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Ectoparasitic flies (Diptera, Streblidae) on bats (Mammalia, Chiroptera) in a dry tropical forest in the northern Colombia

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ABSTRACT

This work represents the first report of host-parasite associations between flies of the family Streblidae and their host bats in the Colombian Caribbean region. Specimens were collected in a dry tropical forest in the Sucre department. A total of 17 species (eight genera) of Streblidae, as well as 19 species from five bat families were recorded. Strebla mirabilis, Trichobius costalimai, Trichobius parasiticus *and* Paradyschiria parvuloides *were the most abundant ectoparasites. Prevalence of ectoparasites on bat assemblage was 48.57%. In nine bat species, more than one Streblidae species were recorded.* Trichobius costalimai *had the greatest number of host species. We have found remarkable new associations between* Artibeus planirostris *and* Trichobius costalimai, Lophostoma silvicolum *and* Strebla mirabilis, *as well as* Lophostoma silvicolum *and* Trichobius parasiticus.

Key-Words: Colombia; Host; Parasitism; Phyllostomidae.

INTRODUCTION

Streblidae Kolenati, 1863 is a family of blood-sucking flies specialized in ectoparasitism of bats. Like all Hippoboscoidea, fertilization and embryonic period occur inside females, and three instars larvae develop through nourishment by intrauterine glands. Gravid female flies leave the host, looking for a suitable substrate at the refuge sites and deposit a single 3rd instar larva that is ready to pupate, a phenomenon known as adenotrophic viviparity (Dick & Dittmar, 2014).

Streblid flies are distributed in all biogeographic regions, with a greater diversity in the Americas (Guerrero, 1993). Currently it is divided into five subfamilies: Nycteriboscinae, Ascodipterinae, Trichobiinae, Streblinae, and Nycterophiliinae, the last three being found in the New World and are comprised of 26 genera and 158 species (Dick *et al.,* 2016). Nineteen genera and 73 species are currently known from

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Colombia, whose hosts are member of the following bat families: Emballonuridae, Furipteridae, Molossidae, Mormoopidae, Natalidae, Noctilionidae, Phyllostomidae, and Vespertilionidae (Dick *et al.,* 2016); however, knowledge about the host-parasite relationship among ectoparasitic flies and bats is still incipient in this country. Due to this, the present study aimed at studying the association of Streblidae with bat species in a dry tropical forest relict in northern Colombia.

MATERIAL AND METHODS

Study area

The study was carried out at the Reserva Forestal Protectora Serranía de Coraza, in the department of Sucre, Colombia (09°31'58.02"N; 75°20'59.85"W) (Figure 1). This zone corresponds to a dry tropical forest relict (Holdridge, 1979), the climate is warm, with average temperatures of 26.8°C and relative humidity of 77%. The average annual rainfall is between 1,000 and 1,200 mm (Aguilera, 2005). A detailed description of the vegetation may be consulted in Cuervo *et al.* (1986).

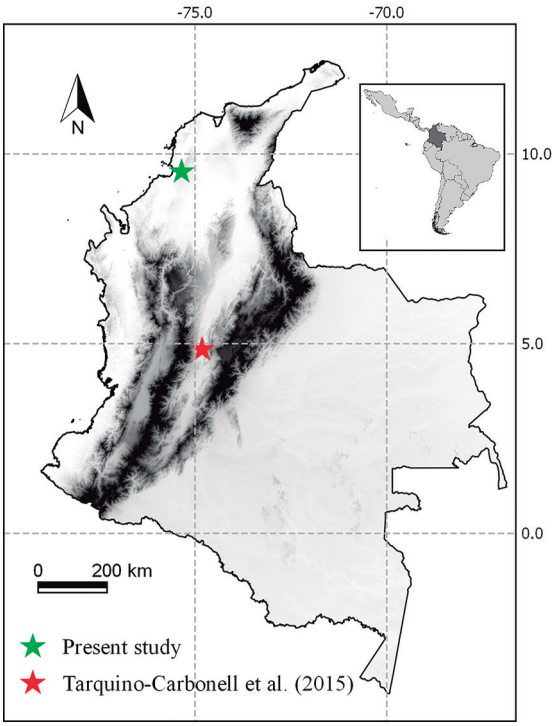

FIGURE 1: Study sites of host-ectoparasite relationship between Streblidae and bats in Colombia. Darker areas correspond to higher altitudes.

Captures of hosts and bat flies

Sampling was carried out between June 2013 and March 2014. Four mist nets (6 × 2.5 m each) were set up, at ground level, from 6 to 12 pm. Bats were sexed and identified based on Linares (2000) and Muñoz (2001). Bat flies were removed with entomological tweezers and conserved in 70% ethanol. All samples were labeled with host information, collection site, and date. Streblidae specimens collected were identified following taxonomic keys published by Guerrero (1993), Guerrero (1994a, b), Guerrero (1995a, b) and Guerrero (1996). Diptera material was deposited at the Coleção Zoológica de Referência da Universidade Federal de Mato Grosso do Sul (ZUFMS), Campo Grande (Brasil) and at the Entomology Laboratory of the Sucre University (LEUS), in Sincelejo (Colombia).

Data analysis

To evaluate the associations of ectoparasites among different hosts, we used the following indices (Bush *et al.,* 1997): Prevalence (P = number of infested hosts divided by number of examined hosts, multiplied by 100), and Mean Intensity (MI = number of ectoparasites of a particular parasite species divided by the infected members of a particular host species). The indices were calculated using Quantitative Parasitology 3.0 software (Rózsa *et al.,* 2000). We also calculated the Specificity Index (SI = percentage of all individuals of an ectoparasite species found on a host) (Dick & Gettinger, 2005). The difference in the sex ratio in Streblidae species was evaluated by Exact Binomial Test (McDonald, 2008).

Primary associations were determined when a host species had 5% or more of the individuals of a given parasite species (Dick, 2007), as well as considering high prevalence and mean intensity, and the literature data; while accidental or transitory associations in which a host was associated with less than 5% of the total individuals of a parasite species, in rare cases, and/or low prevalence and mean intensity (Dick, 2007; Santos *et al.,* 2009).

RESULTS

A total of 300 bat flies belonging to 17 species and eight genera of Streblidae were collected. The most abundant species was *Strebla mirabilis* (Waterhouse, 1879) (24.33%), followed by *Trichobius cos-*

TABLE 1: List of species, abundance and sex ratio of Streblidae on bats in a dry tropical forest in the Colombian Caribbean region.

Species	Abundance	Male/Female (♂:♀)
Aspidoptera phyllostomatis[a]	7 (2.3%)	4/3 (1:0.8)
Mastoptera minuta[a]	2 (0.7%)	1/1 (1:1)
Megistopoda aranea[a,b]	11 (3.7%)	7/4 (1:0.6)
Megistopoda proxima[a,b]	1 (0.3%)	1/0 (1:0)
Paradyschiria parvuloides[a]	39 (13.0%)	21/18 (1:0.9)
Speiseria ambigua[a]	1 (0.3%)	1/0 (1:0)
Strebla alvarezi[a,b]	1 (0.3%)	0/1 (0:1)
Strebla hertigi[a,b]	2 (0.7%)	0/2 (0:1)
Strebla kohlsi[a,b]	1 (0.3%)	0/1 (0:1)
Strebla mirabilis	73 (24.3%)	31/42 (0.7:1)
Strebla wiedemannii	20 (6.7%)	9/11 (0.8:1)
Trichobioides perspicillatus[a]	22 (7.3%)	16/6 (1:0.4)
Trichobius costalimai[a]	55 (18.3%)	33/22 (1:0.7)
Trichobius dugesii[a]	1 (0.3%)	1/0 (1:0)
Trichobius joblingi	16 (5.3%)	11/5 (1:0.5)
Trichobius longipes[a]	1 (0.3%)	1/0 (1:0)
Trichobius parasiticus	47 (15.7%)	31/16 (1:0.5)*

[a]: New record for the Sucre department; [b]: New record for the Colombian Caribbean region; *: Significant statistical difference (p = 0.04, 95% confidence interval = 0.50-0.80).

talimai Guimarães, 1938 (18.33%), *Trichobius parasiticus* Gervais, 1844 (15.67%) and *Paradyschiria parvuloides* Wenzel, 1966 (13%), while the other species had relative abundances below 8% (Table 1). Male number (n = 168; 56%) was higher than female (n = 132; 44%), with a male-biased sex ratio in 11 species, although with a significant difference only in *T. parasiticus* (Table 1).

Nineteen species were represented in 105 bats captured, of the following families: Phyllostomidae (15 spp.), Noctilionidae (1 sp.), Molossidae (1 sp.), Emballunuridae (1 sp.) and Mormoopidae (1 sp.). The 80% of specimens were collected from the first family, while the remaining 20% belonged to the other four. The most abundant host species was *Glyphonycteris daviesi* (Hill, 1964) (14.29%), followed by *Desmodus rotundus* (E. Geoffroy, 1810) (10.48%), *Lonchophylla concava* Goldman (1914) (10.48%), *Noctilio albiventris* Desmarest, 1818 (10.48%), *Artibeus lituratus* (Olfers, 1818) (9.52%), *Artibeus planirostris* (Spix, 1823) (8.57%), *Molossus molossus* (Pallas, 1766) (7.62%) and *Phyllostomus discolor* Wagner, 1843 (6.67%), the remaining represented 21.89% of the total (Table 2).

Ectoparasites prevalence in bat assemblage was 48.57%, while that in the species ranged of 0% to 100%. Four species of bats were not parasitized: *Pteronotus parnellii* (Gray, 1843), *Saccopteryx bilineata* (Temminck, 1838), *Micronycteris megalotis* (Gray, 1843) and *M. molossus.* Nine bat species were found with more than one Streblidae, *D. rotundus* and *A. planirostris* had the greatest ectoparasites richness (seven species each), followed by *Lophostoma silvicolum* d'Orbigny, 1836 (6 spp.), *Platyrrhinus helleri* (Peters, 1866) and *G. daviesi* (5 spp.), *A. lituratus* (4 spp.), *P. discolor* (3 spp.), and *Trinycteris nicefori* Sanborn, 1949 and *N. albiventris* (2 spp.) (Table 2).

Streblidae with greatest number of host species were: *T. costalimai* associated with 6 spp. of bats, followed by *S. mirabilis, T. perspicillatus* and *T. joblingi* (associated with 5 spp.), *T. parasiticus* and *Strebla wiedemannii* Kolenati, 1856 (associated with 4 spp.). While, *Megistopoda aranea* (Coquillet, 1899) and *Aspidoptera phyllostomatis* (Perty, 1833) were associated with 3 spp., *Strebla hertigi* Wenzel, 1966, *Mastoptera minuta* (Costa-Lima, 1921) and *P. parvuloides* were found on 2 spp. Only one specimen was collected of *Strebla alvarezi,* Wenzel, 1966, *Strebla kohlsi* Wenzel, 1966, *Trichobius dugesii* Townsend 1891, *Trichobius longipes* (Rudow, 1767), *Megistopoda proxima* (Séguy, 1926) and *Speiseria ambigua* Kessel, 1925, only these bat flies were found on just a single host species (Table 2). Also, three new host-parasite associations were found: *Artibeus planirostris-Trichobius costalimai, Lophostoma silvicolum-Strebla mirabilis* and *Lophostoma silvicolum-Trichobius parasiticus.*

DISCUSSION

Streblidae species found in this study (17 spp.) correspond to 23.28% of the total species recorded in Colombia (73 spp.) (Dick *et al.,* 2016). The department of Sucre has previously reported nine species, five of which were not found in this work: *Nycterophilia parnelli* Wenzel, 1966, *Strebla altmani* Wenzel, 1966, *Mastoptera guimaraesi* Wenzel, 1966, *Trichobius galei* Wenzel, 1966 and *Trichobius caecus* Edwards, 1918 (Dick *et al.,* 2016). The richness of Streblidae in the department of Sucre is extended to 22, with 13 new records. The species *M. aranea, M. proxima, S. alvarezi, S. hertigi, S. kohlsi* and *T. dugesii* are new records for the Colombian Caribbean, with current total of 33 species for this region (Dick *et al.,* 2016).

The higher male abundance of Streblidae found in this study is consistent with that reported by other authors (Fritz, 1983; Dick & Patterson, 2008; Autino *et al.,* 2011). According to Wenzel (1976), this difference can be caused by the collecting method, since male flies are more active and more easily detected on host bodies than females. On the other hand, Fritz (1983) suggested that females leave the host during the first hours of the night for larviposition, so bats

TABLE 2: Associations between bats and Streblidae in a dry tropical forest in the Colombian Caribbean region.

Host (Nb)	Nib	P	Ectoparasite (Ne)	Nib	P (95% CI)	MI (95% CI)	SI
Artibeus lituratus (10)	4	40	*Aspidoptera phyllostomatis* (2)	2	20 (2.5-55.1)	1[c]	29
			Megistopoda aranea (5)	2	20 (2.5-55.6)	2.5 (1.0-2.5)	46
			Trichobius costalimai (4)[a]	1	10 (0.3-44.5)	4[c]	7
			Trichobioides perspicillatus (4)[a]	1	10 (0.3-44.5)	4[c]	18
Artibeus planirostris (9)	6	66.7	*Aspidoptera phyllostomatis* (3)	1	11.1 (0.3-48.3)	3[c]	43
			Megistopoda aranea (4)	2	22.2 (2.8-60)	2[c]	36
			Strebla mirabilis (2)[a]	1	11.1 (0.3-48.3)	2[c]	3
			Strebla kohlsi (1)[a]	1	11.1 (0.3-48.3)	1[c]	100
			Trichobius joblingi (2)	1	11.1 (0.3-48.3)	2[c]	13
			Trichobius costalimai (11)[b]	2	22.2 (2.8-60)	5.5 (3-5.5)	20
			Trichobioides perspicillatus (5)[a]	1	11.1 (0.3-48.3)	5[c]	23
Carollia brevicauda (1)	1	100	*Trichobius joblingi* (6)	1	100[c]	6[c]	38
Desmodus rotundus (11)	9	81.8	*Strebla wiedemannii* (6)	3	27.3 (6.0-61)	2 (1-2.7)	30
			Strebla mirabilis (52)	5	45.5 (16.7-77)	10.4 (4.4-16.4)	71
			Trichobius joblingi (2)	2	22.2 (2.8-60)	1[c]	13
			Trichobius costalimai (1)[a]	1	9.1 (0.2-41.3)	1[c]	2
			Trichobius parasiticus (26)	6	54.5 (23.4-83.3)	4.3 (1.8-8)	55
			Speiseria ambigua (1)[a]	1	9.1 (0.2-41.3)	1[c]	100
			Mastoptera minuta (1)[a]	1	9.1 (0.2-41.3)	1[c]	50
Glossophaga soricina (4)	1	25	*Trichobius dugesii* (1)	1	25 (0.6-80.6)	1[c]	100
Lonchophylla mordax (11)	1	9.1	*Strebla mirabilis* (1)[a]	1	9.1 (0.2-41.3)	1[c]	1
Lophostoma silvicolum (2)	2	100	*Strebla wiedemannii* (2)[a]	1	50 (1.3-98.8)	2[c]	10
			Strebla mirabilis (11)[b]	1	50 (13-98.8)	11[c]	15
			Trichobius joblingi (4)[a]	1	50 (1.3-98.8)	4[c]	25
			Trichobius longipes (1)[a]	1	50 (1.3-98.8)	1[c]	100
			Trichobius parasiticus (11)[b]	2	100 (15.8-100)	5.5 (4-5.5)	23
			Mastoptera minuta (1)	1	50 (1.3-98.8)	1[c]	50
Glyphonycteris daviesi (15)	8	53.3	*Paradyschiria parvuloides* (1)[a]	1	6.7 (0.16-32.9)	1[c]	3
			Strebla wiedemannii (11)[a]	4	26.7 (7.8-55.1)	2.8 (1-4)	55
			Trichobius costalimai (15)[a]	3	20 (4.3-48.1)	5 (1-7.7)	27
			Trichobius parasiticus (9)[a]	2	13.3 (1.7-40.5)	4.5 (3-4.5)	19
			Trichobioides perspicillatus (1)	1	6.7 (0.2-32)	1[c]	5
Micronycteris megalotis (4)	0	0	—	0	0	0	0
Micronycteris nicefori (3)	1	33.3	*Strebla hertigi* (1)[a]	1	33.3 (0.8-90.6)	1[c]	50
			Strebla alvarezi (1)	1	33.3 (0.8-90.6)	1[c]	100
Molossu molossus (8)	0	0	—	0	0	0	0
Noctilio albiventris (11)	9	81.8	*Megistopoda aranea* (2)[a]	2	18.2 (2.3-51.8)	1[c]	18
			Paradyschiria parvuloides (38)	10	90.9 (58.7-99.8)	3.8 (2.1-6.9)	97
Phyllostomus discolor (7)	4	57.1	*Strebla hertigi* (1)	1	14.3 (0.36-57.9)	1[c]	50
			Trichobius costalimai (23)	4	57.1 (18.4-90.1)	5.8 (2.3-7.8)	42
			Trichobioides perspicillatus (11)	4	57.1 (18.4-90.1)	2.8 (1-4)	50
Phyllostomus hastatus (1)	1	100	*Strebla mirabilis* (7)	1	100[c]	7[c]	10
Platirrhynus helleri (1)	1	100	*Megistopoda proxima* (1)[a]	1	100[c]	1[c]	100
			Strebla wiedemannii (1)[a]	1	100[c]	1[c]	5
			Trichobius costalimai (1)[a]	1	100[c]	1[c]	2
			Trichobius parasiticus (1)[a]	1	100[c]	1[c]	2
			Trichobioides perspicillatus (1)[a]	1	100[c]	1[c]	5
Pteronotus parnellii (1)	0	0	—	0	0	0	0
Saccopterix bilineata (3)	0	0	—	0	0	0	0
Sturnira erythromus (2)	2	100	*Aspidoptera phyllostomatis* (2)	1	50 (1.3-98.8)	2[c]	29
Sturnira lilium (1)	1	100	*Trichobius joblingi* (2)	1	100[c]	2[c]	13

Nb: Number of bats; **Nib:** Number of infested bats; **P:** Prevalence; **Ne:** Number of ectoparasites; **MI:** Mean intensity; **CI:** Confidence interval; **SI:** Specificity index; **[a]:** Accidental or transitory record; **[b]:** New association; **[c]:** Insufficient data to calculate confidence intervals.

may have more males than females during times in which they are foraging outside the refuges. While, Dick & Patterson (2008) and Dittmar *et al.* (2011) indicated that the bias is due to selective grooming by the hosts, because females are larger than males, host-grooming activity removes or kills more females than males. However, sex ratio can vary seasonally (Marshall, 1981) and evaluations based on short-term or limited surveys may provide an incomplete picture (Autino *et al.,* 2011).

Phyllostomidae was the family with greatest species richness and abundance, which agrees with results found by other studies in the department of Sucre (Sampedro *et al.,* 2007; Galván-Guevara *et al.,* 2009; Montes *et al.,* 2012; Durán & Canchila, 2015). This area has a dry tropical forest relict with abundant food and refuge availability, moreover, this family has the highest diversity in the Neotropical region, with a wide range of trophic guilds and foraging habits in all forest strata (Bonaccorso, 1979; Fleming, 1986; Gardner, 2008). On the other hand, the low number of individuals caught from other families, such as Mormoopidae and Emballonuridae, is due to sampling limitations (mist nets being installed only at ground level) and flight behavior, because these families are characterized as species with high flight between and above the forest canopy (Bonaccorso, 1979; Muñoz, 2001; Gardner, 2008; Tarquino-Carbonell *et al.,* 2015).

Ectoparasites prevalence in the bat assemblage (P: 48.57%) was greater than reported in other dry tropical forest of Colombia (P: 36.42%) (Figure 1), which present approximately twice of average annual rainfall (Tarquino-Carbonell *et al.,* 2015). On the other hand, studies in Brazil show a prevalence of 36.88% in São Paulo (Bertola *et al.,* 2005), 29.90% in Pernambuco (Soares *et al.,* 2013), 28.9% in Maranhão (Santos *et al.,* 2009), 23% in Rio de Janeiro (França *et al.,* 2013), and 20.12% in Rio Grande do Sul (Rui & Graciolli, 2005); while Cuxim-Koyoc *et al.* (2015) found a prevalence of 74.06% in Yucatán-México. These differences may be related to the conditions in which the studies were conducted, variations in host and ectoparasites communities, and to different biogeographic history (Rui & Graciolli, 2005; Lourenço *et al.,* 2016).

The new host-ectoparasites associations (*Artibeus planirostris-Trichobius costalimai, Lophostoma silvicolum-Strebla mirabilis,* and *Lophostoma silvicolum-Trichobius parasiticus*) can be considered primary according to the established definition of Dick (2007). On the other hand, several associations found in this study may be classified as accidental or transitory because they have not previously registered and had low SI (Table 2). Graciolli & Carvalho (2001) suggested that this type of association may be related to failures in the collection methodology or due to the proximity of refuges used by different bats species, and will require additional studies in order to validate these parasitic relationships.

The absence of Streblidae on *M. megalotis, M. molossus, P. parnellii,* and *S. bilineata* could be related to the low number of individuals captured or due to unevidenced reasons. Several studies show some unparasitized bat species (Hofstede *et al.,* 2004; Bertola *et al.,* 2005), however, Guerrero (1997) offers a Streblidae list with host reported in America, and *Saccopteryx leptura* Schreber, 1774 is the only species that is not associated with any ectoparasite. Futhermore, these species of bats were also found infested in other studies, as Hofstede *et al.* (2004), Bertola *et al.* (2005), Dick & Gettinger (2005), Autino *et al.* (2011), Figueiredo *et al.* (2015), and Tlapaya-Romero *et al.* (2015).

It is important to highlight that this is the second study carried out in the Colombian dry tropical forests (Figure 1). Through this work, it was possible expand the knowledge of streblid flies and their host-parasitic associations in the Sucre department and the Colombian Caribbean region. However, other species are expected to be registered in this and other regions of the country, because there are still few studies related to bat flies and also by the existence of different geographical areas to explore.

RESUMEN

Este trabajo constituye el primer registro de las relaciones de parasitismo entre moscas Streblidae y murciélagos en la región Caribe colombiana. Los especímenes se capturaron en un bosque seco tropical del departamento de Sucre. Se registraron 17 especies de ocho géneros de Streblidae y 19 especies pertenecientes a cinco familias de murciélagos. Strebla mirabilis, Trichobius costalimai, Trichobius parasiticus *y* Paradyschiria parvuloides *fueron los ectoparásitos más abundantes. La prevalencia de ectoparásitos sobre el ensamblaje de murciélagos fue del 48,57%. En nueve especies de murciélagos se encontró más de una especie de Streblidae.* Trichobius costalimai *fue la que presentó el mayor número de especies huéspedes. Resaltan por ser novedosas las asociaciones entre* Artibeus planirostris-Trichobius costalimai, Lophostoma silvicolum-Strebla mirabilis *y* Lophostoma silvicolum-Trichobius parasiticus.

Palabras Clave: Colombia; Huésped; Parasitismo; Phyllostomidae.

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