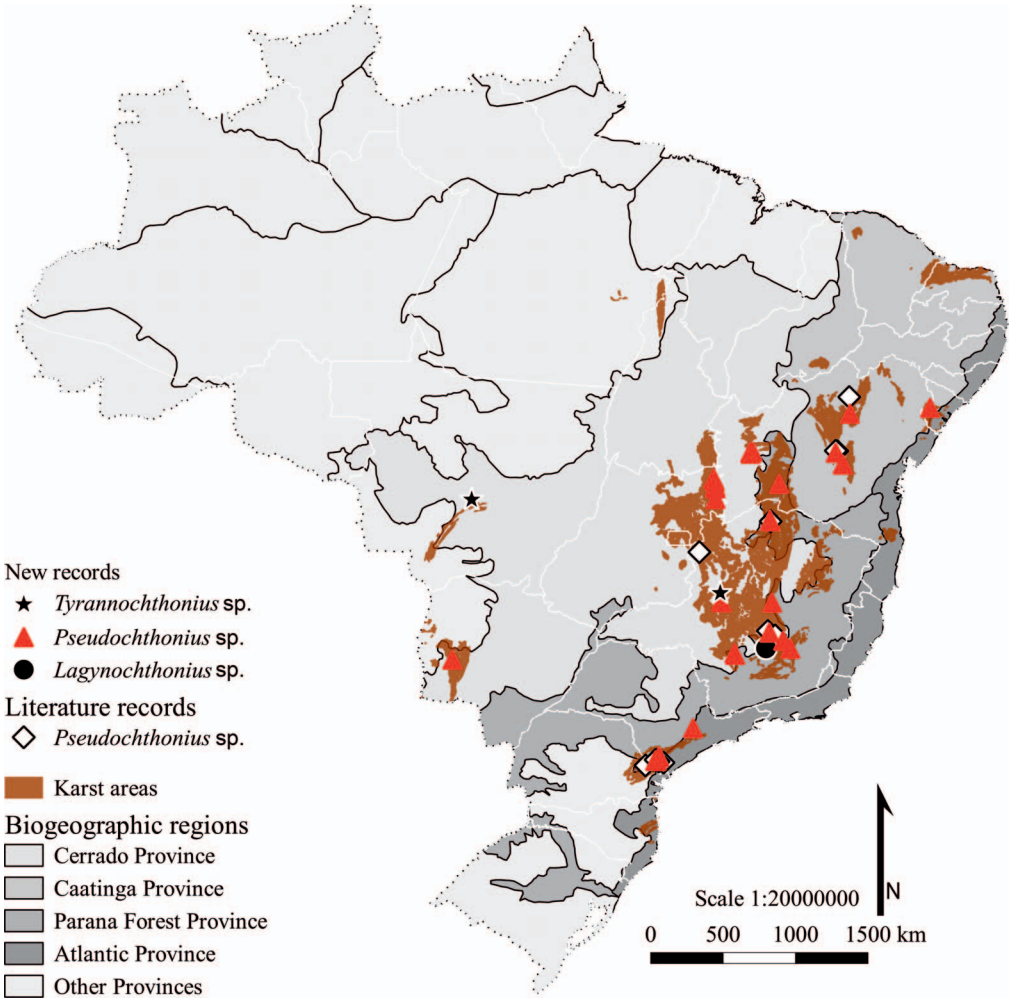

Figure 6.—Map showing the distribution of Chthoniidae sampled in Brazilian caves. Previous record from the literature: *Pseudochthonius* (white diamond); new records of three genera: *Tyrannochthonius* (black star), *Pseudochthonius* (red triangle), and *Lagynochthonius* (black circle). The Brazilian biogeographical provinces in which these specimens occur are indicated by grey shading, the Brazilian karst regions are indicated by brown shading, and Brazilian States are outlined in white.

should be considered a troglobite genus at least until such time when non-subterranean *Spelaeochernes* are found in epigean habitats, despite its large distributional range. Considering the unidentified genera of this family, the record from Rio Grande do Sul is quite important because it is the only pseudoscorpion record for extreme south Brazil and in the Pampas biogeographical province.

The family Olpiidae has only six species records from subterranean habitats worldwide (Harvey & Leng 2008), with four of those species occurring in Brazilian caves, belonging to the genus *Progarypus*. Despite that, we recorded this genus in several karst areas and biogeographical provinces, increasing its known range. Moreover, *Pachyolpium* also shows a wide distribution in many areas of Brazil, whereas *Olpiolum* is more restricted.

The genus *Pseudochthonius* is the only member of the Chthoniidae that has previously been found in Brazilian caves, with four species occurring in 13 caves (Beier 1969; Mahnert 2001). Even so, we recorded this genus in other karst areas and biogeographical provinces and increase its distribution to 37 more caves. Two other genera (*Lagynochthonius* and *Tyrannochthonius*) are newly recorded from caves in Brazil; however, they were already recorded in caves in Mexico (Muchmore 1969), USA (Muchmore & Chamberlin 1995; Muchmore 1996), Australia (Edward & Harvey 2008) and Vietnam (Judson 2007) with troglobitic representatives.

The first records of the family Atemnidae, with two genera (*Brazilatemnus* and *Paratemnoides*) and Geogarypidae, with one genus (*Geogarypus*) in Brazilian caves, are quite important due to their low richness in Brazil, both families with only four named species. Moreover, these two families occur in caves in Australia (Moulds et al. 2007; Moulds & Bannink 2012; Alexander et al. 2014), and Geogarypidae has Gondwanan origins (Harvey 1996).

Brazilatemnus is a genus only recorded from the Amazon region with one species, yet it was found in a sandstone cave in Parana Forest Province in São Paulo state. *Paratemnoides* is a widely distributed tropical genus, and two species occur in Brazilian territory. Until now, none have been recorded from caves.

The genus *Geogarypus* is found in different parts of world. It has only four named species in Brazil (*G. amazonicus* Mahnert,

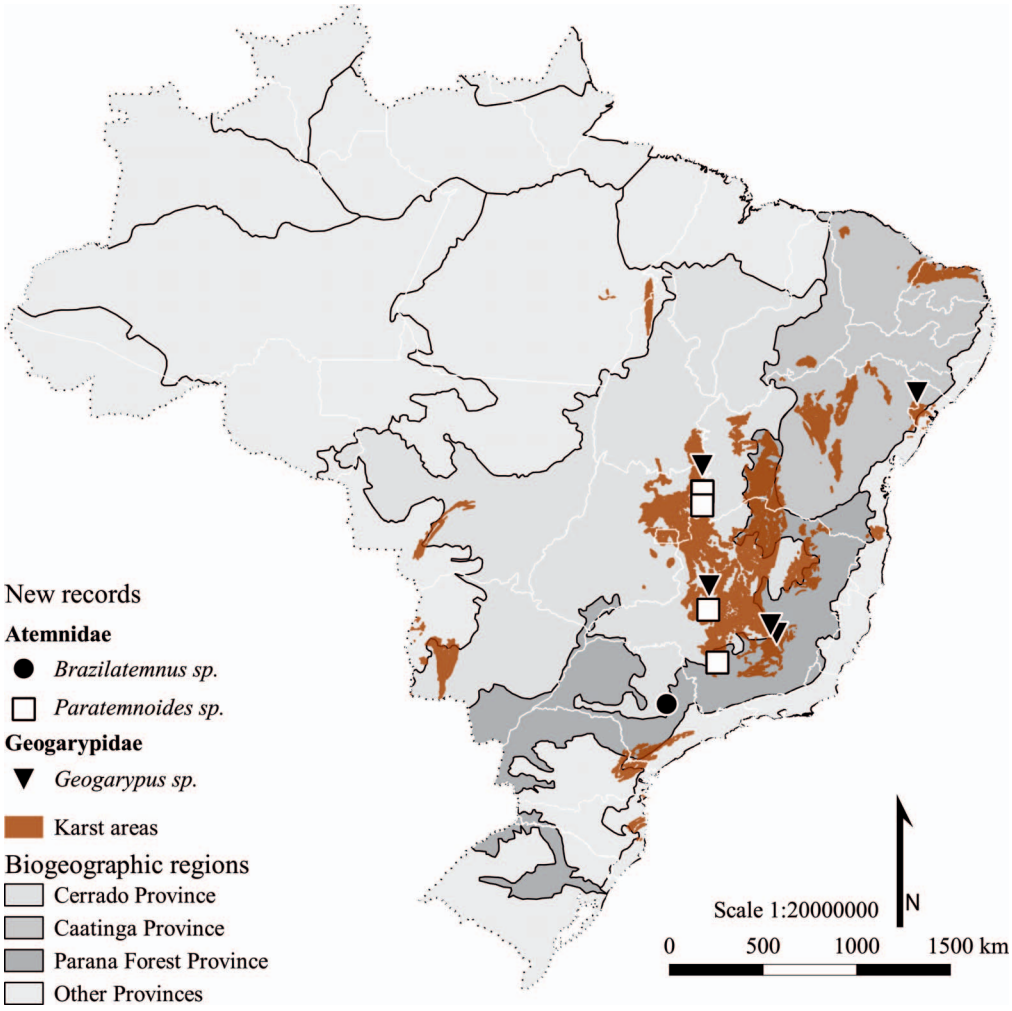

Figure 7.—Map showing the distribution of the families Atemnidae and Geogarypidae. There were no previous records of these families from Brazilian caves. New records: Atemnidae, *Brazilatemnus* (black circle) and *Paratemnoides* (white square); and Geogarypidae, *Geogarypus* (black inverted triangle). The Brazilian biogeographical provinces in which these specimens occur are indicated by grey shading, the Brazilian karst regions are indicated by brown shading, and Brazilian States are outlined in white.

1979, *G. cuyabanus* (Balzan, 1887), *G. formosus* Mello-Leitão, 1937 and *G. paraguayanus* Beier, 1931), with none of them recorded in cave habitat heretofore.

Cheiridiidae was previously recorded in Brazilian caves with a single record of *Cheiridium* (Mahnert 2001). The new records of this genus are quite far from where it was previously known, and the finding of other genera of this family (*Neocheiridium*) suggests that those organisms present species that are cave-dwellers, and not accidentals. Therefore, the findings indicate that some species in those genera should be troglophiles, due to their occurrence in deep zones of 19 caves (Table 4) with established populations. The first one occurs now in three biogeographical provinces as well as the last one, implying in an increase range distribution southern to the previous record.

Ideoroncus has two species previously recorded in four caves in the region of Parque Estadual Turístico do Alto Ribeira (PETAR); one of them, the troglobite *I. cavicola*, is recorded in three caves and the other, *I. setosus* Mahnert, 1984, could be a troglophile but has only a single record for one cave. Despite that, this genus has seven other epigean species (six in Brazil and one in Paraguay). For the family Ideoroncidae, that genus has a considerable increase in cave occurrences as well as in its general distribution in Brazil to different biogeographical provinces in lower latitudes.

The majority of Bochicidae are obligatory cave-dwellers (troglobites), and some authors suggest that this family could be relictual (Beier 1956, 1970a; Chamberlin & Malcolm 1960; Muchmore 1972). New occurrences for the Bochicidae were recorded for the states of Minas Gerais and Bahia (*Spelaeobochica* genus).

Lechytiidae, Syarinidae and Tridenchthoniidae have few records in general and few new records, but they are in different biogeographical provinces and far from where they were previously known. For the first one, *Lechytia* was previously known in Mato do Grosso do Sul state, and now it is recorded in Bahia and Sergipe states, in a different biogeographical province and isolated areas. For the second, previously known only in the Amazonian region, we recorded *Nannobisium* in other caves in the same region of Xingu-

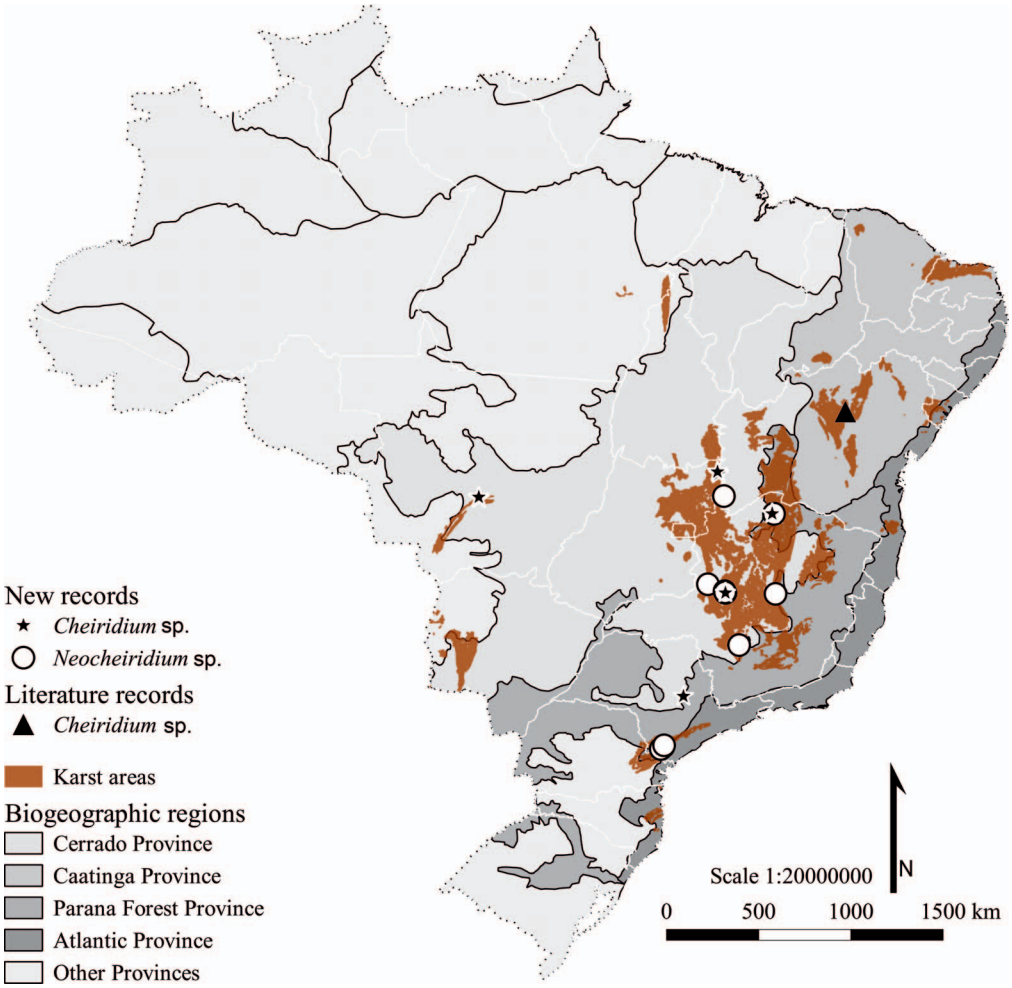

Figure 8.—Map showing the distribution of Cheiridiidae sampled in Brazilian caves. Previous record from the literature: *Cheiridium* (black triangle); new records: *Cheiridium* (black star) and *Neocheiridium* (white circle). The Brazilian biogeographical provinces in which these specimens occur are indicated by grey shading, the Brazilian karst regions are indicated by brown shading, and Brazilian States are outlined in white.

Tapajós province and in caves in the Chapada Diamantina region (Bahia state) in an isolated semi-arid region. *Ideoblothrus* was already recorded in a Mexican cave (Muchmore 1982), but for Brazil, it is the first record for a subterranean habitat. In Tridenchthoniidae, the genus *Cryptoditha* has its range distribution increased and the genus *Heterolophus* was recorded for the first time in caves.

In our records, some samples were identified to species level, and concerning the species considered troglobites in literature, none have had their range increased, except *Pseudochthonius biseriatus*, which was found in another cave (Lapa do Cipó) in the same region of Minas Gerais state. This suggests that these caves (Olhos d'Água and Lapa do Cipó) are part of the same subterranean system, as observed for other taxa, such as opilionids and amblypygids (do Monte et al. 2015).

Concerning the number of positively sampled caves with literature records of pseudoscorpions (314), it may seem small compared to the total number of about 17,500 registered caves in Centro Nacional de Pesquisa e Conservação de Cavernas (CECAV 2017), but it is worth noting that many cave records in this database are derived from consulting works, and some caves registered by consultants may no longer exist. Furthermore, the effort required to collect in this environment has to be considered due to the inherent difficulties of working in such places.

Many caves are endangered, under threat from mining, hydroelectric power plants, agriculture, and rampant tourism (Gallão & Bichuette 2018), with the exception of some caves inside parks, but even these suffer from the lack of supervision and are often abandoned.

All these threats and the change in Brazilian cave legislation in recent years (Brasil 2008, 2009, 2017) concern us about the conservation of the nation's speleological heritage. We therefore present our data by Brazilian political states, since each state has its own environmental legislation, and they may use these data in the way that fits them. Nowadays, this kind of information is particularly important regarding conservation politics. It should be useful to environmental organisations and companies that need to make environmental studies and plan their actions.

In addition, pseudoscorpions have been listed in the IUCN Red List of Brazilian Threatened Fauna since 2003: *M.*

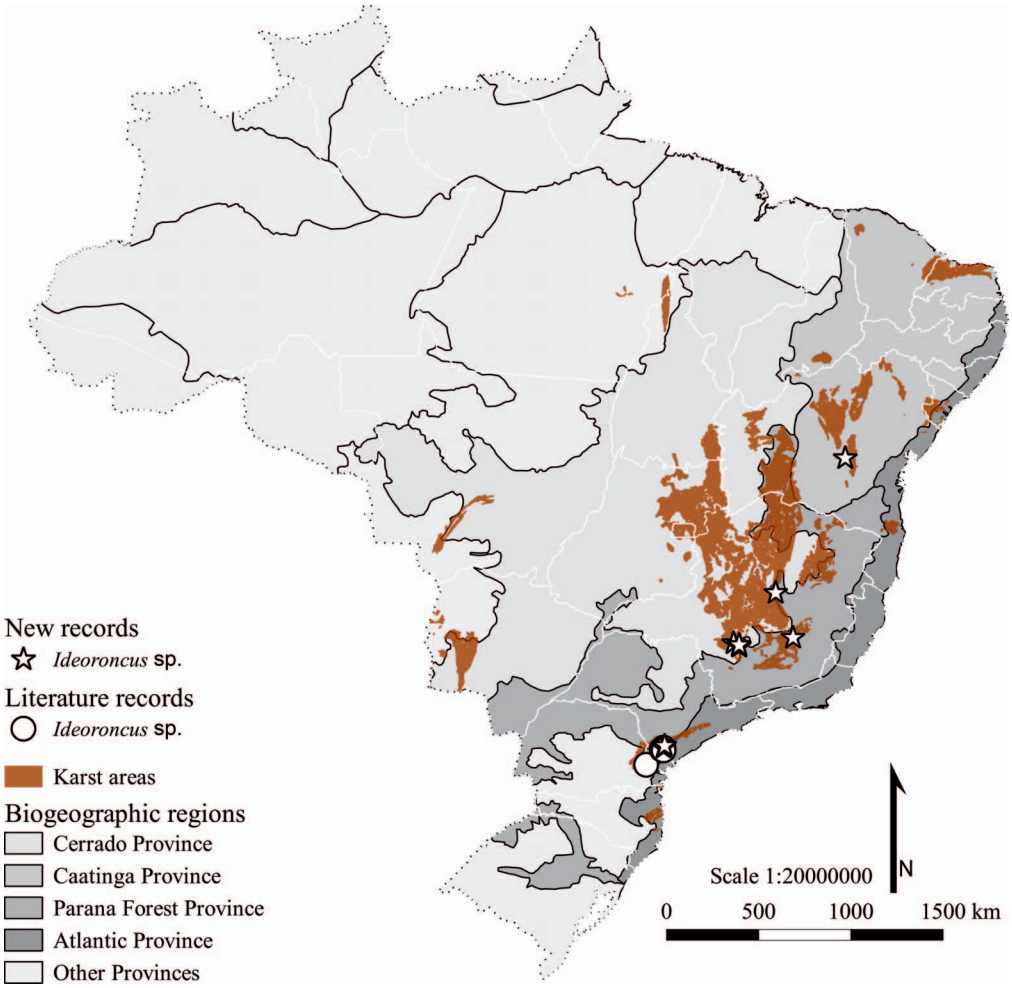

Figure 9.—Map showing the distribution of Ideoroncidae, with only one genus, *Ideoroncus*, occurring in Brazilian caves. Previous records shown by white circles, new records by white stars. The Brazilian biogeographical provinces in which these specimens occur are indicated by grey shading, the Brazilian karst regions are indicated by brown shading, and Brazilian States are outlined in white.

iporangae and *P. strinatii* (Brasil 2003). Recently, in a review of the list by IUCN (Brasil 2014), seven other species joined this list, as Vulnerable (VU), Endangered (EN), or Critically Endangered (CR) categories: three species of *Spelaeobochica* [*S. allodentatus* Mahnert, 2001 (CR), *S. iuiu* (CR) and *S. muchmorei* (EN)], two species of Chernetidae [*Spelaeochernes gracilipalpus* (EN) and *Maxchernes iporangae* (CR)], *Pseudochthonius biseriatus* (CR) (Chthoniidae), *Ideoroncus cavicola* (VU) (Ideoroncidae), and *Progarypus nigrimanus* Mahnert, 2001 (CR) (Olpiidae) (Brasil 2014). The troglobite *Pseudochthonius strinatii* does not appear in the last update of the official list because during the review, this species was classified as data deficient (DD).

It is noteworthy that all pseudoscorpions in the Red List are cave-dwellers, and four are troglobites. There appears to be a correlation between the threats to cave habitats and the pseudoscorpion fauna. However, despite this new distribution data for cave-dwelling pseudoscorpions, there is still little information about the distribution for the epigean species, except the original species descriptions or some ecological works (e.g., Lira & Tizo-Pedroso 2017).

Despite the concerted effort for samples from Brazilian caves, the absence of new occurrences for troglobitic species reinforces the endemism and fragility of this fauna. The ranges of all families recorded have considerably increased, and some genera are associated with subterranean environment. However, there is still no clear pattern of distribution for cave-dwellers pseudoscorpions in Brazil, although some genera have restricted occurrence areas.

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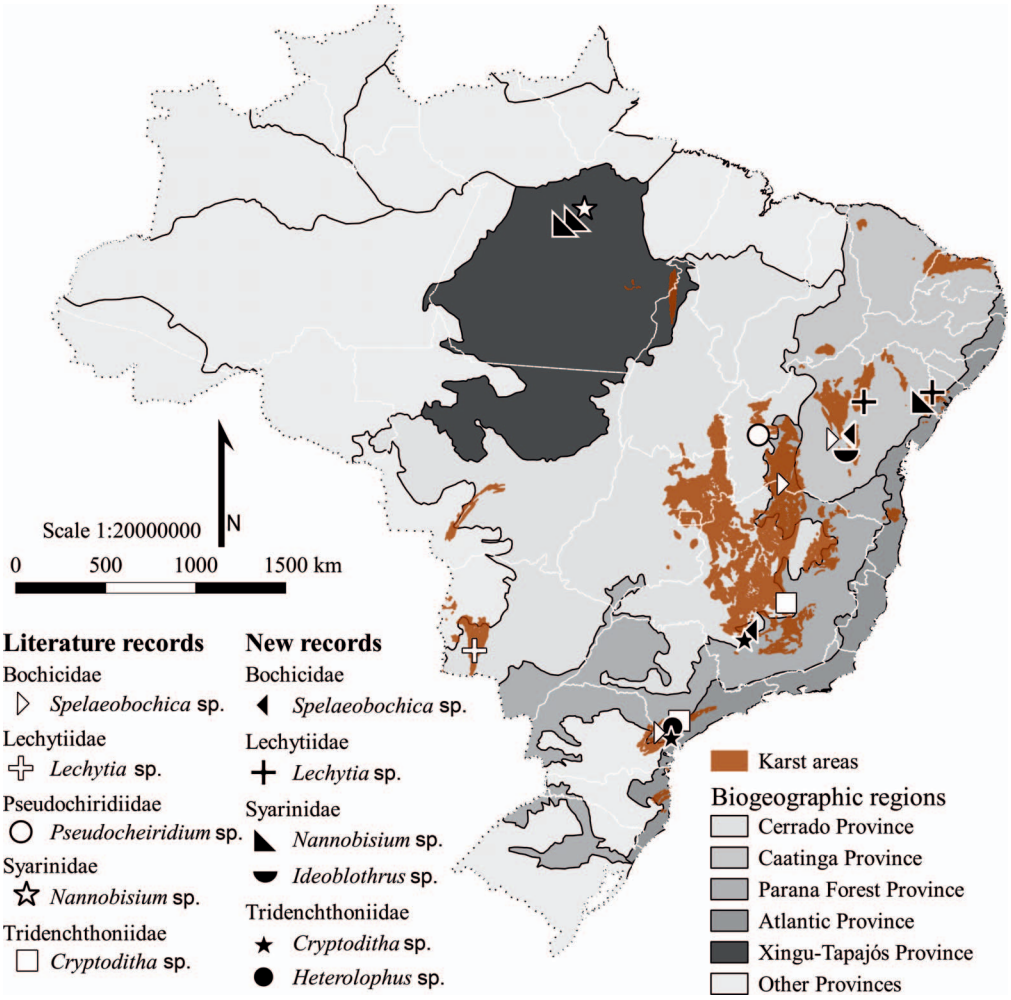

Figure 10.—Map showing the distribution of Pseudoscorpion families in Brazil as indicated by previous and new records of their genera in Brazil: Bochicidae (*Spelaeobochica*: previous record, white arrowhead pointing right; new record, black arrowhead pointing left), Lechytiidae (*Lechytia*: previous record, white cross; new record, black cross), Pseudochiridiidae (*Pseudocheiridium*: literature record only, white circle), Syarinidae (*Nannobisium*: literature record, white star; new record, black right triangle; *Ideoblothrus*: new record, black semi-circle) and Tridenchthoniidae (*Cryptoditha*: literature record, white square; new record, black star; and *Heterolophus*: new record only, black circle). The Brazilian biogeographical provinces in which these specimens occur are indicated by grey shading, the Brazilian karst regions are indicated by brown shading, and Brazilian States are outlined in white.

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