

# First records of ectoparasitic insects (Diptera: Hippoboscoidea) of bats in the department of Caldas, Colombia

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**Abstract.** In Colombia, the taxonomical understanding of ectoparasites (Diptera: Streblidae and Nycteribiidae) of bats is scarce, despite the high diversity of hosts. This fact reflects the lack of important information on the group and poses the need for studies that expand the knowledge on bat ectoparasites in different regions of the country. The aim of this study was to contribute pioneer knowledge on bat ectoparasitic insects in the department of Caldas, located in the Central Andes Mountain range of Colombia. We assessed 318 bats from four eco parks in the city of Manizales, and collected 234 ectoparasitic insects. We provide the first report of the family Streblidae for Caldas, with seven genera and eight species: *Anastrebla caudifera* Wenzel, 1976, *Anatrichobius scorzai* Wenzel, 1966, *Exastinion oculatum* Wenzel, 1976, *Megistopoda proxima* (Séguy, 1926), *Paratrichobius longicrus* Ribeiro, 1907, *Paraeuctenodes similis* Wenzel, 1976, *Trichobius longipes* Rudow, 1871, and *Trichobius tiptoni* Wenzel, 1976. In addition, we report the species *Basilina ferrisi* Schuurmans Stekhoven, 1931 and *Basilina* sp. for the family Nycteribiidae.

**Key-Words.** Insects; Ectoparasites; Bats; Caldas.

## INTRODUCTION

In the last two decades, the study of bat ectoparasites has shown important advances in South America (Autino & Claps, 2000; Graciolli & Carvalho, 2001; Presley, 2004; Graciolli *et al.*, 2007; Dick *et al.*, 2007; Autino *et al.*, 2009, 2011, among others).

Currently, seven orders and approximately 6,000 species of mammal ectoparasitic insects have been registered. Of these, four orders (with approximately 687 species) have been reported as bat ectoparasites (Marshall, 1981).

The South American countries with the most studies on ectoparasitic insects include Argentina (Autino *et al.*, 1999, 2009; Autino & Claps, 2000), Brazil (Graciolli & Carvalho, 2001; Santos *et al.*, 2009; Graciolli *et al.*, 2010; Almeida *et al.*, 2011), Venezuela (Wenzel, 1976; Guerrero, 1994a, b, 1995a, b), Bolivia (Dick *et al.*, 2007), Peru (Guerrero, 1996b; Claps *et al.*, 2005; Graciolli *et al.*,

2007; Autino *et al.*, 2011), and Paraguay (Presley, 2004; Dick & Gettinger, 2005). In South America, the most representative bat ectoparasitic insects are Streblidae and Nycteribiidae (Wenzel, 1970; Guerrero, 1993, 1994a, b, 1995a, b, 1996a, 1997; Autino & Claps, 2000; Dick & Gettinger, 2005; Dick, 2006; Graciolli *et al.*, 2007). Other insect groups that exclusively parasitize bats are Hemiptera (Polycetenidae and some species of Cimicidae) and Siphonaptera (Ischnopsyllidae), as well as *Hectopsylla (Rhynchopsyllus) pulex* (Haller, 1880) (Tungidae), *Craneopsylla m. minerva* (Rothschild, 1903) and *C. m. wolffhuegeli* (Rothschild, 1909) (Stephanocircidae) (Autino & Claps, 2000; Lareschi *et al.*, 2016).

In Colombia, three orders, five families, 21 genera, and 85 bat ectoparasitic insect species are known to date (Bequaert, 1940; Guerrero, 1997; Marinkelle & Grose, 1981; Tarquino-Carbonell *et al.*, 2015; Dick *et al.*, 2016; Graciolli *et al.*, 2016; Durán *et al.*, 2017). The study by Bequaert (1940)

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was the first effort to study bat ectoparasitic insects from different localities of Colombia and Panamá. Later on, Marinkelle & Grose (1981) published an extensive list on Colombian bat ectoparasites of the orders Diptera, Hemiptera, and Siphonaptera. Recently, Tarquino-Carbonell *et al.* (2015) conducted a study on ectoparasites of chiroptero fauna in the vereda Chorrillo, municipality of Ambalema, Tolima. Meanwhile, Durán *et al.* (2017) made the first report of Streblidae for the department of Sucre. Other contributions include the catalogues on Streblidae of the New World by Wenzel (1970) and Guerrero (1997), which include the species found in Colombia; in addition to the studies by Dick *et al.*, 2016 and Graciolli *et al.*, 2016 on Streblidae and Nycteribiidae species found in the country.

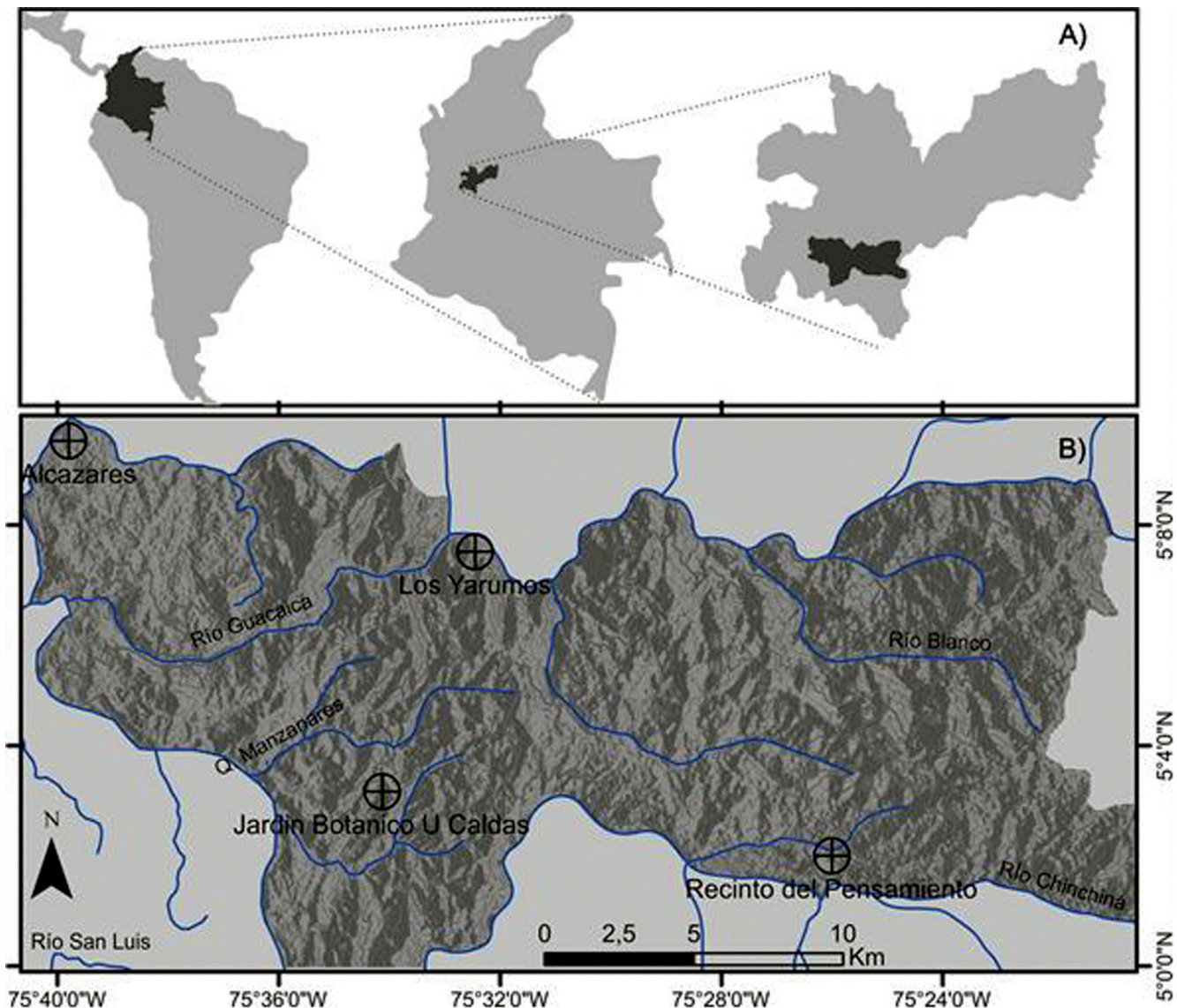
Despite the above, the information available for Colombia is scarce in comparison to other countries. Furthermore, there are no detailed studies on the taxonomy and/or composition of ectoparasitic species in several regions of the country. Considering the high

diversity of bats in Colombia, this study aims to contribute to the understanding of ectoparasitic insects (Streblidae and Nycteribiidae) and their hosts, including the first reports for the department of Caldas, by studying bats and their ectoparasites in eco parks in the region.

## MATERIAL AND METHODS

### Study area

Sampling was done in four eco parks of the municipality of Manizales, department of Caldas (Fig. 1). **Ecoparque Alcázares-Arenillo:** located in the southwestern region of the municipality of Manizales (05°04'N, 75°32'W), it has an extension of 70.55 Ha, altitude ranging between 1,730 m a.s.l. and 1,960 m a.s.l., and an average annual precipitation of 2,223 mm (Arango *et al.*, 2007). This area is inhabited by species such as: *Fraxinus chin-*



**Figure 1.** (A) Colombia, Caldas, Manizales. (B) Digital elevation model of Manizales, showing the eco parks network of the city: Alcázares-Arenillo, Los Yarumos, Jardín Botánico de la Universidad de Caldas, El Recinto del Pensamiento.

*ensis* Roxb, 1820, *Cecropia peltata* Linneo, 1758, *Salix* sp., *Dracaena draco* (Linneo, 1767), *Verbesina* sp., *Guadua angustifolia* Kunth, 1822, *Schefflera* sp. (Forst & Forst, 1775), *Eucalyptus* sp. (Héritier, 1789), *Cyathea* sp., and *Toxicodendron* sp., as well as species of Piperaceae and Moraceae. An area of particular interest in this eco park contains pastures and gardens with ornamental plants, such as *Musa paradisiaca* Linneo, 1753, *Solanum lycopersicum* Linneo, 1753, *Coffea arabica* Linneo, 1753, *Allium cepa* Linneo, 1753, and *Phaseolus* sp. (Arango et al., 2007).

**Jardín Botánico de la Universidad de Caldas:** Located in southeast Manizales (05°04'N, 75°31'W), it has an extension of 7 Ha, at 2,150 m a.s.l., with an average precipitation over 1,800 mm (Corpocaldas, 2002). It is forested predominantly with trees of the species *Quercus humboldtii* Bonpl., 1805, *Podocarpus oleifolius* D. Don, 1824, *Eucalyptus* sp., *Dendropanax* sp., and *Cecropia* sp. Other abundant plants include *Monstera deliciosa* Liebm, 1849 and *Asplenium* sp.

**Recinto del Pensamiento “Jaime Restrepo Mejía”:** A natural reserve in the Montane Region (IGAC, 1990), located in eastern Manizales in the industrial sector of Maltería (05°02'N, 75°26'W), it extends 176 Ha, all at 2,250 m a.s.l. The vegetation is predominantly *Podocarpus* sp. and *Alnus acuminata* Kunth, 1817, *Fraxinus chinensis*, *Guadua angustifolia*, *Piper* sp. and species of Moraceae in primary reforestation.

**Ecoparque Los Yarumos:** Located in northeastern Manizales (05°03'N, 75°28'W), at 2,153 m a.s.l., with an extension of 70.9 Ha (Arias, H. pers. comm. 2012). There are also 31.14 Ha in the process of secondary regeneration, following active intervention. This area was previously used for livestock farming, and was later destined for reforestation (Corpocaldas, 2002), with the inclusion of several species of *Cecropia* sp., *Alnus acuminata*, and *Smallanthus* sp.

### Material collection and identification

Sampling was conducted from May to November 2014. Six 12 m × 2.5 m mist nets were utilized for bat capturing; the nets were relocated nightly to cover the greatest possible area. In total, 2,304 net hours were obtained from the four sampled zones. Morphometric data were collected from the bats according to Barquez (1987), along with additional data including sex, reproductive status, developmental stage, temperature, and weight. Bat identification was done according to the keys by Linares (1986), Timm et al., (1999); Muñoz (2001); Mantilla-Meluk & Baker (2006); Gardner (2007); Zurc & Velazco (2010); Solari et al. (2013). Several bats were taxidermized, including at least one individual per species (voucher), and eventually deposited in the Colección de Mamíferos del Museo de Historia Natural de la Universidad de Caldas (MHN-UC). Species collection was registered under permit number 215, emitted June 19<sup>th</sup>, 2014 by the Corporación Autónoma Regional de Caldas (CORPOCALDAS).

Ectoparasites were collected from each live bat by screening the fur using a fine point tweezer and then ob-

served under a stereoscopic magnifying glass (Gracioli & Carvalho, 2001). The specimens were deposited in Eppendorf tubes with 70% alcohol and later photographed in the laboratory using a Leica MC170 camera coupled to a Leica M205 stereomicroscope. The ectoparasites were identified using the taxonomic keys by Guimarães (1946), Guimarães & D'Andretta (1956), Wenzel et al. (1966), Wenzel (1970, 1976), Guerrero (1995a, b), Autino et al. (1999), Gracioli & Carvalho (2001), and Dick & Miller (2010), among others, and the identifications were further confirmed by experts in the field.

Finally, the ectoparasites insects were deposited in the Colección Entomológica del Programa de Biología at the Universidad de Caldas (CEBUC) and the CMLA (Colección de Anexos de la Colección Mamíferos Lillo, de la Facultad de Ciencias Naturales e Instituto Miguel Lillo, Universidad Nacional de Tucumán, Argentina). Each Streblidae and Nycteribiidae specimen was catalogued by its corresponding number in the CMLA and deposited in the same collection.

### Data analysis

Parasitism was assessed by prevalence values (P), which indicate the proportion or number of infested host bats in a population compared to the total number of bats examined. Furthermore, we calculated the intensity of infestation (I), also called parasitic load, which is defined as the number of parasites that live in or on a host (Wisnivesky, 2003). Finally, we estimated the specificity index (SE), which corresponds to the percentage of parasitism specificity of each ectoparasitic species in relation to each host bat species (Dick & Gettinger, 2005): Specificity index (SI) = ((Abundance of X ectoparasitic species in each host species/Total abundance of the ectoparasitic species) (100)).

### RESULTS

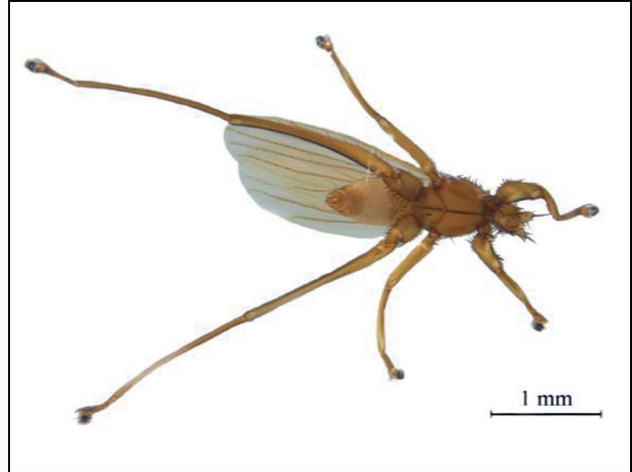
We collected a total of 234 ectoparasitic insects of the order Diptera (Hippoboscoidea), distributed in 10 species, eight genera, and two families (Table 1): Streblidae (91.2%) with eight species and Nycteribiidae (8.8%) with two. The most abundant species in the eco parks were *P. longicrus* (Fig. 2) (38.39%), *P. similis* (Fig. 3) (22.22%), *T. tiptoni* (Fig. 4) (8.12%), and *A. caudiferae* (Fig. 5) (8.12%) (all of these belong to Streblidae), while the remaining species showed relative abundances below 8.12% (Table 1). We identified the species *B. ferrisi* (2.56%), belonging to Nycteribiidae. We also collected male specimens of the genus *Basilia* Miranda-Ribeiro, 1903, but these could not be identified to the species level, since most available identification keys and the descriptions correspond to females.

Three hundred eighteen host bat specimens were captured (Table 2), of which 129 exhibited ectoparasites. We identified 20 bat species distributed in 13 genera and three families: Phyllostomidae (90.8%), Vespertilionidae

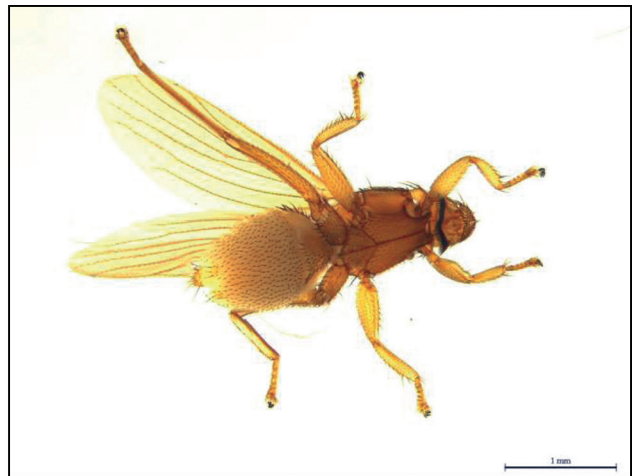
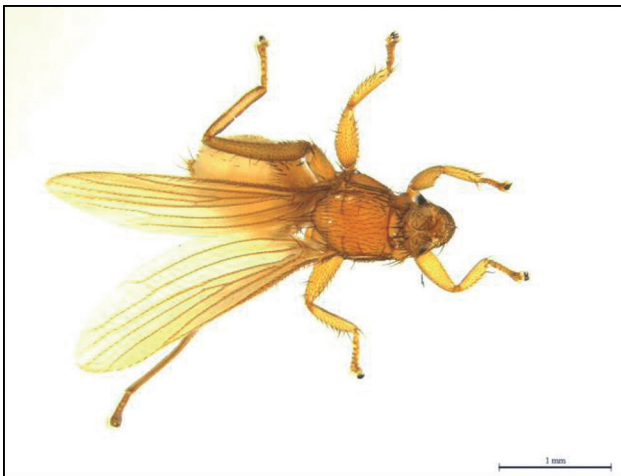
(8.8%), and Molossidae (0.4%). The dominant species were: *Artibeus lituratus* (Olfers, 1818) (38.4%), *Carollia brevicauda* (Schinz, 1821) (27%), *Dermanura bogotensis* (Andersen, 1906) (9.7%), and *Glossophaga soricina* (Pallas, 1776) (4.7%) (all belonging to Phyllostomidae). Of the total bats captured, six species were not parasitized: *Platyrrhinus dorsalis* (Thomas, 1900) (Phyllostomidae), *Eptesicus brasiliensis* (Desmarest, 1819), *Eptesicus chiriqui-*

*nus* Thomas, 1920, *Eptesicus fuscus* (Beauvois, 1796), *Myotis riparius* Handley, 1960 (Vespertilionidae), and *Molossus molossus* (Pallas, 1776) (Molossidae).

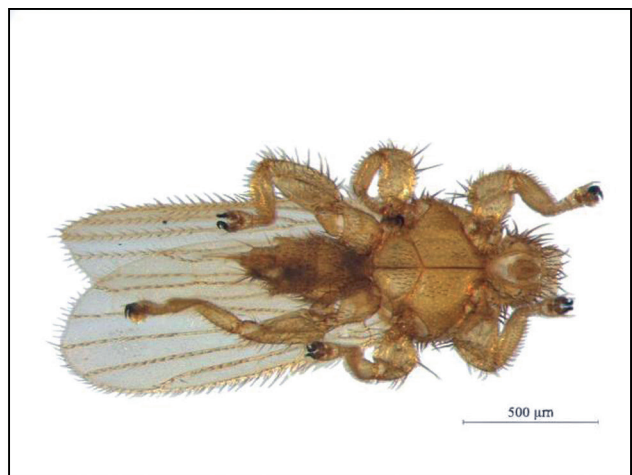
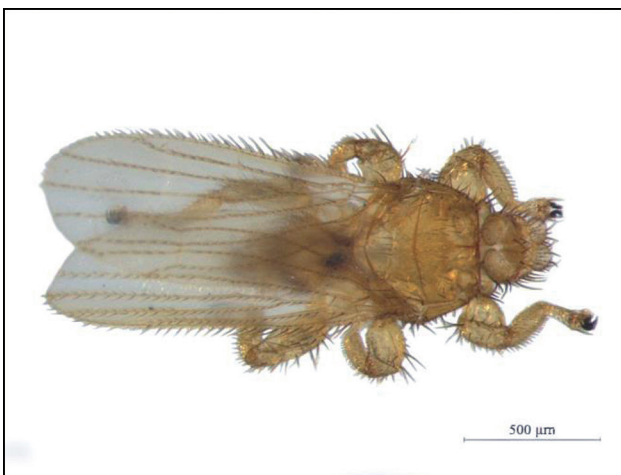
The family Phyllostomidae was the most parasitized, specifically, by eight species of Streblidae; while the family Vespertilionidae was parasitized by three species, one belonging to Streblidae (*A. scorzai*) and two to Nycteribiidae (*B. ferrisi* and *Basilia* sp.). We found that 82%



**Figure 2.** Dorsal and ventral macroscopic view of *Paratrichobius longicus* (Diptera, Streblidae) (CEBUC Dip. Streblidae C-Dip0140) on *Artibeus lituratus*.



**Figure 3.** Dorsal and ventral macroscopic view of *Paraeuctenodes similis* (Diptera, Streblidae) (CEBUC Dip. Streblidae C-Dip0145) on *Carollia brevicauda*.



**Figure 4.** Dorsal and ventral macroscopic view of *Trichobius tiptoni* (Diptera, Streblidae) (CEBUC Dip. Streblidae C-Dip0142) on *Carollia brevicauda*.

**Table 1.** Ectoparasitic insects species of Streblidae and Nycteribiidae (Diptera) and their host bats, with relative abundance (RA) and specificity index (SI). The specificity behavior to the host is also shown (HS): M: monoxene (found on only one host species); O: oligoxene (found on different bat hosts species, but of the same genus); PI: pleioxene (found on different species and genera of host bats, but of the same family); Po: polyxene (found on different species and genera of host bats, and different families).

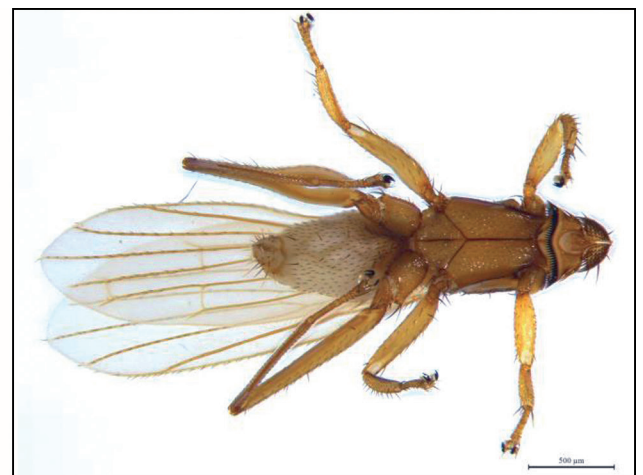
Diptera (n)	RA (%)	Chiroptera (n)	SI	HS		
<b>Streblidae</b>						
<i>Anastrebla caudiferae</i>	(1)	<i>Anoura caudifer</i>	(1)	5.26	PI	
	(9)	<i>Carollia brevicauda</i>	(2)	47.37		
	(1)	<i>Enchisthenes hartii</i>	(1)	5.26		
	(8)	<i>Glossophaga soricina</i>	(2)	42.11		
<i>Anatrichobius scorzai</i>	(1)	<i>Myotis oxyotus</i>	(1)	50.00	O	
	(1)	<i>Myotis nigricans</i>	(1)	50.00		
<i>Exastinion oculatum</i>	(12)	<i>Carollia brevicauda</i>	(3)	75.00	PI	
	(4)	<i>Glossophaga soricina</i>	(1)	25.00		
<i>Megistopoda proxima</i>	(5)	<i>Sturnira ludovici</i>	(3)	100.0	M	
<i>Paraeuctenodes similis</i>	(49)	<i>Carollia brevicauda</i>	(30)	94.23	PI	
	(1)	<i>Dermanura bogotensis</i>	(1)	1.92		
	(2)	<i>Glossophaga soricina</i>	(2)	3.85		
<i>Paratrachobius longicrus</i>	(65)	<i>Artibeus lituratus</i>	(33)	71.43	PI	
	(2)	<i>Carollia brevicauda</i>	(2)	2.20		
	(9)	<i>Dermanura bogotensis</i>	(7)	9.89		
	(5)	<i>Enchisthenes hartii</i>	(3)	5.49		
	(7)	<i>Platyrrhinus helleri</i>	(2)	7.69		
	(3)	<i>Platyrrhinus vittatus</i>	(3)	3.30		
	(6)	<i>Artibeus lituratus</i>	(6)	66.67		
<i>Trichobius longipes</i>	(2)	<i>Carollia brevicauda</i>	(1)	22.22	PI	
	(1)	<i>Sturnira ludovici</i>	(1)	11.11		
	(1)	<i>Artibeus lituratus</i>	(1)	5.26		
<i>Trichobius tiptoni</i>	(13)	<i>Carollia brevicauda</i>	(9)	68.42	PI	
	(2)	<i>Dermanura bogotensis</i>	(1)	10.53		
	(3)	<i>Glossophaga soricina</i>	(2)	15.79		
	(1)	<i>Carollia brevicauda</i>	(1)	6.67		Po
	(9)	<i>Histiotes montanus</i>	(3)	60.00		
(2)	<i>Myotis nigricans</i>	(1)	13.33			
(3)	<i>Myotis keaysi</i>	(2)	20.00			
<i>Basilisa sp.</i>	(2)	<i>Glossophaga soricina</i>	(1)	33.33	Po	
	(2)	<i>Myotis keaysi</i>	(1)	33.33		
	(2)	<i>Myotis oxyotus</i>	(1)	33.33		

**Table 2.** Bat host species and number of captured specimens with their relative abundance (RA).

Bat species	Total	RA%
<b>Phyllostomidae</b>		
<i>Stenodermatinae</i>		
<i>Artibeus lituratus</i>	122	38.4
<i>Dermanura bogotensis</i>	31	9.7
<i>Enchisthenes hartii</i>	10	3.1
<i>Platyrrhinus helleri</i>	5	1.3
<i>Platyrrhinus vittatus</i>	5	1.9
<i>Platyrrhinus dorsalis</i>	1	0.3
<i>Sturnira ludovici</i>	10	3.1
<i>Vampyressa thyoene</i>	1	0.3
<i>Carollinae</i>		
<i>Carollia brevicauda</i>	86	27
<i>Glossophaginae</i>		
<i>Anoura caudifer</i>	3	0.9
<i>Glossophaga soricina</i>	15	4.7
<i>Vespertilionidae</i>		
<i>Myotinae</i>		
<i>Eptesicus fuscus</i>	4	1.3
<i>Eptesicus chiriquinus</i>	2	0.6
<i>Eptesicus brasiliensis</i>	1	0.3
<i>Histiotes montanus</i>	8	2.5
<i>Myotis nigricans</i>	3	0.9
<i>Myotis keaysi</i>	5	1.6
<i>Myotis oxyotus</i>	3	0.9
<i>Myotis riparius</i>	2	0.6
<i>Molossidae</i>		
<i>Molossinae</i>		
<i>Molossus molossus</i>	1	0.3
<b>Total</b>	<b>318</b>	<b>1</b>

of specimens were collected from Phyllostomidae, while the remaining 12% were extracted from Vespertilionidae.

The hosts with the highest number of ectoparasites were: *C. brevicauda* (n 79), *A. lituratus* (n 67), *G. soricina* (n 17), and *D. bogotensis* (n 12). We captured eight host species that were parasitized by more than one ectoparasitic species: *C. brevicauda* (6 species of Streblidae and 1 sp. of Nycteribiidae); *G. soricina* (4 spp. of Streblidae, and 1 sp. of Nycteribiidae); *A. lituratus* and *D. bogoten-*



**Figure 5.** Dorsal and ventral macroscopic view of *Anastrebla caudiferae* (Diptera, Streblidae) (CEBUC Dip. Streblidae C-Dip0138) ectoparasite of *Anoura caudifer*.

**Table 3.** Bat species with their corresponding Streblidae and Nycteribiidae ectoparasitic species and number (N) of ectoparasites per host.

Bat species	Streblidae	N	Nycteribiidae	N
Phyllostomidae				
Stenodermatinae				
<i>Artibeus lituratus</i>	<i>P. longicrus</i>	65		
	<i>T. longipes</i>	1		
	<i>T. tiptoni</i>	1		
<i>Dermanura bogotensis</i>	<i>P. longicrus</i>	9		
	<i>T. tiptoni</i>	2		
	<i>P. similis</i>	1		
<i>Enchisthenes hartii</i>	<i>A. caudiferae</i>	1		
	<i>P. longicrus</i>	5		
<i>Platyrrhinus helleri</i>	<i>P. longicrus</i>	7		
<i>Platyrrhinus vittatus</i>	<i>P. longicrus</i>	3		
<i>Platyrrhinus dorsalis</i>	Not parasitized	0		
<i>Sturnira ludovici</i>	<i>M. proxima</i>	5		
	<i>T. longipes</i>	1		
<i>Vampyressa thylene</i>	Not parasitized	0		
Carollinae				
<i>Carollia brevicauda</i>	<i>A. caudiferae</i>	9	<i>B. ferrisi</i>	1
	<i>E. oculatum</i>	12		
	<i>P. similis</i>	49		
	<i>P. longicrus</i>	2		
	<i>T. longipes</i>	2		
	<i>T. tiptoni</i>	13		
Glossophaginae				
<i>Anoura caudifer</i>	<i>A. caudiferae</i>	1		
<i>Glossophaga soricina</i>	<i>A. caudiferae</i>	8	<i>Basilia</i> sp.	2
	<i>E. oculatum</i>	4		
	<i>P. similis</i>	2		
	<i>T. tiptoni</i>	3		
Vespertilionidae				
Myotinae				
<i>Eptesicus fuscus</i>	Not parasitized	0		
<i>Eptesicus chiroquinus</i>	Not parasitized	0		
<i>Eptesicus brasiliensis</i>	Not parasitized	0		
<i>Histiotus montanus</i>			<i>B. ferrisi</i>	9
<i>Myotis nigricans</i>	<i>A. scorzai</i>	1	<i>B. ferrisi</i>	2
<i>Myotis keaysi</i>			<i>B. ferrisi</i>	3
			<i>Basilia</i> sp.	2
<i>Myotis oxyotus</i>	<i>A. scorzai</i>	1	<i>Basilia</i> sp.	1
<i>Myotis riparius</i>	Not parasitized	0		
Molossidae				
Molossinae				
<i>Molossus molossus</i>	Not parasitized	0		

*sis* (3 spp. of Streblidae); *Enchisthenes hartii* Thomas, 1892 and *Sturnira ludovici* (2 spp. of Streblidae); *Myotis nigricans* Schinz, 1821 (1 sp. of Streblidae and 1 sp. of Nycteribiidae); *Myotis keaysi* J.A. Allen, 1914 (2 spp. of Nycteribiidae). The remaining hosts showed parasitism by only one species of Nycteribiidae or Streblidae, or were not parasitized (Table 3).

Bat parasitism prevalences and intensities in the four ecological parks show the highest prevalence for Los Alcázares eco park and highest intensity for El Recinto del Pensamiento (Table 4).

Among the infested bat species, we found that *Myotis oxyotus* Peters, 1867, and *M. nigricans* showed the highest prevalence with 66.66%, followed by *C. brevicauda* 51.16%, *E. hartii* and *G. soricina* 40%. Meanwhile, *P. helleri* showed the highest intensity with 87.5% (Table 5).

**Table 4.** Percentages of bat parasitism intensities and prevalences in each ecological park in Manizales: Jardín botánico Universidad de Caldas (JB), Ecoparque los Yarumos, (EY), Ecoparque los Alcázares (EA) and Ecoparque Recinto del Pensamiento (RP).

Eco park	% Prevalence	% Intensity
JB	27.7	2.0
EY	37.9	2.1
EA	40.6	2.0
RP	35.7	6.5

**Table 5.** Percentages of ectoparasitic insect intensities and prevalences for each bat species in the ecological parks in Manizales.

Hosts (n infested – n total)	% Prevalence	Intensity
<i>Anoura caudiferae</i> (1 – 3)	33.3	0.333
<i>Artibeus lituratus</i> (36 – 122)	29	0.016
<i>Carollia brevicauda</i> (44 – 86)	50	0.023
<i>Dermanura bogotensis</i> (8 – 31)	25.8	0.048
<i>Enchisthenes hartii</i> (4 – 10)	40	0.15
<i>Glossophaga soricina</i> (6 – 15)	40	0.21
<i>Histiotus montanus</i> (3 – 8)	37.5	0.37
<i>Myotis keaysi</i> (2 – 5)	40	0.50
<i>Myotis nigricans</i> (2 – 3)	66.6	0.50
<i>Myotis oxyotus</i> (2 – 3)	66.6	0.50
<i>Myotis riparius</i> (2 – 3)	66.6	0.50
<i>Platyrrhinus helleri</i> (2 – 4)	50	0.85
<i>Platyrrhinus vittatus</i> (3 – 6)	50	0.16
<i>Sturnira</i> sp. (3 – 10)	30	0.20

## DISCUSSION

This study of ectoparasitic insects in bats of Caldas (Colombia) allows us to expand the understanding of the relations between ectoparasitic insects and their hosts. We found that the distribution and specificity of the ectoparasite is associated with the presence or absence of a given host species, and that the intensity and prevalence of insect parasitism in bats can vary according to the host species. For Colombia, there are reports of 19 genera and 73 species of Streblidae parasitizing Emballonuridae, Furipteridae, Molossidae, Mormoopidae, Natalidae, Noctilionidae, Phyllostomidae, and Vespertilionidae (Dick *et al.*, 2016); and two genera and eight species of Nycteribiidae for Vespertilionidae, Phyllostomidae, and Thyropteridae (Gracioli *et al.*, 2016). The 10 ectoparasitic species found in this study comprise 14% of the total species reported for the country and they represent the first records of Streblidae and Nycteribiidae (Diptera) for the department of Caldas.

Regarding Streblidae ectoparasites, *A. caudiferae* has been reported in Argentina, Bolivia, Brazil, Venezuela, and Colombia (Caldas in this study, Cauca, Cundinamarca, Huila, Nariño) (Bequaert, 1940; Wenzel, 1970; Guerrero, 1997; Gracioli & Carvalho, 2001; Autino *et al.*, 2009; Bertola *et al.*, 2005; Dick *et al.*, 2016). This species is associated with Phyllostomidae hosts in its area of distribution, including *Anoura caudifer* E. Geoffroy Saint-Hilaire, 1818, as its primary host, and additionally *Anoura geof-*

*froyi* Gray, 1838, *A. lituratus*, and *G. soricina* (Bertola et al., 2005). Here we also report *C. brevicauda* and *E. hartii* as accidental hosts. The species shows a pleioxene behavior throughout all its distribution area in Caldas.

*Anatrichobius scorzai* has been reported in Argentina, Bolivia, Brazil, Colombia (Caldas in this study, Huila), Costa Rica, Ecuador, Honduras, Panama, Peru, and Venezuela (Marinkelle & Grose, 1981; Guerrero, 1997; Autino & Claps, 2000; Graciolli, 2003; Autino et al., 2009; Dick et al., 2016). Hosts for this species mainly belong to the genus *Myotis* (*Myotis albescens* E. Geoffroy Saint-Hilaire, 1806, *M. keaysi*, *M. nigricans*, *Myotis oxyotus*) (Guerrero, 1997; Autino et al., 2009), although it has also been found on *Lonchophylla robusta* Miller, 1912 (Phyllostomidae), which might correspond to an accidental infestation, considering its preference for Vespertilionidae hosts.

*Exastinion oculatum* has a more restricted distribution, which includes Colombia (Caldas in this study, Huila) and Panama (Wenzel, 1976; Guerrero, 1997; Dick et al., 2016). This species prefers hosts of the genus *Anoura*, specifically *Anoura cultrata* Handley, 1960 and *A. geoffroyi* (Guerrero, 1997; Dick et al., 2016). In this study, we report the species parasitizing *C. brevicauda* and *G. soricina*, potentially accidental hosts, a finding that broadens the range of known hosts for the species. It displays a pleioxene behavior in Caldas, since it expands hosts. In the rest of its distribution, however, it exhibits an oligoxene behavior.

*Megistopoda proxima* has a wide distribution that spans several countries, from Mexico in the north to Argentina in the south of the continent. In Colombia, it has been reported in the departments of Huila, Nariño, Putumayo, Santander, Sucre, Tolima, and Valle del Cauca (Tarquino-Carbonell, et al., 2015; Dick et al., 2016; Durán et al., 2017) and is herein reported in Caldas. It has various hosts, mainly Phyllostomidae (Marinkelle & Grose, 1981; Guerrero, 1997; Autino et al., 1999, 2009, 2011; Graciolli & Carvalho, 2001; Tarquino-Carbonell et al., 2015; Dick et al., 2016; Durán et al., 2017), although it was also found on *Noctilio leporinus* Linnaeus, 1758 (Noctilionidae). This species behavior is polyxene in its distribution area, yet in Caldas, it was only found on *S. ludovici*.

*Paraeuctenodes similis* has been reported in Bolivia, Brazil, Colombia (Caldas in this study, Huila, and Santander), Costa Rica, Ecuador, Peru, and Venezuela (Wenzel, 1976; Guerrero, 1996b, 1997; Graciolli & Carvalho, 2001; Dick et al., 2016). Its hosts include *C. brevicauda*, *C. perspicillata*, *Trachops cirrhosus* Spix, 1823, *Sturnira lilium* E. Geoffroy, 1810 (Guerrero, 1996a; Graciolli & Carvalho, 2001; Bertola et al., 2005). In this study, we extend the range of hosts to include *D. bogotensis* and *G. soricina*, which would be accidental hosts. The species has the same pleioxene behavior throughout its entire distribution.

*Paratrichobius longicrus* is a complex of species that parasitizes bats of the genera *Artibeus* and *Platyrrhinus* Saussure, 1860 (Wenzel et al., 1966). It is widely distributed in several countries, from Mexico in the north to Argentina in the south of the continent. In Colombia, it has been found in the departments of Antioquia,

Meta, Tolima, Valle del Cauca, and Caldas in this study. The species has a wide range of hosts, mainly of the family Phyllostomidae, although *Molossops planirostris* Peters, 1865 and *Molossops temminckii* Burmeister, 1854 (Molossidae) have also been reported (Graciolli & Carvalho, 2001). Here, we report *C. brevicauda*, *D. bogotensis*, and *Platyrrhinus helleri* Peters, 1866 as hosts of *P. longicrus*. This species displays a polyxene behavior in its area of distribution, although, in Caldas, it is pleioxene.

*Trichobius longipes* is also a widely distributed species, from Guatemala in the north to Bolivia in the south. In Colombia, it has been reported in the departments of Antioquia, Huila, Magdalena, Meta, Norte de Santander, Sucre, Tolima, Valle del Cauca (Guerrero, 1997; Graciolli & Carvalho, 2001; Tarquino-Carbonell et al., 2015; Dick et al., 2016; Durán et al., 2017), and Caldas in this study. It has several hosts of the family Phyllostomidae, in addition to *Rhynchonycteris nasso* Wied-Neuwied, 1820 (Emballonuridae), *N. leporinus* (Noctilionidae), *Molossus ater* (Molossidae) (Graciolli & Carvalho, 2001). In this study, we include *A. lituratus*, *C. brevicauda*, and *S. ludovici* as further hosts. This species is clearly polyxene in its distribution area, however, in Caldas its behavior is pleioxene.

*Trichobius tiptoni* is distributed in Bolivia, Brazil, Colombia (Nariño and Caldas in this study), French Guiana, and Venezuela (Guerrero, 1997; Graciolli & Carvalho, 2001; Dick et al., 2007, 2016). Its hosts include *A. caudifer*, *Chrotopterus auritus* Peters, 1856, *C. perspicillata*, *P. helleri*, *S. lilium*, and *S. ludovici*. Herein, we also report *A. lituratus*, *C. brevicauda*, *D. bogotensis*, and *G. soricina*. This species' behavior in Caldas is pleioxene, a finding that matches the rest of its distribution area and it is always found on hosts of the family Phyllostomidae.

For the Nycteribiidae family, we report ectoparasites of the species *B. ferrisi*. The species was reported in Brazil, Colombia (Antioquia, Bolívar, Caldas in this study, Chocó, Meta, Santander), Costa Rica, Guatemala, Guiana, Panama, Peru, and Venezuela (Graciolli et al., 2007, 2016). Its range of hosts includes *Desmodus rotundus* E. Geoffroy, 1810, *L. robusta*, *Uroderma bilobatum* Peters, 1866 (Phyllostomidae), *Dasypterus* sp., *Myotis albescens*, *M. keaysi*, *M. nigricans*, *M. oxyotus*, *M. riparius*, *M. simus* Thomas, 1901 (Vespertilionidae), *M. molossus* (Molossidae) (Guerrero, 1997; Graciolli et al., 2007). Furthermore, in this study, we include *Histiotus montanus* Philippi & Landbeck, 1861. The species clearly exhibits a polyxene behavior in its distribution area; although, in Caldas, it is oligoxene.

Our findings showed that, in Caldas, each species behavior varies in terms of its hosts, which is likely due to a smaller sample area compared to the extensive distribution of each ectoparasite. As for the hosts, the family Phyllostomidae showed the highest species richness and abundance (11 spp.), encompassing 24% of the reported species for Caldas (48 spp.) (Castaño, 2012). This is followed by Vespertilionidae with eight species (61%) out of 13 species reported for Caldas and Molossidae with one species (20%) out of five reported for the department (Castaño, 2012). The forests in Caldas have un-

dergone transformations from anthropic intervention and expansion of the agricultural frontier, among other causes, that affect the biodiversity of host bats and mammals in general (Castaño, 2012). This study on Streblidae and Nycteribiidae ectoparasites and their hosts in Caldas (Manizales) contributes a basis for future studies in other departments of Colombia that have not yet been sampled. Our study documents the enrichment of the diversity of host and ectoparasitic fauna in the country, in an ever-changing landscape.

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