ARTHROPODS AND MEDICAL ENTOMOLOGY - ORIGINAL PAPER

# *Monunguis streblida* (Neothrombidiidae) in Brazil and its parasitic relationships with dipteran ectoparasites (*Anastrebla* and *Trichobius*) of bats

Aline da Silva Reis[1] · Robson de Almeida Zampaulo[2] · Leopoldo Ferreira de Oliveira Bernardi[3] · Sônia A. Talamoni[1]

## Abstract

The mite species *Monunguis streblida* Wharton, 1938 (Neothrombidiidae) is reported in association with dipteran ectoparasites (Streblidae) of Brazilian bats for the first time. A 1-year study of two populations of the bat *Anoura geoffroyi* Gray, 1838 in caves in the state of Minas Gerais, Brazil, found them to be parasitized by four species of streblids, three of which were parasitized by *M. streblida*. Three hundred and thirty-two individuals of *M. streblida* were collected in association with 135 individuals of *Anastrebla modestini* Wenzel, 1966, two individuals of *A. caudiferae* Wenzel, 1976, and two individuals of *Trichobius* sp. (*dugesii* complex). The predominant association of *M. streblida* with *A. modestini* suggests a preference for this host for the larvae of this mite. Fluctuations in the abundance of mites were found to accompany seasonal cycles and fluctuations in the abundance of their main host, with the mites being more abundant in months with higher temperatures and greater rainfall. The present work represents the first formal record of the occurrence of *M. streblida* in South America, increasing its range of occurrence southward by more than 5000 km.

**Keywords** Cave · Chiroptera · Ecological interactions · Trombidiformes · Hyperparasitism

## Introduction

Parasitic interactions of mites, especially those of the larval stages of species of Parasitengona (Trombidiformes), have been reported for a great diversity of both vertebrate and invertebrate hosts (Shatrov and Kudryashova 2008; Mąkol and Wohltmann 2012, 2013; Stroiński et al. 2013). This group has a complex life cycle in which the larvae are generally parasitic while the post-larval stages are free-living and mainly predators of small soil invertebrates (Shatrov and Kudryashova 2008). Among the taxa of Parasitengona, species of the family Neothrombidiidae are known to be associated with many invertebrates, including coleopterans, orthopterans, dipterans, lepidopterans, hemipterans, opiliones, pseudoscorpions, and spiders (Mąkol and Wohltmann 2012; Stroiński et al. 2013).

The family Neothrombidiidae is widely distributed, with occurrences on all continents (Beron 2007); however, it has only four described genera: *Discotrombidium* Feider, 1977; *Monunguis* Wharton, 1938; *Neotrombidium* Leonardi, 1901; and *Anomalothrombium* André, 1936. The genus *Monunguis* is the only monospecific genus of the family, containing only *Monunguis streblida* Wharton, 1938, which was described in association with dipterans of the family Streblidae. The known distribution of this species has been restricted, until now, to Mexico, specifically the cave Cinquo de Mayas in the state of Yucatan, and the Dominican Republic (Lindquist and Vercammen-Grandjean 1971; Stroiński et al. 2013). Information about the species provided in these works is limited to occurrence data and the identification of its hosts.

Despite numerous records of species of the hyporder Parasitengona in Brazil, there has only been one officially published record for the family Neothrombidiidae (Lindquist and Vercammen-Grandjean 1971), which was a species attributed to the genus *Neotrombidium*. Nonetheless, other

---

Section Editor: Boris R. Krasnov

✉ Aline da Silva Reis
  alineambiental@yahoo.com.br

[1] Pontifícia Universidade Católica de Minas Gerais, Belo Horizonte, MG, Brazil

[2] Vale S.A, Gerência de Licenciamento Ambiental e Espeleologia, Belo Horizonte, Brazil

[3] Bolsista de PNPD/CAPES, Departamento de Entomologia, Universidade Federal de Lavras, Lavras, Minas Gerais, Brazil

occurrences are known, especially of larvae, but have not been published (LFO Bernardi, personal observation). Due to the lack of information about the group, the objective of the present study was to report new occurrences of mites of the species *M. streblida* and to provide information regarding is larval population, which are hyperparasites of streblid dipterans.

## Material and methods

Bats of the species *Anoura geoffroyi* Gray, 1838 present in the caves MJ-05 (WGS 84; 23K; 20°5′40″ S and 44°4′36″ W, 1072 m a.s.l.) and Loca dos Morcegos (WGS 84; 23K; 19°48′51″ S and 43°41′12″ W, 1220 m a.s.l), located in the municipalities of Brumadinho and Caeté, respectively, in the state of Minas Gerais, Brazil (Fig. 1), were sampled monthly for a period of 1 year (2017–2018) using a pole net. About 60 bats were collected each month in each colony. The bats were individually packaged in a cloth bag in order to prevent the contamination of ectoparasites among captured individuals (Postaswa and Szubert-Kruszynska 2014). Each bat was carefully examined immediately after capture and all parasites observed were collected with forceps and brushes and preserved in 92% alcohol in tubes labeled with host information.

In the laboratory, the streblid hosts were separated from other ectoparasites and identified to the species level according to the taxonomic keys of Graciolli and Carvalho (2001) and Guerrero (1993). The hosts were then examined carefully, with those that were parasitized by mites being separated. All mites associated with the dipterans were counted, removed from the host, clarified with Nesbitt's fluid, and mounted on slides with coverslips using Hoyer's medium. The slides were placed in an oven for 15 days to dry and then were sealed (Walter and Krantz 2009). The mite specimens were observed and identified under a phase-contrast optical microscope, Leica MDLS using taxonomic keys and species descriptions of Walter et al. (2009), Lindquist and Vercammen-Grandjean (1971), and Womersley (1963).

After the collection of data, the bats were released inside their respective cave, with the exception of voucher material, which was deposited in the reference collection of Mestrado em Biologia de Vertebrados of Pontifícia Universidade Católica de Minas Gerais (PUC Minas). Voucher specimens of dipterans and mites are deposited at the Acarological Collection (UFMG-AC) of the Universidade Federal de Minas Gerais (UFMG) and at Collection of Subterranean Invertebrates (ISLA) of the Universidade Federal de Lavras (UFLA), both in the state of Minas Gerais.

Prevalence was obtained by the number of infested flies divided by the number of flies examined and is expressed as



**Fig. 1** Map of the distribution of *M. streblida* including pre-existing records (red triangles) and new records for Brazil (red circles)

a percentage. The mean abundance refers to the number of parasite mites per number of flies examined (Bush et al. 1997). Ecological aspects of the parasite-host (mites and flies) interaction were evaluated by linear regression of the number of parasites as a function of the number of hosts both monthly collected. Linear regression was also used to evaluate the relationship between the abundance of *M. streblida* and the abiotic parameters of temperature, precipitation, and humidity. The temperature and humidity data were collected hourly and obtained through data loggers (Onset—Model Hobo Prov2) installed in the cave and in the epigean environment. Regional precipitation values were obtained from the meteorological station of the National Institute of Meteorology (INMET). All analyses were performed with the program RStudio with a significance level of 5%.

## Results

A total of 1189 bats of the species *A. geoffroyi* were examined, 573 of which were in the cave Loca dos Morcegos and 616 in the cave MJ-05. A total of 985 (83%) of the bats were parasitized by a total of 5047 dipterans of four species of two genera of the family Streblidae. The most abundant dipteran species in both populations of bats was *Exastinion clovisi* (Pessoa and Guimarães 1936) (2877 individuals—57%), followed by *Anastrebla modestini* Wenzel, 1966 (1479 individuals—29%), *A. caudiferae* Wenzel, 1976 (32 individuals—1%), and *Trichobius* sp. (*dugesii* complex) (659 individuals—13%). Of these, 139 individuals (2.7%) were parasitized by *M. streblida* (Table 1), with 137 individuals from cave MJ-05 and two from the cave Loca dos Morcegos.

*Anastrebla modestini* had the greatest number of individuals infested by mites ($N = 135$, prevalence = 9.1%), followed by *A. caudiferae* and *Trichobius* sp., both with two individuals each (prevalence = 6.2% and 0.3%, respectively) (Fig. 2). All of the mite parasites were observed in association with the abdomen of the dipterans, with the rate of infestation ranging from one to eight individuals of *M. streblida* per dipteran parasite (median = 2). The values of mean abundance can be observed in Table 1.

The abundance of *M. streblida* fluctuated throughout the year, with lower abundance from March to June, with 17, 13, 5, and 12 individuals, respectively, representing 14% of the total of specimens collected. No parasites were found in association with the streblids during the months of July, August, and September. From October onward, the population of *M. streblida* increased, until reaching its peak abundance in the month of December ($n = 125$; 38% of the total of specimens collected), after which it decreased in the subsequent months (Fig. 3).

Fluctuations in the abundance of *M. streblida* accompanied fluctuations in the host population. Linear regression showed that the abundance of *M. streblida* varied positively and significantly as a function of *A. modestini* abundance ($r^2 = 0.34$; $p = 0.04$) (Fig. 4), temperature ($r^2 = 0.37$; $p = 0.03$) (Fig. 5), and precipitation ($r^2 = 0.38$; $p = 0.03$) in the epigean environment (Fig. 6). In contrast, no significant relationship was found between the abundance of *M. streblida* and relative air humidity at the epigean environment ($p = 0.2$) and neither between the host and these environmental variables ($p = 0.06$ for temperature and $p = 0.63$ for precipitation).

## Discussion

The present work represents the first formal record of the occurrence of *M. streblida* in South America, increasing its range of occurrence southward by more than 5000 km. The distribution of the species was previously restricted to North and Central America, more specifically Mexico and the Dominican Republic (Lindquist and Vercammen-Grandjean 1971).

According to Lindquist and Vercammen-Grandjean (1971), the larvae of *M. streblida* have a specific association with dipterans of the family Streblidae, which are ectoparasites of bats. At the time, *M. streblida* was known to be associated with three species of streblids: *Megistopoda aranea* Coquillett, 1899; *Trichobius pseudotruncatus* Jobling, 1939; and *Trichobius dugesii* Townsend 1891. According to these authors, these ectoparasitic flies were probably collected from the phyllostomid bats *Artibeus jamaicensis* Leach, 1821, and *Glossophaga soricina* Pallas, 1766, and the vespertilionid

**Table 1** Data on the occurrence of streblids on the bat *A. geoffroyi* and their hyperparasite *M. streblida*

| Family | Species | Total abundance of Streblidae | Dipterans infested by *M. streblida* | Prevalence | Mean abundance |
|---|---|---|---|---|---|
| Streblidae | | | | | |
| | *Exastinion clovisi* (Pessoa & Guimarães, 1936) | 2.877 | 0 | 0 | 0 |
| | *Anastrebla modestini* Wenzel, 1966 | 1.479 | 135 | 9.12 | 0.22 |
| | *Anastrebla caudiferae* Wenzel, 1976 | 32 | 2 | 6.25 | 0.09 |
| | *Trichobius* sp. (*dugesii* complex) | 659 | 2 | 0.30 | 0.003 |
| Total | | 5047 | 139 | – | – |

**Fig. 2** **a** *Anastrebla modestini* infested by *M. streblida*. **b** Details of mites of *M. streblida* associated with the abdomen of an infested streblida. **c** *Trichobius sp.*
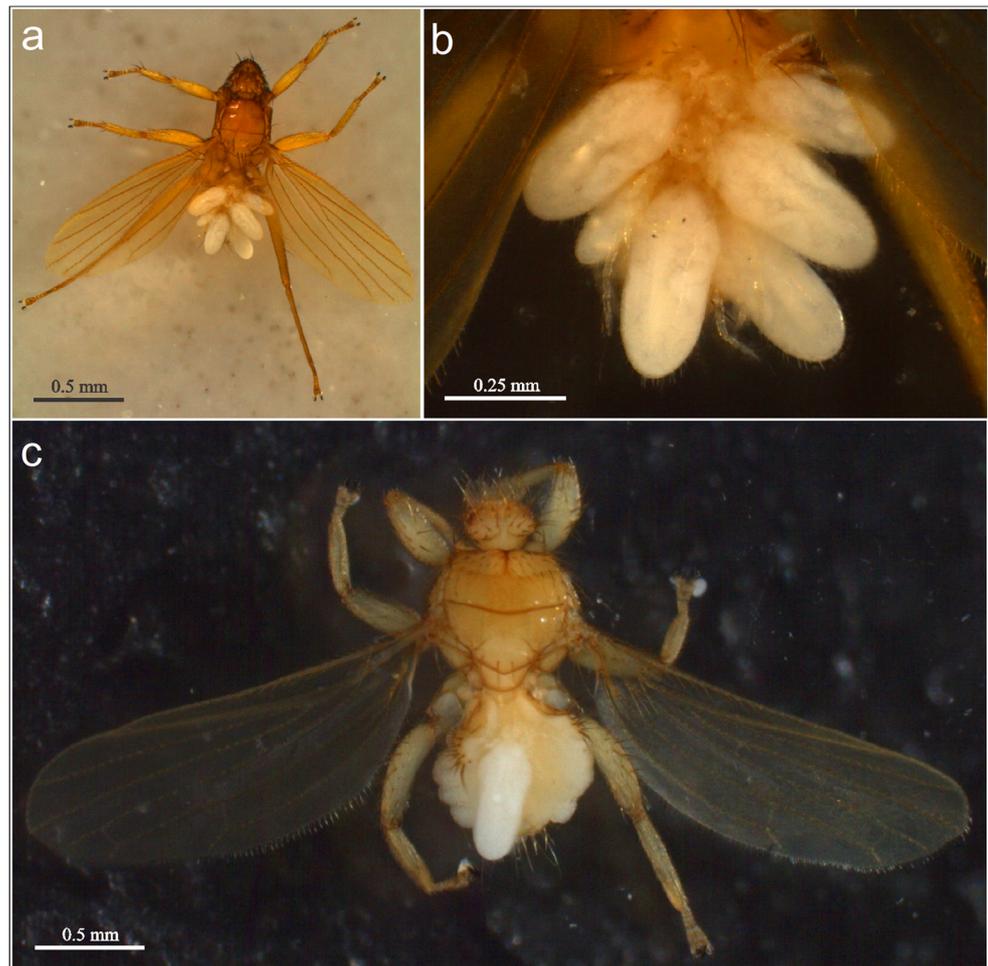


*Myotis nigricans* Schinz, 1821 (Lindquist and Vercammen-Grandjean 1971). The present work observed the preferential association of *M. streblida* with *Anastrebla modestini*, in addition to other new hosts.

**Fig. 3** Monthly fluctuations in the number of individuals collect of *Monunguis streblida* and *Anastrebla modestini*
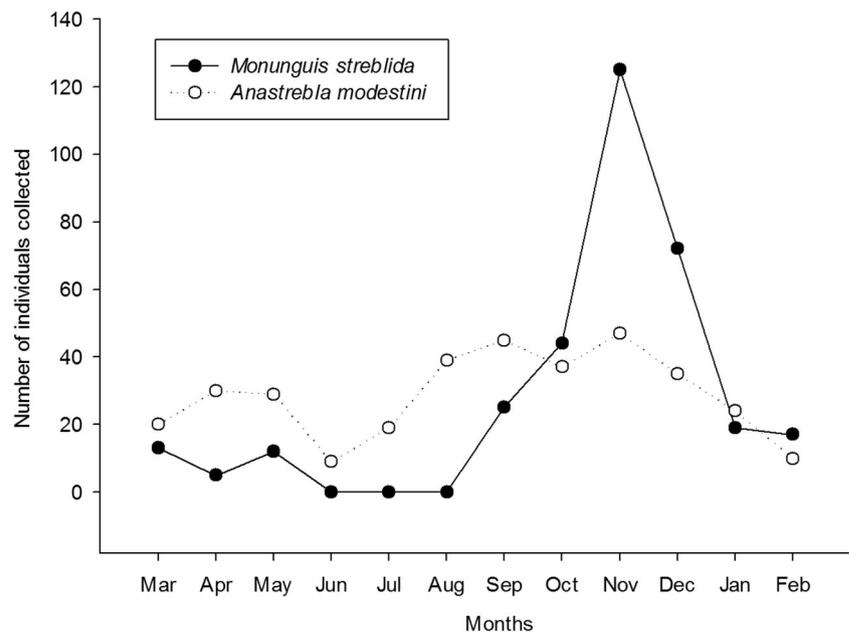
**Fig. 4** Linear regression between the number of parasites collected monthly and the number of hosts



$r^2 = 0,34$; $r = 0,58$; $p = 0,04$; $y = -21,8107 + 1,726*x$; 0,95 Conf.Int.
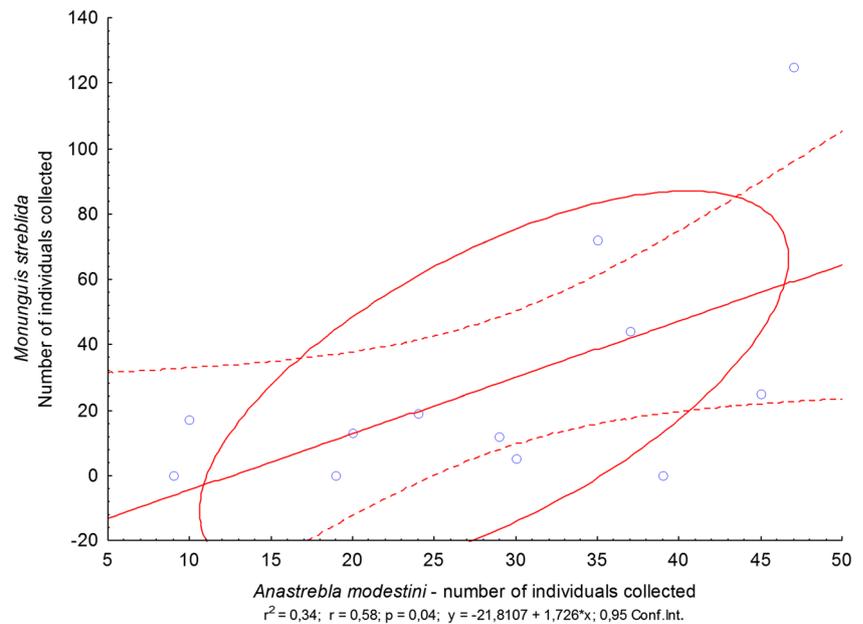
Despite the significant geographic distance between the previously established occurrences and the new records presented herein, parasites associated with hosts with great dispersal capacity are capable of occupying large geographic areas. Good examples of this include the species *Whartonia nudosetosa* Wharton, 1938, which is distributed from northern Mexico to southeastern Brazil (da Silveira et al. 2015), and the species *Eutrombicula alfreddugesi* Oudemans, 1910, for which there are records of occurrence from the USA to Brazil (Jacinavicius et al. 2018). In this study, the wide distribution observed by *M. streblida* species is an interesting fact and is the result of the association in which it is involved. *Monunguis streblida* is a parasite of Streblidae, which

associates intimately with bats with great ability to disperse and which in turn are vectors capable of carrying the species of mite and its host to places that would be impossible to reach without help. *Anoura geoffroyi* and *G. soricina* are among the various species of bats that possess wide distributions in the Neotropics, occurring in North, Central, and South America from Mexico to Brazil (Eisenberg and Redford 1999; Gardner 2008).

Although *M. streblida* was found on three different species of Streblidae, it is notable that it was preferentially associated with *A. modestini*, with only two records of parasitism on each of *A. caudiferae* and *Trichobius* sp. (*dugesii* complex). *Trichobius* exhibited peaks of abundance during the months

**Fig. 5** Linear regression between the number of parasites collected monthly and the temperature in the cave
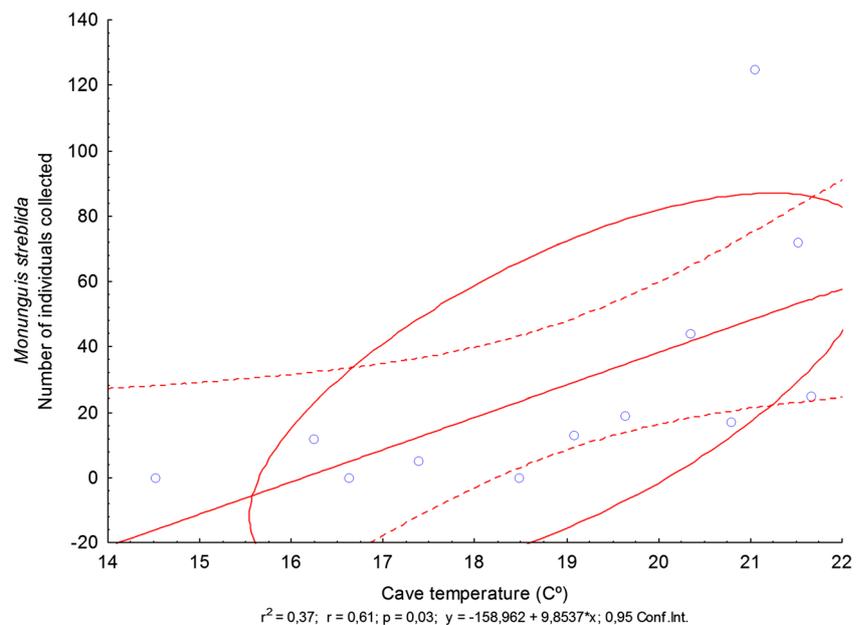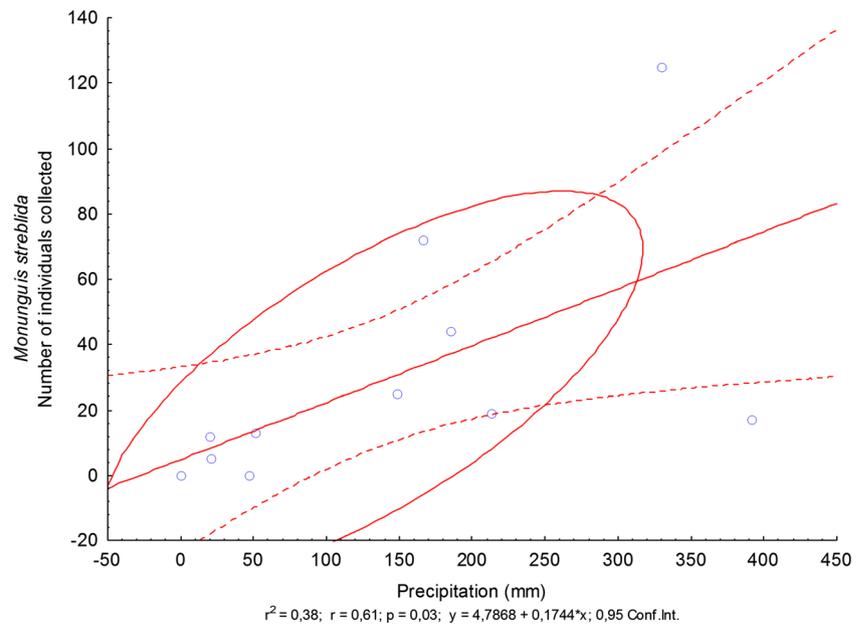


$r^2 = 0,37$; $r = 0,61$; $p = 0,03$; $y = -158,962 + 9,8537*x$; 0,95 Conf.Int.

**Fig. 6** Linear regression between the number of parasites collected monthly and precipitation values in the epigean environment



$r^2 = 0,38$; $r = 0,61$; $p = 0,03$; $y = 4,7868 + 0,1744*x$; 0,95 Conf.Int.

of February, March, April, and May and even became more recurrent that *A. modestini*. Nonetheless, no further associations of *M. streblida* with this host were observed. Thus, the parasitism observed on these two species in the present study can only be considered accidental, although Lindquist and Vercanmen-Grandjean (1971) also recorded this hyperparasite in association with *T. dugesii*.

It is important to highlight a relationship preference between *M. streblida* and *A. modestini*, especially considering that *A. modestini* presented about half abundance of *E. clovisi*. This fact, in addition to the close association observed between the population's cycle of *M. streblida* and *A. modestini*, suggests a specificity relationship for this host, which was not observed by Lindquist and Vercammen-Grandjean (1971).

According to Begon et al. (2006), high host specificity for parasites is recurrent in nature. Parasitism by a given parasite is more common with its main host, that is, the one with which it is coevolving. However, the host specificity in mites of the Parasitengona is uncommon; the vast majority of species are polyphagous ectoparasites and have been observed associated with more than one host species (Wohltmann 2000).

One of the main morphological differences between the two most abundant species of Streblidae found in the present study is the presence of rudimentary wings in *E. clovisi* and developed wings in *A. modestini*. Also, *M. streblida* was always associated to the abdomen of *A. modestini*. This behavior could indicate that associations with winged hosts would offer some sort of advantage to the parasite, such as protection of the mite during its development or greater dispersion ability for other hosts.

However, this hypothesis does not seem to make sense, since Lindquist and Vercanmen-Grandjean (1971) found larvae of this same hyperparasite in starred wing species (*Trichobius dugesii* and *T. pseudotruncatus*) and with rudimentary wings (*Megistopoda aranea*), contrary to what we observed here. Besides that, in this same study, species of *T. dugesii* were parasitized by *M. streblida* which apparently in our study was only a random occurrence. Thus, unfortunately, the lack of information available in the literature on *Monunguis* host specificity, and the data presented here, does not allow us to make inferences at this time about the preference of *M. streblida* by *A. modestini* in our studies.

The life cycles of several terrestrial species of Parasitengona are influenced by environmental factors, with their least activity occurring during periods of low temperatures and higher ovipositioning during hot periods (Robaux 1974). These facts explain the close relationship between fluctuations in the abundance of *M. streblida* and the climatic parameters of temperature and precipitation observed in the present study. Likewise, ovipositioning and the subsequent emergence of larvae, during hot periods (Robaux 1974), also coincided with an increase in the population of *A. modestini* in the studied caves. However, all specimens found in the present study were immature individuals. Thus, integrative molecular techniques could help elucidate the reproductive cycle of *M. streblida* in caves in Brazil and lead to a better understanding of the distribution of the species.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

## References

Begon M, Townsend CR, Harper JL (2006) Ecology: from individuals to ecosystems, 4th edn. Blackwell Publishing, Oxford

Beron P (2007) Terrestrial cave animals in Bulgaria. In: Fet V, Popov A (eds) Biogeography and ecology of Bulgaria. Springer, Dordrecht, pp 493–526

Bush AO, Lafferty KD, Lotz JM, Shostaki AW (1997) Parasitology meets ecology on its own terms: Margolis et al. Revisited. J Parasitol 83: 575–583

Coquillett DW (1899) New genera and species of Nycteribiidae and Streblidae. Can Entomol 31:333–336. https://doi.org/10.4039/Ent31333-11

Eisenberg JF, Redford KH (1999) Mammals of the Neotropics: The Central Neotropics. The University of Chicago Press, Chicago

Gardner AL (2008) Mammals of South America. Marsupials, xenarthrans, shrews and bats. The University of Chicago Press, Chicago

Graciolli G, Carvalho CJB (2001) Moscas ectoparasitas (Diptera, Hippoboscoidea, Nycteribiidae) de morcegos Mammalia, Chiroptera do Estado do Paraná, Brasil. I. Basilia, taxonomia e chave pictórica para as espécies. Revta Bras Zool 18:33–49

Gray JE (1838) A revision of the genera of bats (Vespertilionidae), and the description of some new genera and species. Mag Zool Bot 2: 483–505

Guerrero R (1993) Catalogo de los streblidae (Diptera: Pupipara) parasitos de murcielagos (Mammalia: Chiroptera) del nuevo mundo. I chave para los generos y Nycterophiliinae. Acta Biol Venez 14:61–75

Jacinavicius FC, Bassini-Silva R, Mendoza-Roldan JA et al (2018) A checklist of chiggers from Brazil, including new records (Acari: Trombidiformes: Trombiculidae and Leeuwenhoekiidae). Zookeys 743:1–41. https://doi.org/10.3897/zookeys.743.22675

Lindquist EE, Vercammen-Grandjean PH (1971) Revision of the chigger-like larvae of the genera *Neotrombidium* Leonardi and Monunguis Wharton, with a redefinition of the subfamily Neotrombidiinae Feider in the Trombidiidae (Acarina:Prostigmata). Can J Zool 103: 1557–1590

Mąkol J, Wohltmann A (2012) An annotated checklist of terrestrial Parasitengona (Actinotrichida: Prostigmata) of the world, excluding Trombiculidae and Walchiidae. Ann Zool 62:359–562. https://doi.org/10.3161/000345412X656671

Mąkol J, Wohltmann A (2013) Corrections and additions to the checklist of terrestrial Parasitengona (Actinotrichida: Prostigmata) of the world, excluding Trombiculidae and Walchiidae. Ann Zool 63:15–27. https://doi.org/10.3161/000345413X666075

Pessoa SB, Guimarães LR (1936) Notas sobre Streblidae (Diptera), com a descripção de um novo genero e duas novas especies. Anais Fac Med Univ São Paulo 12:255–267

Postaswa P, Szubert-Kruszynska A (2014) Is parasite load dependent on host aggregation size? The case of the greater mouse-eared bat *Myotis myotis* (Mammalia: Chiroptera) and its parasitic mite *Spinturnix myoti* (Acari: Gamasida). Parasitol Res 113(5):1803–1811. https://doi.org/10.1007/s00436-014-3826-8

Robaux P (1974) Recherches sur le developpement et la biologie des acariens Thrombidiidae. Mem du Museum Natl D'Histoire Nat Serie A Zo 1–186

Shatrov AB, Kudryashova NI (2008) Taxonomic ranking of major Trombiculid subtaxa with remarks on the evolution of host-parasite relationships (Acariformes: Parasitengona: Trombiculidae). Ann Zool 58:279–287. https://doi.org/10.3161/000345408X326591

da Silveira PSA, Bernardi LFO, Pepato AR (2015) New records of the genus *Whartonia* (Acari, Leeuwenhoekiidae) associated with the bat *Carollia perspicillata* from southeastern Brazil. Check List 11:1–6. https://doi.org/10.15560/11.2.1580

Stroiński A, Felska M, Mąkol J (2013) A review of host-parasite associations between terrestrial Parasitengona (Actinotrichida: Prostigmata) and bugs (Hemiptera). Ann Zool 63:195–221. https://doi.org/10.3161/000345413X669522

Walter DE, Krantz GW (2009) Collecting, rearing and preparing specimens. In: Krantz GW, Walter DE (eds) A manual of acarology. Texas Tech University Press, Texas, pp 83–95

Walter DE, Lindquist EE, Smith IM et al (2009) Order Trombidiformes. In: Krantz GW, Walter DE (eds) A manual of acarology. Texas Tech University Press, Texas, pp 233–420

Wenzel RL (1976) The streblid batflies of Venezuela (Diptera: Streblidae). Brigham Young Univ Sci Bull Biol Ser 20:1–177

Wenzel RL, Tipton VJ, Kiewlicz A. (1966) The streblid batflies of Panama (Diptera: Calyptera: Streblidae), p. 405–675. In: R.L. Wenzel, V.J. Tipton (Eds). Ectoparasites of Panama. Chicago, Field Mus. Nat. Hist., XII+861p

Wharton GW (1938) Acarina of Yucatan caves. Carnegie Inst Wash Publ 491:137–152

Wohltmann A (2000) The evolution of life histories in Parasitengona (Acari: Prostigmata). Acaraologia 41:145–204

Womersley H (1963) "*Monunguis*" Wharton 1938, avalid genus (Acarina, Trombidioidea). Rec South Aust Museum 14:477–485