Revista Mexicana de Biodiversidad

Revista Mexicana de Biodiversidad 90 (2019): e902485

Taxonomy and systematics

Updated species list of the bat ectoparasitic flies (Diptera: Nycteribiidae and Streblidae) in the state of Paraíba, Northeastern Brazil

Lista actualizada de especies de moscas ectoparásitas (Diptera: Nycteribiidae y Streblidae) de murciélagos en el estado de Paraíba, noreste de Brasil

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Received: 2 October 2017; accepted: 15 October 2018

Abstract

Bat ectoparasitic flies are highly specialized hematophagous insects exclusive to Chiroptera. Between November 2014 and August 2016, we surveyed these ectoparasites in urban and protected areas in the state of Paraíba, northeastern Brazil. We recorded 15 fly species in 10 genera in the families Streblidae (13) and Nycteribiidae (2). Twelve species and 5 genera represent first records for the state. *Basilia anceps* and *Noctiliostrebla* sp., are new records for the northeastern region of Brazil. Fly specimens were collected on 8 species of bats, mainly phyllostomids, and ~87% were monoxenous. Our survey increased the number of known bat ectoparasitic flies in the state from 10 to 22 species, from 5 to 10 genera, and from 31 to 34 known species in the northeastern portion of the Atlantic Forest.

Keywords: Atlantic Forest; Chiroptera; Ectoparasites; Host-parasite relationship; New records; Species richness

https://doi.org/10.22201/ib.20078706e.2019.90.2485

Resumen

Las moscas ectoparásitas de murciélagos son hematófagos altamente especializados de quirópteros. Desde noviembre de 2014 hasta agosto de 2016 realizamos un estudio de estos ectoparásitos en áreas urbanas y protegidas en el estado de Paraíba, noreste de Brasil. Se registraron 15 especies de moscas de 10 géneros de las familias Streblidae (13) y Nycteribiidae (2). Doce especies y 5 géneros de moscas representan el primer registro para el estado. *Basilia anceps* y *Noctiliostrebla* sp. son nuevos registros para el noreste de Brasil. Las moscas fueron recolectadas en 8 especies de murciélagos, principalmente en filostomídeos, y ~87% eran monoxenas. A través de nuestro estudio, el número de moscas ectoparásitas de murciélagos conocidas en el estado aumentó de 10 a 22 especies, de 5 a 10 géneros y de 31 a 34 especies conocidas en la porción noreste del Bosque Atlántico.

Palabras clave: Bosque Atlántico; Chiroptera; Ectoparásitos; Relación hospedero-parásito; Nuevos registros; Riqueza de especies

Introduction

Streblidae and Nycteribiidae (Diptera: Hippoboscoidea) are 2 worldwide distributed families of blood feeding and obligate ectoparasitic flies (Dick & Patterson, 2006). Bat flies are found exclusively infesting the body or wing membranes of these flying mammals (Marshall, 1982). Even though they should be able to colonize multiple host species, researchers have suggested species-specific host-parasite relationships (Dick & Dick, 2006; ter Hofstede & Fenton, 2005).

Ecological and behavioral features of bats, such as social structure, roost environment, and species fidelity to roosting sites play an important role in the host-parasite dynamics (Patterson et al., 2007). Therefore, studies on the diversity and interactions between these parasites and bats can offer valuable information concerning different biological, phylogenetic, and systematic aspects of these mammalian hosts. They can also shed light on the role of blood-feeding arthropods in the epidemiology of bat-borne pathogens (e.g., virus and bacteria; Fritz, 1983; Joffrin et al., 2018) which is at the present moment speculative. However, basic knowledge regarding ectoparasites' diversity, distribution, and host-parasite relationships are still incipient.

In Brazil, the knowledge about these hematophagous bat flies is geographically biased where, for example, the smallest federative unit (Federal District) has the highest species richness (n = 56; Figueiredo et al., 2015), representing approximately half of the species occurring in the country. At a national level, the most surveyed region is the southeastern (Lourenço et al., 2016); the north and northeastern regions remain with the largest sampling gaps.

Currently, throughout northeastern Brazil, 47 streblid and only 3 nycteribiid species have been recorded infesting 8 bat families, mainly Phyllostomidae (Barbier & Bernard, 2017). Despite the advance in recent years (Bezerra et al., 2016; Santos et al., 2013; Soares et al., 2013, 2016), species richness in the northeastern is underestimated and the majority of states is undersampled or lack information about bat ectoparasitic flies' diversity (Barbier & Bernard, 2017). The state of Paraíba, for instance, has had only 1 survey on bat ectoparasitic flies —conducted in the Caatinga (seasonally dry tropical forest)— with 10 species recorded (Barbier et al., 2016).

In the present study, we provide updated information on streblid and nycteribiid flies in the state of Paraíba, extending the known geographical range of 5 genera and 12 species. In this sense, we surveyed bats in residential areas and urban forest remnants of Atlantic Forest and produced an annotated species list of bat ectoparasitic flies with comments on associations with their hosts.

Materials and methods

Field studies were conducted in 5 protected areas of Atlantic Forest and residential neighborhoods within the metropolitan region of João Pessoa, state of Paraíba (07°07' S, 34°51' W), northeastern Brazil. The sampled areas were: *1)* Mata do Buraquinho Wildlife Refuge (517.8 ha), *2)* Restinga de Cabedelo National Forest (136.36 ha), *3)* Cuiá Natural Park (42 ha), *4)* Arruda Câmara Zoobotanical Park (26.8 ha), *5)* Cidade Verde Municipal Forest (22 ha) and the neighborhoods, *6)* Altiplano, *7)* Alto do Mateus, *8)* Bairro dos Novaes, *9)* Funcionários IV, *10)* Jardim Veneza, *11)* Paratibe, and *12)* Penha (Fig. 1).

A wide variety of phytophysiognomies of the Atlantic Forest biome can be identified among sampling sites, including areas of typical seasonal semi-deciduous forests, savanna formations on sandy soils, "restingas" (coastal vegetation), and mangroves (Amazonas & Barbosa, 2011; Gadelha-Neto & Barbosa, 2012; Vicente et al., 2014). The local climate is the type As' of Köppen's classification, hot and humid, with the wet season from March to August and a dry season from September to February. The annual rainfall varies between 1,500 mm to 1,700 mm, and the annual average temperatures and humidity are usually

https://doi.org/10.22201/ib.20078706e.2019.90.2485

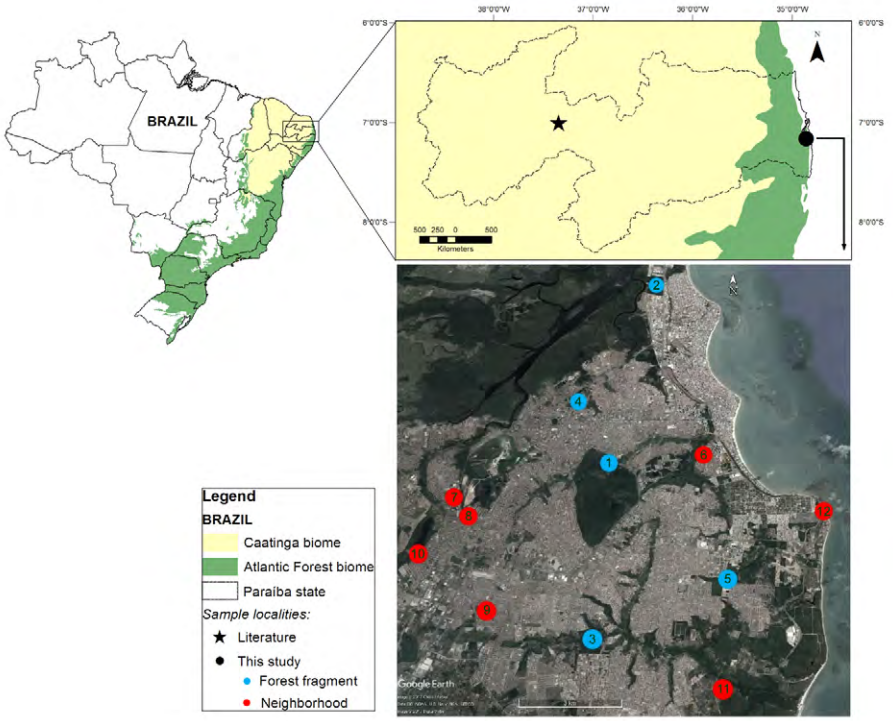

Figure 1. Sampling sites for bat ectoparasitic flies (Diptera: Nycteribiidae and Streblidae) in the state of Paraíba, northeastern Brazil.

around 22-26 °C and 80%, respectively (Feliciano & Melo, 2003).

Between November 2014 and August 2016, bats were captured in forest fragments using mist nets set both at canopy (4 mist nets of 3.0 m × 2.5 m) and understory levels (8 of 9.0 m × 2.5 m), opened from dusk until 10:00 pm. Captures in residential sites were performed with various sets of mist nets with different sizes according to the available area in each house (e.g., presence of roosts, backyards, gardens). During 60 sampling nights, the total effort was 55,580 h.m^2 following Straube & Bianconi (2002); calculated by multiplying mist net area (m^2), the number of mist nets, and hours of exposure (h).

Nets were checked every 15-30 minutes, and captured bats were individually placed in cotton bags and later weighed, measured, sexed, and identified according to taxonomic keys (Díaz et al., 2016; Gardner, 2008). We followed Nogueira et al. (2014) for bat nomenclature. Bat capture was carried out under authorization of the Chico Mendes Institute for Biodiversity Conservation (ICMBio) (SISBIO permit number 45168-3) and residences were sampled with owner's consent. All animal procedures were approved by the Ethics Committee on Animal Use of the Federal University of Paraíba (CEUA/UFPB number 027/2016).

Bat ectoparasitic flies were collected with forceps and placed in individually labeled vials with 70% ethanol. In the laboratory, flies were identified according to Guerrero (1995), Guimarães & D'Andretta (1956), Wenzel (1976), and Wenzel et al. (1966). For flies' nomenclature, we followed Dick & Graciolli (2008) for Streblidae and Graciolli & Dick (2008) for Nycteribiidae. Voucher specimens were deposited in the Entomological Collection of the Federal University of Pernambuco (CE-UFPE).

Results

We collected 197 bat ectoparasitic flies belonging to 15 species and 10 genera from the families Streblidae (13 species) and Nycteribiidae (2 species) (Table 1). Five genera and 12 fly species represent first records for the state of Paraíba, including *Basilia anceps* and *Noctiliostrebla* sp., as new records for northeastern Brazil. Most fly species (n = 13; ~87%) were species-specific, found on a single host species (Table 1, Fig. 2). Only *Trichobioides perspicillatus* and *Trichobius costalimai* were found on more than 1 host species (both on *Artibeus planirostris* and *Phyllostomus discolor*). The flies were collected on 102 bat specimens of 9 species and 7 genera in the families Phyllostomidae (6 species), Vespertilionidae (2 species), and Noctilionidae (1 species) (Table 1). *Phyllostomus discolor* was the bat most parasitized by flies (*Strebla hertigi*, *Trichobioides perspicillatus*, *T. costalimai*, and *T. longipes*; Fig. 2).

Below, we present, for each recorded ectoparasitic fly species, its host, comments on their geographic distribution, host-parasite interactions, information about the material examined, collection data, and voucher numbers.

Nycteribiidae Samouelle, 1819
Nycteribiinae Westwood, 1835
Basilia Miranda-Ribeiro, 1903
Basilia anceps Guimarães & D'Andretta, 1956

Host: *Myotis riparius* Handley, 1960 (Vespertilionidae).

Material examined (n = 1): 1 ♀ (CE-UFPE 100829), on *M. riparius*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 19/X/2015, Nunes, H. coll.

Remarks

Basilia anceps is widely distributed in the Neotropical region (Graciolli et al., 2007), although its records are still isolated. Our record is the first of this species in northeastern Brazil, increasing to 4 the number of *Basilia* species known in this region (Barbier et al., 2017; Dias et al., 2009; Guimarães, 1938). In Brazil, *B. anceps* was previously recorded in the Federal District on *Myotis nigricans* (Schinz, 1821) and *M. riparius* (Graciolli & Aguiar, 2002), and in the municipality of Serranópolis, state of Goiás, on *Myotis* sp. (Graciolli et al., 2010) both in the midwestern region of Brazil. Here, we increase the known geographic distribution of this species in approximately

Table 1
Ectoparasitic flies (Diptera: Nycteribiidae and Streblidae) and their hosts (Chiroptera) in the state of Paraíba, northeastern Brazil.

Family/fly species	Host species	Site***	Source
Nycteribiidae			
Basilia anceps Guimarães & D'Andretta, 1956	*Myotis riparius* Handley, 1960	1	PS
Basilia travassosi Guimarães, 1938	*Myotis lavali* Moratelli et al., 2011	1, 2, 4	**, PS
Streblidae			
Aspidoptera falcata Wenzel, 1976	*Sturnira lilium* (É. Geoffroy, 1810)	8, 10	PS
Aspidoptera phyllostomatis (Perty, 1833)	*Artibeus planirostris* (Spix, 1823)	1, 3-8, 10, 11	PS
Megistopoda aranea (Coquillett, 1899)	*Artibeus planirostris*	1-8, 10-12	**, PS
Megistopoda proxima (Séguy, 1926)	*Sturnira lilium*	1, 9, 10	PS
Noctiliostrebla sp.	*Noctilio leporinus* (Linnaeus, 1758)	1	PS
Paradyschiria fusca Speiser, 1900	*Noctilio leporinus*	1, 4	PS
Paratrichobius longicrus (Miranda Ribeiro, 1907)	*Artibeus planirostris*	1	PS
Speiseria ambigua Kessel, 1925	*Glossophaga soricina* (Pallas, 1766)*, *Carollia perspicillata* (Linnaeus, 1758)	5	**, PS
Strebla hertigi Wenzel, 1966	*Phyllostomus discolor* (Wagner, 1843)	2	PS
Strebla wiedemanni Wenzel, 1966	*Desmodus rotundus* (É. Geoffroy, 1810)	NA	**
Trichobioides perspicillatus (Pessôa & Galvão, 1937)	*Artibeus planirostris**, *Phyllostomus discolor*	1-4	PS
Trichobius costalimai Guimarães, 1938	*Artibeus planirostris**, *Phyllostomus discolor*	1-5, 8	PS
Trichobius diphyllae Wenzel, 1966	*Diphylla ecaudata* Spix, 1823	NA	**
Trichobius dugesii Townsend, 1891	*Glossophaga soricina*	NA	**
Trichobius dugesioides dugesioides Wenzel, 1966	*Trachops cirrhosus* (Spix, 1823)	NA	**
Trichobius galei Wenzel, 1966	*Natalus macrourus* (Gervais, 1856)	NA	**
Trichobius joblingi Wenzel, 1966	*Carollia perspicillata*	1, 4, 5, 10, 11	PS
Trichobius longipes (Rudow, 1871)	*Phyllostomus discolor*	5	PS
Trichobius pallidus (Curran, 1934)	*Furipterus horrens* (Cuvier, 1828)	NA	**
Trichobius parasiticus Gervais, 1844	*Desmodus rotundus*	NA	**
Richness: 10 genera/22 species	12 genera/13 species		

*= Non-primary association; **= Barbier et al. (2016); ***= referring to the sites sampled in the present study, which can be visualized in Fig. 1; NA= not applicable; PS= present study.

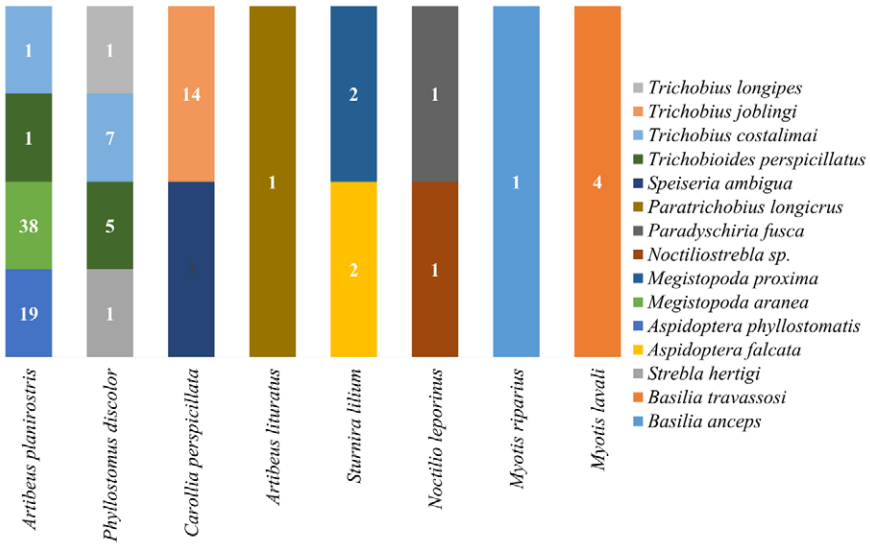

Figure 2. Host-parasite association between bats (Chiroptera) and ectoparasitic flies (Diptera: Nycteribiidae and Streblidae) in the state of Paraíba, northeastern Brazil. The numbers in the columns represent the total of bat specimens parasitized by each fly species.

1,700 km from the Federal District to Paraíba. Throughout its geographic distribution, *B. anceps* has been collected parasitizing at least 7 bat species (Graciolli, 2001; Graciolli et al., 2007).

Basilia travassosi Guimarães, 1938

Host: *Myotis lavali* Moratelli, Peracchi, Dias & Oliveira, 2011 (Vespertilionidae).

Material examined (n = 11): 1 ♂ and 1 ♀ (CE-UFPE 100830), on *M. lavali*, Cabedelo, PB (7°03'51.0" S, 34°51'16.6" W), 02/VII/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100831), on *M. lavali*, same locality data, 07/VII/2015, Nunes, H. coll.; 5 ♀ (CE-UFPE 100832), on *M. lavali*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 26/X/2015, Nunes, H. coll.; 2 ♂ and 1 ♀ (CE-UFPE 100833), on *M. lavali*, João Pessoa, PB (7°06'45.3" S, 34°52'27.2" W), 11/XI/2015, Nunes, H. coll.

Remarks

According to Guimarães and D'Andretta (1956), *B. travassosi* is endemic to northeastern Brazil. This species was recorded in 6 of the 9 states of the region and in different ecoregions (Barbier & Bernard, 2017). In the state of Paraíba, *B. travassosi* was recently recorded in the semi-arid Caatinga, also on *M. lavali* (Barbier et al., 2016).

Streblidae Kolenati, 1863
Streblinae Speiser, 1900
Strebla Wiedemann, 1824
Strebla hertigi Wenzel, 1966

Host: *Phyllostomus discolor* (Wagner, 1843) (Phyllostomidae).

Material examined (n = 1): 1 ♂ (CE-UFPE 100834), on *P. discolor*, Cabedelo, PB (7°03'51.0" S, 34°51'16.6" W), 06/VII/2015, Nunes, H. coll.

Remarks

Although it has relatively few records in Brazil, *S. hertigi* is widely distributed throughout the Neotropics (Guerrero, 1996), primarily associated with *P. discolor* (Wenzel, 1976). This is the first record of the species in the state of Paraíba.

Trichobiinae Jobling, 1936
Aspidoptera Coquillett, 1899
Aspidoptera falcata Wenzel, 1976

Host: *Sturnira lilium* (É. Geoffroy, 1810) (Phyllostomidae).

Material examined (n = 2): 1 ♂ (CE-UFPE 100835), on *S. lilium*, João Pessoa, PB (7°10'06.3" S, 34°54'39.3" W), 19/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100836), on *S. lilium*, João Pessoa, PB (7°09'15.2" S, 34°54'02.0" W), 21/XI/2014, Nunes, H. coll.

Remarks

Sturnira lilium is the primary host for *A. falcata*, although Wenzel (1976) has recorded on another 2 species of *Sturnira* in Venezuela, with some frequency. This fly is relatively well sampled in Brazil and may co-occur with *Megistopoda proxima* (Linhares & Komeno, 2000). In this

study, we recorded *A. falcata* for the first time in the state of Paraíba.

Aspidoptera phyllostomatis (Perty, 1833)

Host: *Artibeus planirostris* (Spix, 1823) (Phyllostomidae).

Material examined (n = 25): 1 ♂ (CE-UFPE 100837), on *A. planirostris*, João Pessoa, PB (7°12'23.8" S, 34°49'13.0" W), 24/XI/2014, Nunes, H. coll.; 1 ♂ and 2 ♀ (CE-UFPE 100838), on *A. planirostris*, João Pessoa, PB (7°11'30.3" S, 34°51'33.1" W), 29/V/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100839), on *A. planirostris*, João Pessoa, PB (7°08'54.7" S, 34°54'19.1" W), 17/XI/2014, Nunes, H. coll.; 1 ♀ (CE-UFPE 100840), on *A. planirostris*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 20/IV/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100841), on *A. planirostris*, João Pessoa, PB (7°07'59.4" S, 34°49'51.3" W), 15/VII/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100842), on *A. planirostris*, same locality data, 15/VII/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100843), on *A. planirostris*, João Pessoa, PB (7°08'53.8" S, 34°54'19.6" W), 17/XI/2014, Nunes, H. coll.; 1 ♀ (CE-UFPE 100844), on *A. planirostris*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 19/X/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100845), on *A. planirostris*, same locality data, 20/X/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100846), on *A. planirostris*, same locality data, 21/X/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100847), on *A. planirostris*, same locality data, 22/X/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100848), on *A. planirostris*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 20/IV/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100849), on *A. planirostris*, João Pessoa, PB (7°06'45.3" S, 34°52'27.2" W), 11/XI/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100850), on *A. planirostris*, same locality data, 13/XI/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100851), on *A. planirostris*, João Pessoa, PB (7°10'06.3" S, 34°54'39.3" W), 19/XI/2014, Nunes, H. coll.; 4 ♂ and 1 ♀ (CE-UFPE 100852), on *A. planirostris*, same locality data, 19/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100853), on *A. planirostris*, João Pessoa, PB (7°08'54.7" S, 34°54'19.1" W), 17/XI/2014, Nunes, H. coll.; 1 ♀ (CE-UFPE 100854), on *A. planirostris*, João Pessoa, PB (7°09'15.2" S, 34°54'02.0" W), 21/XI/2014, Nunes, H. coll.; 1 ♀ (CE-UFPE 100855), on *A. planirostris*, same locality data, 21/XI/2014, Nunes, H. coll.

Remarks

Like *A. falcata*, we recorded *A. phyllostomatis* for the first time in the state of Paraíba. *Artibeus jamaicensis* Leach, 1821 is the host type for this fly (Wenzel, 1976), however, in Brazil, it is associated mainly with *A. planirostris* and *A. fimbriatus* (Barbier & Graciolli, 2016; Dornelles & Graciolli, 2017; Eriksson et al., 2011).

Megistopoda Macquart, 1852

Megistopoda aranea (Coquillett, 1899)

Host: *Artibeus planirostris* (Phyllostomidae).

Material examined (n = 53): 1 ♂ (CE-UFPE 100856), on *A. planirostris*, João Pessoa, PB (7°12'23.8" S, 34°49'13.0" W), 24/XI/2014, Nunes, H. coll.; 1 ♀ (CE-UFPE 100857), on *A. planirostris*, João Pessoa, PB (7°11'30.3" S, 34°51'33.1" W), 29/V/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100858), on *A. planirostris*, João Pessoa, PB (7°12'23.8" S 34°49'13.0" W), 24/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100859), on *A. planirostris*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 26/XI/2014, Nunes, H. coll.; 2 ♂ (CE-UFPE 100860), on *A. planirostris*, João Pessoa, PB (7°08'54.7" S, 34°54'19.1" W), 17/XI/2014, Nunes, H. coll.; 1 ♀ (CE-UFPE 100861), on *A. planirostris*, João Pessoa, PB (7°06'45.3" S, 34°52'27.2" W), 10/VI/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100862), on *A. planirostris*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 20/IV/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100863), on *A. planirostris*, João Pessoa, PB (7°09'36.1" S, 34°47'42.8" W), 13/VII/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100864), on *A. planirostris*, João Pessoa, PB (7°07'59.4" S, 34°49'51.3" W), 15/VII/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100865), on *A. planirostris*, same locality data, 15/VII/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100866), on *A. planirostris*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 20/IV/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100867), on *A. planirostris*, João Pessoa, PB (7°08'43.6" S 34°51'41.3" W), 19/X/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100868), on *A. planirostris*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 20/IV/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100869), on *A. planirostris*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 21/X/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100870), on *A. planirostris*, same locality data, 21/X/2015, Nunes, H. coll.; 1 ♂ and 1 ♀ (CE-UFPE 100871), on *A. planirostris*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 20/IV/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100872), on *A. planirostris*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 21/X/2015, Nunes, H. coll.; 1 ♂ and 2 ♀ (CE-UFPE 100873), on *A. planirostris*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 20/IV/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100874), on *A. planirostris*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 26/X/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100875), on *A. planirostris*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 21/III/2016, Nunes, H. coll.; 1 ♂ (CE-UFPE 100876), on *A. planirostris*, same locality data, 22/IV/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE

100877), on *A. planirostris*, Cabedelo, PB (7°03'51.0" S, 34°51'16.6" W), 25/IV/2016, Nunes, H. coll.; 2 ♂ (CE-UFPE 100878), on *A. planirostris*, João Pessoa, PB (7°11'30.3" S, 34°51'33.1" W), 31/V/2016, Nunes, H. coll.; 1 ♂ (CE-UFPE 100879), on *A. planirostris*, same locality data, 16/VIII/2016, Nunes, H. coll.; 1 ♀ (CE-UFPE 100880), on *A. planirostris*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 23/IV/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100881), on *A. planirostris*, João Pessoa, PB (7°10'06.3" S, 34°54'39.3" W), 19/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100882), on *A. planirostris*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 23/IV/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100883), on *A. planirostris*, João Pessoa, PB (7°08'54.7" S 34°54'19.1" W), 17/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100884), on *A. planirostris*, João Pessoa, PB (7°10'06.3" S, 34°54'39.3" W), 19/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100885), on *A. planirostris*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 24/IV/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100886), on *A. planirostris*, same locality data, 24/IV/2015, Nunes, H. coll.; 2 ♂ (CE-UFPE 100887), on *A. planirostris*, João Pessoa, PB (7°08'54.7" S, 34°54'19.1" W), 17/XI/2014, Nunes, H. coll.; 1 ♂ and 1 ♀ (CE-UFPE 100888), on *A. planirostris*, João Pessoa, PB (7°10'06.3" S, 34°54'39.3" W), 19/XI/2014, Nunes, H. coll.; 2 ♂ and 1 ♀ (CE-UFPE 100889), on *A. planirostris*, same locality data, 19/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100890), on *A. planirostris*, João Pessoa, PB (7°08'54.7" S, 34°54'19.1" W), 17/XI/2014, Nunes, H. coll.; 2 ♂ (CE-UFPE 100891), on *A. planirostris*, João Pessoa, PB (7°09'15.2" S, 34°54'02.0" W), 21/XI/2014, Nunes, H. coll.; 2 ♂ (CE-UFPE 100892), on *A. planirostris*, same locality data, 21/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100893), on *A. planirostris*, João Pessoa, PB (7°08'54.7" S, 34°54'19.1" W), 17/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100894), on *A. planirostris*, João Pessoa, PB (7°09'15.2" S, 34°54'02.0" W), 21/XI/2014, Nunes, H. coll.; 1 ♀ (CE-UFPE 100895), on *A. planirostris*, same locality data, 21/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100896), on *A. planirostris*, same locality data, 21/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100897), on *A. planirostris*, João Pessoa, PB (7°08'54.7" S, 34°54'19.1" W), 17/XI/2014, Nunes, H. coll.

Remarks

M. aranea occurs in all regions and different ecoregions of Brazil (Barbier & Graciolli, 2016; Graciolli & Bernard, 2002; Rui & Graciolli, 2005; Santos et al., 2009). In the state of Paraíba, *M. aranea* was recently recorded in a Caatinga biome also on *A. planirostris* (Barbier et al., 2016).

Megistopoda proxima (Séguy, 1926)

Host: *Sturnira lilium* (Phyllostomidae).

Material examined (n = 4): 1 ♂ (CE-UFPE 100898), on *S. lilium*, João Pessoa, PB (7°10'52.4" S, 34°53'18.7" W), 20/VII/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100899), on *S. lilium*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 21/X/2015, Nunes, H. coll.; 2 ♂ (CE-UFPE 100900), on *S. lilium*, João Pessoa, PB (7°10'06.3" S, 34°54'39.3" W), 19/XI/2014, Nunes, H. coll.

Remarks

The characteristic host for *M. proxima* is *S. lilium* (Dick & Gettinger, 2005). This species is widely distributed, occurring in all Brazilian regions (Barbier & Graciolli, 2016; Bertola et al., 2005; Santos et al., 2013; Soares et al., 2013), as well as in other American countries (Dick & Gettinger, 2005; Dick et al., 2007; Durán et al., 2017). Here, we recorded *M. proxima* for the first time in the state of Paraíba.

Noctiliostrebla Wenzel, 1966

Noctiliostrebla sp.

Host: *Noctilio leporinus* (Linnaeus, 1758) (Noctilionidae).

Material examined (n = 2): 2 ♀ (CE-UFPE 100901), on *N. leporinus*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 20/X/2015, Nunes, H. coll.

Remarks

Noctiliostrebla is a genus exclusively associated with the family Noctilionidae, formed by a species complex, including undescribed species (Wenzel et al., 1966). Currently, 4 species are recognized, but with the only 2 specimens we had, we were unable to identify to the species level. Even so, this is the first record of this genus in northeastern Brazil.

Paradyschiria Speiser, 1900

Paradyschiria fusca Speiser, 1900

Host: *Noctilio leporinus* (Noctilionidae).

Material examined (n = 6): 3 ♂ and 2 ♀ (CE-UFPE 100902), on *N. leporinus*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 20/X/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100903), *N. leporinus*, João Pessoa, PB (7°06'45.3" S, 34°52'27.2" W), 12/XI/2015, Nunes, H. coll.

Remarks

Like *Noctiliostrebla*, *Paradyschiria* is a specific parasite of Noctilionidae (Wenzel et al., 1966). In northeastern Brazil, *P. fusca* was recorded only in the state of Bahia (cited as *P. dubia*; Guimarães, 1941). This

is the first record of the species for Paraíba and the second record to northeastern Brazil after a 77-year hiatus.

Paratrichobius Costa Lima, 1921
Paratrichobius longicrus (Miranda Ribeiro, 1907)

Host: *Artibeus lituratus* (Olfers, 1818) (Phyllostomidae).

Material examined (n = 1): 1 ♂ (CE-UFPE 100904), on *A. lituratus*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 19/X/2015, Nunes, H. coll.

Remarks

Paratrichobius constitutes a species complex (Graciolli & Carvalho, 2001; Wenzel et al., 1966), frequently found on Stenodermatinae (Dick & Miller, 2010). *Artibeus lituratus* is considered primary host for *P. longicrus*. Probably, the *P. longicrus* infesting another Stenodermatinae (such as *Platyrrhinus* spp.) are undescribed species (Graciolli & Carvalho, 2001; Wenzel et al., 1966). Our record is the first for this species in the state of Paraíba.

Speiseria Kessel, 1925
Speiseria ambigua Kessel, 1925

Host: *Carollia perspicillata* (Linnaeus, 1758) (Phyllostomidae).

Material examined (n = 3): 1 ♂ (CE-UFPE 100905), on *C. perspicillata*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 26/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100906), on *C. perspicillata*, same locality data, 22/IV/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100907), on *C. perspicillata*, same locality data, 22/IV/2015, Nunes, H. coll.

Remarks

Recently, Barbier et al. (2016) recorded *S. ambigua* on *Glossophaga soricina* (Pallas, 1766) in the Caatinga of the state of Paraíba. This species is a primary parasite of *C. perspicillata* (Guerrero, 1994). Its record on other host species is classified as a transitory association or sampling contamination.

Trichobioides Wenzel, 1966
Trichobioides perspicillatus (Pessôa & Galvão, 1937)

Hosts: *Artibeus planirostris*, *Phyllostomus discolor* (Phyllostomidae).

Material examined (n = 22): 6 ♂ and 3 ♀ (CE-UFPE 100908), on *A. planirostris*, João Pessoa, PB (7°11'30.3" S, 34°51'33.1" W), 28/V/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100909), on *P. discolor*, Cabedelo, PB (7°03'51.0" S, 34°51'16.6" W), 06/VII/2015, Nunes, H. coll.; 1 ♂ and 2 ♀ (CE-UFPE 100910), on *P. discolor*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 21/X/2015, Nunes, H. coll.; 2 ♂ and 1 ♀ (CE-UFPE 100911), on *P. discolor*, same locality data, 22/X/2015, Nunes, H. coll.; 1 ♂ and 1 ♀ (CE-UFPE 100912), on *P. discolor*, same locality data, 22/X/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100913), on *P. discolor*, João Pessoa, PB (7°06'45.3" S, 34°52'27.2" W), 09/XI/2015, Nunes, H. coll.; 2 ♂ and 1 ♀ (CE-UFPE 100914), on *P. discolor*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 18/V/2015, Nunes, H. coll.

Remarks

The primary host of *Trichobioides perspicillatus* is *P. discolor* (Wenzel et al., 1966). We also found this species infesting *A. planirostris* but certainly represent a transitory association or contamination, as reported by Durán et al. (2017). This is the first record of *Trichobioides perspicillatus* in the state of Paraíba.

Trichobius Gervais, 1844
Trichobius costalimai Guimarães, 1938

Hosts: *Artibeus planirostris*, *Phyllostomus discolor* (Phyllostomidae).

Material examined (n = 41): 2 ♂ and 1 ♀ (CE-UFPE 100915), on *P. discolor*, João Pessoa, PB (7°09'15.2" S, 34°54'02.0" W), 21/XI/2014, Nunes, H. coll.; 8 ♂ (CE-UFPE 100916), on *A. planirostris*, João Pessoa, PB (7°11'30.3" S, 34°51'33.1" W), 28/V/2015, Nunes, H. coll.; 5 ♂ and 2 ♀ (CE-UFPE 100917), on *P. discolor*, Cabedelo, PB (7°03'51.0" S, 34°51'16.6" W), 06/VII/2015, Nunes, H. coll.; 1 ♂ and 2 ♀ (CE-UFPE 100918), on *P. discolor*, same locality data, 06/VII/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100919), on *P. discolor*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 22/X/2015, Nunes, H. coll.; 2 ♂ (CE-UFPE 100920), on *P. discolor*, same locality data, 22/X/2015, Nunes, H. coll.; 2 ♀ (CE-UFPE 100921), on *P. discolor*, same locality data, 22/X/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100922), on *P. discolor*, João Pessoa, PB (7°06'45.3" S, 34°52'27.2" W), 09/XI/2015, Nunes, H. coll.; 1 ♂ and 1 ♀ (CE-UFPE 100923), on *P. discolor*, same locality data, 12/XI/2015, Nunes, H. coll.; 1 ♂ and 1 ♀ (CE-UFPE 100924), on *P. discolor*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 24/IV/2015, Nunes, H. coll.; 2 ♂ and 2 ♀ (CE-UFPE 100925), on *P. discolor*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 14/V/2015, Nunes, H. coll.; 2 ♂ and 4 ♀ (CE-UFPE 100926), on *P. discolor*, same locality data, 18/V/2015, Nunes, H. coll.

Remarks

T. costalimai is widely distributed and occurs on *P. discolor*, its primary host, throughout its range (Wenzel, 1976). Infestation on other hosts is considered as a non-primary association. Conversely, Durán et al. (2017) found frequently association between *T. costalimai* and *A.*

planirostris in a dry tropical forest in Colombia. Here, we record this species for the first time in the state of Paraíba.

Trichobius joblingi Wenzel, 1966

Host: *Carollia perspicillata* (Phyllostomidae).

Material examined (n = 24): 2 ♂ and 2 ♀ (CE-UFPE 100927), on *C. perspicillata*, João Pessoa, PB (7°12'23.8" S, 34°49'13.0" W), 24/XI/2014, Nunes, H. coll.; 1 ♂ and 1 ♀ (CE-UFPE 100928), on *C. perspicillata*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 26/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100929), on *C. perspicillata*, same locality data, 26/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100930), on *C. perspicillata*, same locality data, 26/XI/2014, Nunes, H. coll.; 1 ♂ (CE-UFPE 100931), on *C. perspicillata*, João Pessoa, PB (7°06'45.3" S, 34°52'27.2" W), 12/VI/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100932), on *C. perspicillata*, João Pessoa, PB (7°08'43.6" S, 34°51'41.3" W), 19/X/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100933), on *C. perspicillata*, same locality data, 22/X/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100934), on *C. perspicillata*, same locality data, 26/X/2015, Nunes, H. coll.; 2 ♀ (CE-UFPE 100935), on *C. perspicillata*, João Pessoa, PB (7°06'45.3" S, 34°52'27.2" W), 10/XI/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100936), on *C. perspicillata*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 22/IV/2015, Nunes, H. coll.; 2 ♂ (CE-UFPE 100937), on *C. perspicillata*, same locality data, 22/IV/2015, Nunes, H. coll.; 1 ♂ and 1 ♀ (CE-UFPE 100938), on *C. perspicillata*, same locality data, 22/IV/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100939), on *C. perspicillata*, same locality data, 22/IV/2015, Nunes, H. coll.; 1 ♀ (CE-UFPE 100940), on *C. perspicillata*, same locality data, 23/IV/2015, Nunes, H. coll.; 1 ♂ and 1 ♀ (CE-UFPE 100941), on *C. perspicillata*, same locality data, 24/IV/2015, Nunes, H. coll.; 1 ♂ (CE-UFPE 100942), on *C. perspicillata*, João Pessoa, PB (7°10'06.3" S, 34°54'39.3" W), 19/XI/2014, Nunes, H. coll

Remarks

This species occurs throughout Central and South America in association with *C. perspicillata* (Wenzel, 1976) in at least 20 countries (Barbier & Graciolli, 2016), and is probably the most abundant bat ectoparasitic fly in the New World (Guerrero, 1995). Despite the wide distribution and abundance, this is the first record of *T. joblingi* in Paraíba.

Trichobius longipes (Rudow, 1871)

Host: *Phyllostomus discolor* (Phyllostomidae).

Material examined (n = 1): 1 ♂ (CE-UFPE 100943), on *P. discolor*, João Pessoa, PB (7°10'06.5" S, 34°51'50.1" W), 21/IV/2015, Nunes, H. coll.

Remarks

P. hastatus is the host type for *T. longipes*, although this fly may occur in other *Phyllostomus* species as *P. discolor* (Graciolli & Carvalho, 2001; Guerrero, 1994; Santos et al., 2013). In the northeastern, this fly was little recorded (Barbier & Bernard, 2017) and this represents the first record for Paraíba.

Discussion

Although the present study is the second survey on bat ectoparasitic flies conducted in Paraíba, the state is now the fourth in species richness in northeastern Brazil, behind the states of Pernambuco, Maranhão, and Sergipe with 34, 28, and 23 species, respectively (Barbier & Bernard, 2017; Soares et al., 2017). We have increased the number of known Nycteribiidae and Streblidae in the state from 10 to 22 species, and from 5 to 10 genera; as well as from 50 to 52 species known in the region, with the records of *B. anceps* and *Noctiliostrebla* sp. (Barbier & Bernard, 2017). We also increase from 31 to 34 the known species in the northeastern portion of the Atlantic Forest, above the São Francisco River (Barbier & Bernard, 2017). Despite that, the state currently accounts for about 20% (22/111) of bat ectoparasitic fly species richness in Brazil (Barbier et al., 2018; Bezerra et al., 2016; Graciolli et al., 2007; Lourenço et al., 2016).

Except for *Trichobioides perspicillatus* and *Trichobius costalimai*, both found on *A. planirostris* and here considered as non-primary infestations, all other fly species were collected on only 1 bat species, indicating high host specificity. These results corroborate other studies on bat ectoparasitic flies (Barbier & Graciolli, 2016; Komeno & Linhares, 1999; Santos et al., 2013; Soares et al., 2013; ter Hofstede et al., 2004) and reinforce the knowledge about host-parasite relationships, especially in a poorly sampled Brazilian region.

It is quite likely that the richness of bat ectoparasitic flies in Paraíba is still underestimated, not only because this is the second research conducted in the state, but also because other northeastern nearby states present a greater species richness, including the neighbor Pernambuco (with 34 species; Barbier & Bernard, 2017). Additionally, of about 61 bat species occurring in the Paraíba state (Feijó & Langguth, 2011; Feijó et al., 2015; Leal et al., 2014; Nunes et al., 2013; Rocha et al., 2017; Vilar et al., 2015) only 14 species (~23%) were surveyed for ectoparasites (Barbier et al., 2016; present study). As more studies are conducted, including hosts not yet sampled in previous studies, the number of known fly species will most likely increase.

Our records expand the knowledge on bat ectoparasites in northeastern Brazil, where this group is still poorly

studied, despite advances in recent years (Barbier et al., 2016, 2017; Santos et al., 2013; Soares et al., 2013, 2016, 2017). It is likely that the diversity of environments/roosts sampled in this study (e.g., man-made constructions, coastal vegetation, mangroves) have favored the fly species richness recorded here. Studies have shown that bat ectoparasitic fly species richness is correlated with host species richness, and that the host-fly interaction may differ between environments (Barbier & Bernard, 2017; Dick & Gettinger, 2005; Zarazúa-Carbajal et al., 2016).

The possibility of capturing more host species and, consequently, more fly species, will be enhanced when more environments are sampled. However, even with increasing studies on bats in recent years, their ectoparasites have been neglected in most cases. Therefore, we strongly suggest that bat researchers consider collecting ectoparasites whenever possible. In addition, we recommend that future studies also focus on environments with transitional areas (e.g., Atlantic Forest-Caatinga ecotone), Caatinga moist forest enclaves (regionally called "Brejos de Altitude"), and caves. Together, these efforts can help increase our knowledge and fill gaps in the geographic distribution, species richness, and host association of these bat ectoparasites. Furthermore, the great ecological diversity of bats and the conspicuous relationship with ectoparasitic flies make both groups an important model for studies on coevolution, biology, and parasitic ecology, for example. For this, basic questions, such as where species occur, are essential and must be answered. In this sense, this study also represents an important step and can serve as a basis for further studies.

Acknowledgements

To the Environmental Military Police of Paraíba and the Center for Environmental Surveillance and Zoonoses of João Pessoa, for logistic support during fieldwork. We also wish to thank our colleagues from the Laboratory of Mammals of the Federal University of Paraíba for their help during fieldwork and the owners of the residences who allowed us to sample in their houses. To Luciana Iannuzzi (UFPE) for speeding up the deposit of the fly specimens in the collection under her curatorship and Aída Otálora-Ardila for reviewing the abstract in Spanish. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001, through grants awarded to E. B. and H. N., and a PNPD/CAPES fellowship to F. L. R and P. A. R. This studied was also funded by the Programa Pesquisa para o SUS, Edital 01/2013 - PPSUS/ FAPESQ/ MS/ CNPq (grant number EFP_00008705).

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