SCIENTIFIC NOTE

List of soft ticks (Acari, Argasidae) in bat caves, including new records of species occurrence for the Caatinga biome

Thais Giovannini Pellegrini

Universidade Federal de Lavras, Departamento de Entomologia, Campus Universitário, C.P. 3037, 37.200-000, Lavras, Minas Gerais, Brazil

Leopoldo Ferreira de Oliveira Bernardi

Universidade Federal de Lavras, Departamento de Entomologia, Campus Universitário, C.P. 3037, 37.200-000, Lavras, Minas Gerais, Brazil

Gabriel de Souza Ghedin

Universidade Federal de Pernambuco, Departamento de Zoologia, Rua Prof. Nelson Chaves, s/n, Cidade Universitária, 50.670-420, Recife, Pernambuco, Brazil

Mirella Lima Costa

Universidade Federal de Pernambuco, Departamento de Zoologia, Rua Prof. Nelson Chaves, s/n, Cidade Universitária, 50.670-420, Recife, Pernambuco, Brazil

Maykon Vinicius Alves da Silva

Universidade Federal de Pernambuco, Departamento de Zoologia, Rua Prof. Nelson Chaves, s/n, Cidade Universitária, 50.670-420, Recife, Pernambuco, Brazil

Luciana Iannuzzi

Universidade Federal de Pernambuco, Departamento de Zoologia, Rua Prof. Nelson Chaves, s/n, Cidade Universitária, 50.670-420, Recife, Pernambuco, Brazil, luciana.iannuzzi@ufpe.br

Abstract: Species distribution patterns are important aspects of biogeography and conservation and are especially important in environments that have been under-investigated, such as caves in the semiarid region of northeastern Brazil. We collected argasid specimens from the guano of insectivorous bats in five caves of the Caatinga biome and identified six soft tick species of the genera *Antricola* and *Ornithodorus*. *Ornithodoros rodoniensis* was recorded for the first time in the Caatinga biome and had previously only been known to occur in the Amazon.

Keywords: Ixodida, *Ornithodoros*, *Antricola*, semiarid, Neotropical.

Lista dos carrapatos (Acari, Argasidae) em "bat caves", incluindo novos registros de ocorrência de espécie no bioma Caatinga

Resumo: Padrões de distribuição de espécies são aspectos importantes da biogeografia e da conservação e são especialmente importantes em ambientes que tem sido poucos investigados, tais como as cavernas da região semiárida do nordeste do Brasil. Nós coletamos argasídeos do guano de morcegos insetívoros em cinco cavernas do bioma Caatinga e identificamos seis espécies de carrapatos dos gêneros *Antricola* e *Ornithodorus*. *Ornithodoros rodoniensis* foi registrada pela primeira vez no bioma Caatinga, tendo sido registrada apenas na Amazonia até o momento.

Palavras-chave: Ixodida, *Ornithodoros*, *Antricola*, semiárido, Neotropical.

The Caatinga biome of Brazil is a semiarid region characterized by a seasonally dry tropical forest formed by mosaics of different plant physiognomies with most of the rain concentrated in three consecutive months (da Silva et al., 2017). The harshness of the region leads to dry vegetation that harbors unique species able to survive in periods of severe drought (da Silva et al., 2017). These features also drive patterns in the subterranean environment associated with the Caatinga and some caves in the region are considered hotspots of subterranean diversity (Bento et al., 2016; Souza-Silva & Ferreira, 2016; Souza-Silva et al., 2021). The long dry periods in this biome make caves useful environments. This effect was even more pronounced during the last glacial maximum, when many ancient species were housed in caves due to the separation of the contiguous rainforests that existed at the time (Polhemus & Ferreira, 2018; Wang et al., 2005).

Subterranean diversity is also driven by the characteristics of caves. Warm, humid caves inhabited by bat species make the environment favorable to the occurrence of argasid ticks (De la Cruz, 1973; Labruna et al., 2008). The parasitic association between these soft ticks and bat species is often found in bat caves (Barbier et al., 2020), which are defined by the concentration of large bat populations – *i.e.*, more 5,000 individuals (Azevedo & Bernard, 2015). This feature increases the likelihood of the occurrence of soft ticks. Despite the considerable diversity of ticks and their broad distribution in caves (Henrique-Simões et al., 2020), current knowledge on argasid species of the Caatinga is incipient (Bernardi et al., 2009) and bat caves constitute a favorable environment to expand the geographic distribution of the group. In this study, we list species of the family Argasidae in the Caatinga biome, including new records of two rare species of the genus *Ornithodorus*.

The present study was conducted in five bat caves, including two hotspots by hotcaves – all located in the Caatinga biome of northeastern Brazil (Fig. 1A-1C; Tab. 1). The caves have limestone and quartzite lithology and are inhabited by huge colonies of insectivorous bats that produce large amounts of guano.

Sampling was performed in the rainy season, a period with higher diversity of invertebrates (Bento et al.,2016). We choose this season because it is considered the period of greater richness regarding invertebrate fauna in caves of the Caatinga (Araujo et al., 2010; Bento et al., 2016). First, we manually collected the largest specimens found in guano deposits in each cave. We then collected three 100^{-mL} samples of guano in each cave, which were placed in a Berlese-Tullgren funnel for 24 hours. We preserved all extracted invertebrates in vials containing 70% alcohol for further screening and the separation of soft ticks under a stereomicroscope. We identified argasid specimens based on morphological characteristics proposed by Labruna et al. (2008) and Labruna et al. (2011) and we followed the list of valid species names of the Ixodida presented by Guglielmone et al. (2010). We performed identification to the lowest possible taxonomic level (mainly the species level) and then designated morphospecies to obtain data on argasid richness.

We collected a total of six soft tick species belonging to two genera of Argasidae (*Antricola* and *Ornithodorus*) from the five caves sampled (Tab. 2). *Antricola inexpectata* (Estrada-Penã, Barros-Battesti & Venzal, 2004) was the most widespread species, occurring in all caves sampled. The second most widely distributed species was *Antricola guglielmonei* (Estrada-Penã, Barros-Battesti & Venzal, 2004), which was found in three caves and was only absent from the "Gruta do Arnould" and "Caverna do Urubu" caves. We found *Antricola delacruzi* (Estrada-Penã, Barros-Battesti & Venzal, 2004), *Ornithodorus marinkellei* (Kohls, Clifford & Jones, 1969) and *Ornithodorus rodoniensis* (Labruna, Terassini, Camargo, Brandão, Ribeiro & Estrada-Peña, 2008) only in the "Boqueirão de Lavras da Mangabeira II" cave, which was the richest cave studied (five species), while we only found *Ornithodoros fonsecai* (Labruna & Venzal, 2009) in the "Casa de Pedra" cave.

The soft mite genus *Antricola* includes 16 described species that occur in the Americas from the southeastern USA to northeastern Brazil (Estrada-Peña et al., 2004; Guglielmone et al., 2003). *Antricola* species occur in warm, humid caves that often have large bat colonies (De la Cruz, 1973; Labruna et al., 2008). Indeed, we collected all three *Antricola* species recorded for Brazil in the bat caves investigated in the present study: *A. guglielmonei*, *A. delacruzi* and *A. inexpectata*. The habits of this genus differ from those of most tick species. The adults are free-living with mouthparts adapted for quick feeding rather than clinging to the host; the hypostome is small and toothless (Cooley & Kohls, 1942); and these species only exhibit hematophagous parasitic behavior in the larval stage. A recent study suggests that adults feed directly on guano deposits (Ribeiro et al., 2012). This feeding habit in caves with large guano deposits minimizes competition pressure for feeding resources, enabling the occurrence of hundreds of thousands of individuals as well as the co-occurrence of sister species (Nunes et al., 2020). This may also explain the abundances and richness documented here in the "Boqueirão de Lavras da Mangabeira II", "Casa de Pedra" and "Gruta do Sobradinho" caves. The broad geographical dis-

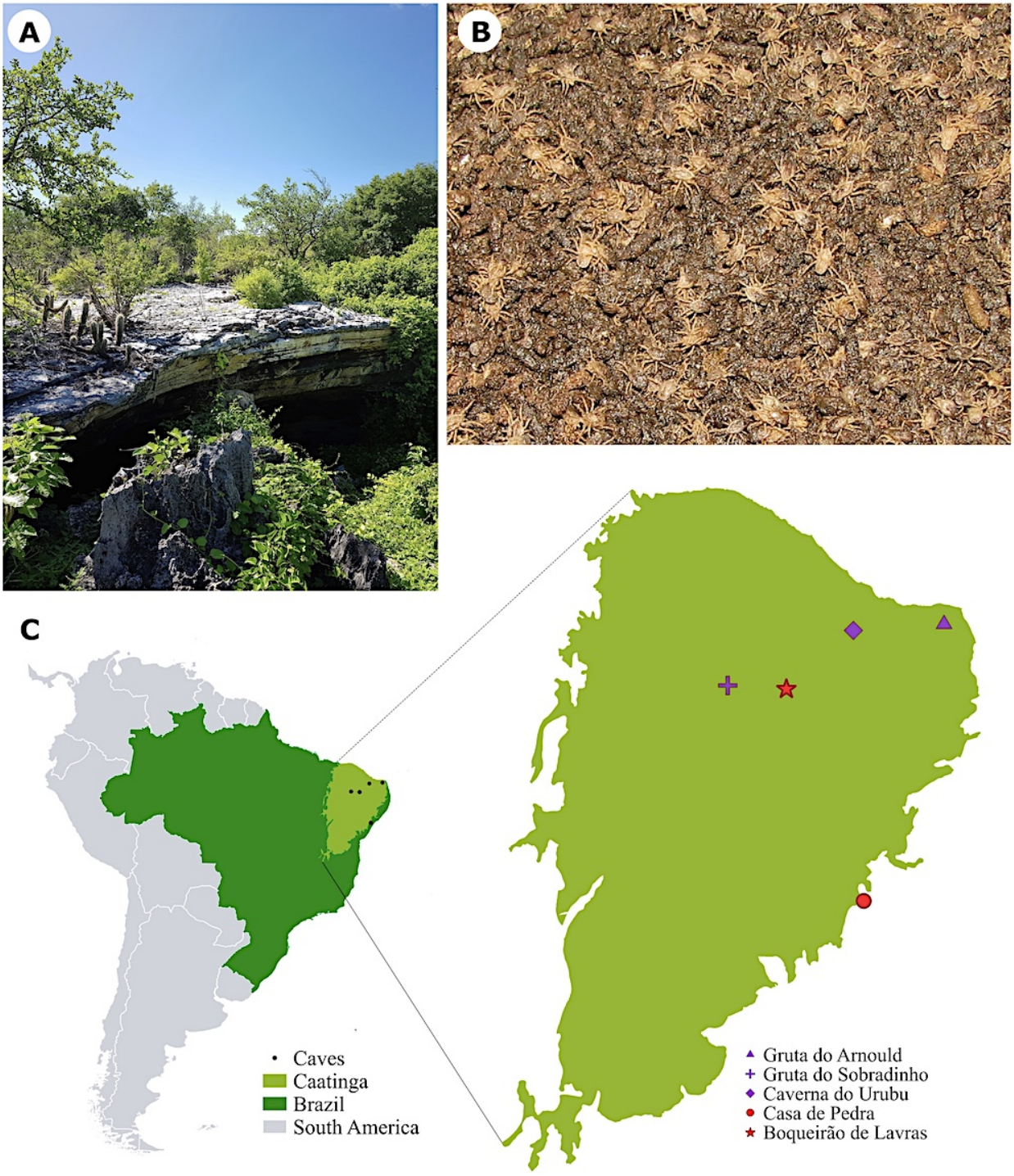

Fig. 1. Geographic localization of the studied caves. A. Entrance area of Caverna do Urubu Cave showing the Caatinga vegetation during the wet season. B. *Antricola inexpectata* (Estrada-Penã, Barros-Battesti & Venzal, 2004) population associated to a guano pile at Caverna do Urubu Cave. C. Map of South America highlighting Brazil and the Cerrado region. The red symbols correspond to the Hot Caves. The red star represents the new occurrence record for *Ornithodoros rondoniensis* (Labruna, Terassini, Camargo, Brandão, Ribeiro & Estrada-Peña, 2008) to the semiarid. (Photographs A and B are from Rodrigo L. Ferreira).

Tab. 1. Studied caves from the Brazilian semiarid, the cave geographic localization, horizontal projection and the cave bat use classification are provided.

Cave	Municipality (state)	Coord.	Horizontal Projection	Cave feature	Lithology	Bat species found	Estimated bat abundance
Boqueirão de Lavras da Mangabeira II	Lavras da Mangabeira (CE)	6º42,745'S 38º57,46'W	~200 m	Hot cave	Quartzite	*Lonchorhina aurita, Phyllostomus hastatus, Pteronotus gymnonotus, Pteronotus personatus, Peropteryx* cf. *macrotis,* Molossidae, *Noctilio albiventris, Noctilio leporinus,* Glossophaginae	~98.000
Casa de Pedra	Campo de Brito (SE)	10º50,0517' S 37º27,06'W	210 m	Hot cave	Limestone	*Lonchorhina aurita, Phyllostomus hastatus, Pteronotus gymnonotus, Pteronotus personatus, Anoura geoffroyi, Carollia perspicillata, Desmodus rotundus, Glossophaga soricina, Natalus macrourus*	~137.000
Gruta do Arnold	João Câmara (RN)	5º26,9167'S 35º53,215'W	80 m	Not hot cave	Limestone	*Pteronotus gymnonotus, Carollia perspicillata, Glossophaga soricina, Natalus macrourus*	~10.000
Furna do Urubu	Felipe Guerra (RN)	5º34,3833'S 37º39,145'W	195 m	Not hot cave	Limestone	*Pteronotus gymnonotus, Pteronotus personatus, Desmodus rotundus, Peropteryx* sp., *Artibeus planirostris, Diphylla ecaudata, Tonatia bidens, Eumops* sp.	~27.000
Gruta do Sobradinho	Aiuba (CE)	6º38,5917'S 40º5,9517'W	235 m	Not hot cave	Limestone	*Lonchorhina aurita, Pteronotus gymnonotus, Pteronotus personatus, Anoura geoffroyi, Carollia perspicillata, Desmodus rotundus, Natalus macrourus, Pteronotus* cf. *alitonus, Peropteryx* sp., *Mimon* spp.	~69.500

Legend: CE – Ceara state, RN – Rio Grande do Norte state, SE – Sergipe state.

tribution of populations of *Antricola* species is often interrupted in long stretches of up to 3,000 km. Despite this, genetic sequence analyses indicate that such populations remain connected (Labruna et al., 2008; Ribeiro et al., 2012).

The genus *Ornithodoros* is represented in Brazil by more than 20 species and, unlike *Antricola*, all species of the genus are hematophagous during all life stages (larvae and adults) (Sonenshine & Roe, 2014). *Ornithodoros* species occur in environments with varying temperature and humidity (*e.g.*, *Ornithodoros cavernicolous* Dantas-Torres et al., 2012) and occupy caves with different sizes of bat colonies (Bernard, pers. com.). Species of this genus associated with bats tend to have broad geographic distribution, as these vertebrates are able to travel long distances, which contributes to the dispersion of their parasites (Labruna et al., 2011; Muñoz-Leal et al., 2017). To date, however, two species found in the present study are restricted to two Brazilian regions. *Ornithodoros marinkellei* occurs exclusively in northern and northeastern Brazil, with two occurrences in the Amazon rainforest in caves of the states of Rondônia and Pará (Henrique-Simões et al., 2012; Labruna et al., 2011). This species and

Tab. 2. Argasidae (Acari) species found in each of the five sampled caves from the Brazilian Caatinga.

Taxa	Caves				
	Boqueirão de Lavras	**Casa de Pedra**	**Gruta do Sobradinho**	**Gruta do Arnold**	**Caverna do Urubu**
Antricola delacruzi (Estrada-Penã, Barros-Battesti & Venzal, 2004)	x				
Antricola guglielmonei (Estrada-Penã, Barros-Battesti & Venzal, 2004)	x	x	x		
Antricola inexpectata (Estrada-Penã, Barros-Battesti & Venzalé, 2004)	x	x	x	x	x
Ornithodoros fonsecai (Labruna & Venzal, 2009)		x			
Ornithodoros marinkellei (Kohls, Clifford & Jones, 1969)	x				
*Ornithodoros rodoniensis** (Labruna, Terassini, Camargo, Brandão, Ribeiro and Estrada-Peña, 2008)	x				

The * symbol represents the new occurrence of Caatinga biome.

O. fonsecai only one occurrence in the Caatinga (Crateús, state of Ceará) (Luz et al., 2016). Thus, with the present study, we recorded the second observation of *O. marinkellei* and *O. fonsecai* in the Caatinga, co-occurring in a cave with a large colony of *Pteronotus* bats in addition to other bat species (Tab. 1). *Pteronotus* bats are recognized as typical hosts of *O. marinkellei* (Henrique-Simões et al., 2012; Labruna et al., 2011; Luz et al., 2016; Muñoz-Leal et al., 2016). The other species (*O. rodoniensis*) was previously only associated with the Amazon rainforest in caves of the states of Rondônia and Pará (Labruna et al., 2008; Nava et al., 2010). Here, we record, for the first time, the occurrence of the species in the Caatinga biome. This new record extends the distribution of the species by approximately 2,500 km.

Thus, our study reports new geographical ranges for two Brazilian soft tick species associated with bats, expanding the distribution of *O. marinkellei* and, even more expressively, *O. rondoniensis* to the semiarid region. These new tick records, together with the new species restricted to caves recently described for the formation of the Caatinga [*i.e.*, *Coarazuphium caatinga* (Pellegrini & Ferreira, 2014, Carabidae); *Cryptops spelaeoraptor* (Ázara & Ferreira, 2014a, Cryptopidae); *Newportia spelaea* (Ázara & Ferreira, 2014b, Scolopocryptopidae); *Girardia spelaea* (Hellmann, Ferreira, Rabelo & Leal-Zanchet, 2020, Dugesiidae); as well as four *Pectenoniscus* species: *P. iuiuensis*, *P. carinhanhensis*, *P. santanensis*, *P. morrensis* (Cardoso, Bastos-Pereira, Souza & Ferreira, 2020, Styloniscidae), among others] and with the occurrence of caves elevated to the status of hotspots of subterranean biodiversity (*e.g.*, the "Toca do Gonçalo" cave in the state of Bahia - Souza-Silva & Ferreira, 2016), increase the importance of the region. However, studies on ticks, especially cave species, are rare, despite the fact that this has proven to be a field of study with considerable potential for new discoveries (*e.g.*, Araújo et al., 2018; Bernardi et al., 2012; Dantas-Torres et al., 2012; Estrada-Peña et al., 2004; and the "Toca do Gonçalo" and the "Águas Claras Cave System", both in the state of Bahia, Souza-Silva & Ferreira, 2016; Souza-Silva et al., 2021). The study of the biodiversity of the Caatinga biome is promising for the discovery of new records as well as new species, which are essential to the improvement of adequate conservation and management measures.

We are grateful to Dr. Enrico Bernard for logistical support during the collections and information on bat populations and Dr. Rodrigo Ferreira for providing photographs of the caves in the region. TGP thanks the Minas Gerais Research Foundation (FAPEMIG) and VALE SA for the post-doctoral grant. LFOB thanks the Coordination for the Advancement of Higher Education Personnel for providing a post-doctoral grant from the National Postdoctoral Program (CAPES-PNPD/Brazil). MBL thanks the National Council of Scientific and Technological Development (CNPq) and the State of São Paulo Research Support Foundation (FAPESP) for financial support. LI is grateful to CNPq for the PQ2 grant (process number: 309750/2019-9).

References

Araujo, V. F. P., A. G. Bandeira & A. Vasconcello. 2010. Abundance and stratification of soil macroarthropods in a Caatinga Forest in Northeast Brazil. Braz. J. Biol. 70(3): 737-746. DOI: https://doi.org/10.1590/S1519-69842010000400006

Araújo, M. S., M. E. Bichuette, G. R. Bauchan, R. Ochoa & R. J. F. Feres. 2018. A new species of cave dwelling *Neocarus* (Acari: Opilioacaridae) from Bahia state, Brazil, with remarks on taxonomic characters. Zootaxa. 4402: 303-322. DOI: https://doi.org/10.11646/zootaxa.4402.2.4

Azevedo, S. I. & E. Bernard. 2015. Avaliação do nível de relevância e estado de conservação da Caverna "Meu Rei" no Parna Catimbau, Pernambuco. Rev. Bras. Espel. 1(5): 1-23.

Barbier, E., E. Bernard & F. Dantas-Torres. 2020. Ecology of Antricola ticks in a bat cave in north-eastern Brazil. Exp. Appl. Acarol. 82(2): 255-264. DOI: https://doi.org/10.1007/s10493-020-00544-9

Bento, D. D. M., R. L. Ferreira, X. Prous, M. Souza-Silva, B. C. Bellini & A. Vasconcellos. 2016. Seasonal variations in cave invertebrate communities in the semiarid Caatinga, Brazil. J. Cave Karst Stud. 78(2): 61-71. DOI: https://doi.org/10.4311/2015LSC0111

Bernardi, L. F. O., M. S. Zacarias, M. Souza-Silva & R. L. Ferreira. 2009. Ácaros cavernícolas do Brasil: uma observação preliminar sobre a ocorrência e distribuição das famílias. Mundos Subterr. 20: 9-17.

Bernardi, L. F. O., M. S. Zacarias & R. L. Ferreira. 2012. A new species of *Neocarus* Chamberlin & Mulaik, 1942 (Acari: Opilioacarida) from Brazilian caves and karst areas. Zootaxa. 68: 53-68. DOI: https://doi.org/10.11646/zootaxa.3416.1.5

Cooley, R. & G. Kohls. 1942. *Antricola* New Genus, *Amblyomma gertschi* New Species, and Notes on *Ixodes spinipalpis* (Acarina: Ixodoidea). Pub. Health Rep. (1896-1970). 57(46): 1733-1736. DOI: https://doi.org/doi:10.2307/4584278

Dantas-Torres, F., J. M. Venzal, L. F. O. Bernardi, R. L. Ferreira, V. C. Onofrio, A. Marcili, S. E. Bermúdez, A. F. Ribeiro, D. M. Barros-Battesti & M. B. Labruna. 2012. Description of a new species of bat-associated argasid tick (Acari: Argasidae) from Brazil. J. Parasitol. 98: 36-45. DOI: https://doi.org/10.1645/GE-2840.1

Da Silva, J. M. C., L. C. F. Barbosa, I. R. Leal & M. Tabarelli. 2017. The Caatinga: Understanding the Challenges. pp. 3-19. In: Silva, J. M. C., I. R. Leal & M. Tabarelli (Eds.). Caatinga. Springer, Cham. DOI: https://doi.org/10.1007/978-3-319-68339-3_1

De La Cruz, J. 1973. Notas sobre las garrapatas del genero *Antricola* Cooley y Kohls, 1942 (Ixodiformes, Argasidae) con la descripción de una nueva especie. Serie Espeleológica y Carsológica 44. Havana, Sociedad Espeleologica de Cuba.

Estrada-Pena, A., J. M. Venzal, D. M. Barros-Battesti, V. C. Onofrio, E. Trajano & J. V. L. Firmino. 2004. Three new species of *Antricola* (Acari: Argasidae) from Brazil, with a key to the known species in the genus. J. Parasitol. 90: 490-498. DOI: https://doi.org/10.1645/GE-172R

Guglielmone, A. A., A. Estrada-Pena, J. E. Keirans & R. G. Robbins. 2003. Ticks (Acari: Ixodida) of the Neotropical Zoogeographic Region. International Consortium on Ticks and Tick-borne Diseases (ICTTD-2), Atalanta, Houten, The Netherlands.

Guglielmone, A. A., R. G. Robbins, D. A. Apanaskevich, T. N. Petney, A. Estrada-Pena, I. G. Horak, R. Shao & S. C. Barker. 2010. The Argasidae, Ixodidae and Nuttalliellidae (Acari: Ixodida) of the world: a list of valid species names. Zootaxa. 2528: 1-28. DOI: http://hdl.handle.net/2263/17278

Henrique-Simões, M., L. F. de Oliveira Bernardi, M. Ogrzewalska, M. B. Labruna & R. L. Ferreira. 2015. New records of rare *Ornithodoros* (Acari: Argasidae) species in caves of the Brazilian Amazon. Persian J. Acarol. 1(2): 127-135. DOI: https://doi.org/10.22073/pja.v1i2.9940

Labruna, M. B., F. A. Terassini, L. M. A. Camargo, P. E. Brandão, A. F. Ribeiro & A. Estrada-Peña. 2008. New reports of *Antricola guglielmonei* and *Antricola delacruzi* in Brazil, and a description of a new argasid species (Acari). J. Parasitol. 94(4): 788-792. DOI: https://doi.org/10.1645/GE-1447.1

Labruna, M. B., S. Nava, F. A. Terassini, V. C. Onofrio, D. M. Barros-Battesti, L. M. A. Camargo & J. M. Venzal. 2011. Description of adults and nymph, and redescription of the larva, of *Ornithodoros marinkellei* (Acari: Argasidae), with data on its phylogenetic position. J. Parasitol. 97: 207-217. DOI: https://doi.org/10.1645/GE-2620.1

Luz, H. R., S. Muñoz-Leal, J. C. de Almeida, J. L. H. Faccini & M. B. Labruna. 2016. Ticks parasitizing bats (Mammalia: Chiroptera) in the Caatinga. Rev. Bras. Parasitol. Vet. 25: 476-483. DOI: https://doi.org/10.1590/s1984-29612016083

Muñoz-Leal, S., L. F. Toledo, J. M. Venzal, A. Marcili, T. F. Martins, I. C. L. Acosta, A. Pinter & M. B. Labruna. 2017. Description of a new soft tick species (Acari: Argasidae: *Ornithodoros*) associated with stream-breeding frogs (Anura: Cycloramphidae: *Cycloramphus*) in Brazil. Ticks Tick Borne Dis. 8: 682-692. DOI: https://doi.org/10.1016/j.ttbdis.2017.04.015

Nava, S., J. M. Venzal, F. A. Terassini, A. J. Mangold, L. M. A. Camargo & M. B. Labruna. 2010. Description of a new argasid tick (Acari: Ixodida) from bat caves in brazilian Amazon. J. Parasitol. 96: 1089-1101. DOI: https://doi.org/10.1645/GE-2539.1

Nunes, L. T., A. C. Siqueira, I. Cord, B. M. Ford, A. M. Liedke, C. E. Ferreira & S. R. Floeter. 2020. The influence of species abundance, diet and phylogenetic affinity on the co-occurrence of butterflyfishes. Mar. Biol. 167(8): 1-11. DOI: https://doi.org/10.1007/s00227-020-03725-7

Polhemus, D. A. & R. L. Ferreira. 2018. Two unusual new genera of cavernicolous Hydrometridae (Insecta: Heteroptera) from eastern Brazil. Tijdschr. Entomol. 161(1): 25-38. DOI: https://doi.org/10.1163/22119434-00002072

Ribeiro, J. M. C., M. B. Labruna, B. J. Mans, S. R. Maruyama, I. M. B. Francischetti, G. C. Barizon & I. K. F. M. I. Santos. 2012. The sialotranscriptome of *Antricola delacruzi* female ticks is compatible with non-hematophagous behavior and an alternative source of food. Insect Biochem. Mol. Biol. 42: 332-342. DOI: https://doi.org/10.1016/j.ibmb.2012.01.003

Souza-Silva, M. & R. L. Ferreira. 2016. The first two hotspots of subterranean biodiversity in South America. Subterr. Biol. 19: 1-21. DOI: https://doi.org/10.3897/subtbiol.19.8207

Souza-Silva, M., R. F. V. Cerqueira, T. G. Pellegrini & R. L. Ferreira. 2021. Habitat selection of cave-restricted fauna in a new hotspot of subterranean biodiversity in Neotropics. Biodivers Conserv. 30: 4223-4250. DOI: https://doi.org/10.1007/s10531-021-02302-8

Sonenshine, D. E. & R. M. Roe. 2014. External and internal anatomy of ticks. In: Sonenshine D. E. & R. M, Roe (Eds.). Biology of Ticks. New York, Oxford University Press.

Venzal, J. M., S. Nava, L. V. Hernández, J. Miranda, A. Marcili & M. B. Labruna. 2018. A morphological and phylogenetic analysis of *Ornithodoros marinkellei* (Acari: Argasidae), with additional notes on habitat and host usage. Exp. Appl. Acarol. 76(2): 249-261. DOI: https://doi.org/10.1007/s10493-018-0307-2

Wang, X., A. S. Auler, R. L. Edwards, H. Cheng, P. S. Cristalli, P. L. Smart, D. A. Richards & C. C. Shen. 2005. Wet periods in northeastern Brazil over the past 210 kyr linked to distant climate anomalies. Nature. 432(7018): 740-743. DOI: https://doi.org/10.1038/nature03067

Editor Associado / Associated Editor: Clever Gomes Cardoso, UFG, Brazil
Recebido / Recibido / Received: 18.05.2021
Revisado / Revised: 03.01.2022
Aceito / Aceptado /Accepted: 04.01.2022
Publicado / Published: 11.01.2022

Dados disponíveis / Datos disponibles / Available data: Not informed