Ectoparasitic insects (Diptera: Streblidae and Siphonaptera: Ischnopsyllidae) of bats from Iquitos and surrounding areas (Loreto, Peru)

Analía Gladys Autino[1], Guillermo Luis Claps[2], Rubén Marcos Barquez[1,3], María Mónica Díaz[1,3]/+

[1]Programa de Investigaciones de Biodiversidad Argentina, Programa de Conservación de los Murciélagos de Argentina, Facultad de Ciencias Naturales e Instituto Miguel Lillo, Universidad Nacional de Tucumán, Tucumán, Argentina
[2]Instituto Superior de Entomología Dr. Abraham Willink, Tucumán, Argentina
[3]Consejo Nacional de Investigaciones Científicas y Técnicas, Tucumán, Argentina

*Based on specimens collected from bats of different families, we add new species and extend the known ecological distribution and host associations of insect ectoparasites of bats in Peru. New information is provided for the distribution of 26 species of parasites (25 Diptera and 1 Siphonaptera: Ischnopsyllidae). Four species (*Neotrichobius ectophyllae, Strebla galindoi, Strebla paramirabilis *and* Myodopsylla wolffsohni wolffsohni*) are new for Peru and 16 represent new records for the department of Loreto. Also, we found 17 new host-ectoparasite relationships. Of note, we found remarkable new association between* Neotrichobius delicatus *and bat species from the families Molossidae and Noctilionidae and a novel association between* Paradyschiria parvula *and a species of Vespertilionidae. Host-ectoparasite specificity was recorded with 14 species as monoxenous, three oligoxenous, seven pleioxenous and two polyxenous.*

Key words: Chiroptera - Streblidae - Ischnopsyllidae - host-parasite interactions - taxonomy

The climatic and biotic diversity of Peru makes it an ideal region for the development of mammalian species (Pacheco 2002). With more than 150 species of bats, Peru is considered one of the areas with the highest diversity and abundance of bats in the Neotropical Region.

Although a number of important studies on bats have originated in Peru, little is known about the ecology and natural history of most Peruvian species and much less is known about the interactions between bats and ectoparasites. This report presents the results from an extensive survey of small mammals and their ectoparasites in the region of Iquitos (department of Loreto) in the northeast portion of the Peruvian Amazon. The survey revealed several new bat ectoparasitic insects.

We found bat flies of the family Streblidae (Diptera), that are primarily associated with bats of the family Phyllostomidae (Dick & Patterson 2007a), and the siphonapterans (family Ischnopsyllidae), that are associated with bats of the family Vespertilionidae (Whiting et al. 2008). We report 25 species of Streblidae, three of them new to Peru and one flea (Ischnopsyllidae), also new to the country. Several new host-parasite associations are reported and the known ecological ranges of many species of ectoparasites are extended.

Financial support: NIAID-NIH, USA (R01TW005860, D43TW007120, K24AI068903), CONICET
+ Corresponding author: mmonicadiaz@arnetbiz.com.ar
Received 14 January 2011
Accepted 9 August 2011

Currently, 230 species, 33 genera and five subfamilies are recognised in the family Streblidae (Dick & Graciolli 2007). Three of these five subfamilies (Nycterophiliinae, Streblinae and Trichobiinae) are distributed in the New World, including South America (Dick & Graciolli 2007). Streblinae is an abundant and diverse subfamily of neotropical distribution (Guerrero 1996a) that contains 33 species in South America (Guerrero 1997, Graciolli 2003, Graciolli & Dick 2004). These parasites occur with bats from the families Mormoopidae, Emballonuridae, Phyllostomidae, Natalidae, Vespertilionidae and Molossidae (Autino & Claps 2008). Trichobiinae includes 17 genera and 113 species (Guerrero 1996b, 1997, Graciolli 2003) that parasitize bats of the families Noctilionidae, Phyllostomidae, Molossidae, Mormoopidae, Natalidae, Vespertilionidae and Furipteridae (Autino & Claps 2008). The genus *Trichobius* Gervais is the most diverse within this subfamily (68 species), but it is not analysed in the present paper because a future report is in preparation.

A species (*Synthesiostrebla amorphochili*) of bat fly from the family Streblidae that is endemic to Peru was first described by Townsend in 1913 and was later re-described by Jobling (1947). Koepcke (1987) also mentioned species of this family in reference to bat parasites studied at Estación Panguana, Huanuco. Guerrero (1996a) did an ecological analysis of the species parasitising bats in Pakitza, Manu National Park; the next year, he published a catalog of New World species, including 59 species from Peru (Guerrero 1997). Recently, Claps et al. (2005) added two species [*Anastrebla modestini* Wenzel and *Exastinion clovisi* (Pessôa & Guimarães)], raising the number of currently known Peruvian species to 61.

Infestation by mites and bat flies is very common in bats. Flea parasitism is not often observed, although members of the family Ischnopsyllidae are exclusive to bats (Marshall 1981a). Fleas primarily parasitize insectivorous bats. This preference may be because the bats live in caves and tree holes, which provide optimal conditions for the development of flea larvae and pupae (Johnson 1957). The family Ischnopsyllidae contains two subfamilies, 20 genera and 122 species distributed worldwide (Lewis 1998). The subfamily Ischnopsyllinae includes five South American genera. From Peru, two species of *Hormopsylla* (*Hormopsylla egena* Jordan and *Hormopsylla trux* Jordan), one of *Myodopsylla* (*Myodopsylla setosa* Johnson) and one of *Sternopsylla* (*Sternopsylla distincta speciosa* Johnson) (Del Ponte 1977) have been reported.

MATERIALS AND METHODS

Field research was conducted between December 2003-December 2006. Collecting sites were along the Iquitos-Nauta Highway, in several districts of the provinces of Maynas and Requena, in Loreto (Supplementary data). These points included primary and secondary forest, as well as rural, suburban and urban areas. Bats were captured with mist nets placed at different heights, from 0.2 m above the ground up to the sub-canopy (2-4 m) and canopy levels (6-18 m). The nets were active from 06:00 pm-01:00 am and checked every hour. Some specimens were found while searching diurnal roosts in tree cavities, foliage, culverts, buildings and so on. Each bat was placed individually in a fabric bag in order to collect only the parasites belonging to that particular specimen.

For the bats, we followed the nomenclature introduced by Simmons (2005) and Gardner (2008) for most taxa and that of Solari et al. (2009) for *Dermanura*. External measurements, body mass, sex and reproductive condition were all recorded in the field for each bat specimen, following Díaz et al. (1998). Voucher specimens of bats were prepared as skins and skeletons or preserved in alcohol. Most of the specimens are still being catalogued for deposit in the Museo de Historia Natural de San Marcos, Lima, Peru and the Colección Mamíferos Lillo, Tucumán, Argentina. Meanwhile, host voucher specimens are identified with the acronyms of the field catalogue of María Mónica Díaz (MMD) and, for specimens already catalogued there, with the acronyms of the Colección Mamíferos Lillo (CML).

Ectoparasites were taken in the field from the pelage of 129 specimens of bats and preserved in 70% ethyl alcohol. In the lab, the parasites were placed in a solution of 70% ethylic alcohol, 5% glycerin and 25% distilled water (Whitaker Jr. 1988, Autino 1996). The parasites were identified at the laboratory with a stereoscopic microscope and some individuals were mounted in Canada balsam to be observed with a compound microscope. All parasite specimens mentioned in this report were deposited at the Annexes section of the CML with the same number of the host voucher specimen.

For the systematic arrangement of Diptera, we followed Wenzel et al. (1966), Wenzel (1976) and Graciolli and Carvalho (2001), for Siphonaptera, we followed Hopkins and Rothschild (1953, 1956) and Johnson (1957). Host-ectoparasite specificity (Marshall 1981b) and a comparison for each specimen with previous information available from Peru are shown in Table I.

Ectoparasites were classified according to the number and diversity of host species on which they were found: monoxenous, found only on one host species; oligoxenous, found on more than one host species of the same genus; pleioxenous, found on hosts from a single family and polyxenous, found on host species of two or more families (Marshall 1981b, Jameson 1985, ter Hofstede et al. 2004).

All cited localities have been alphabetically arranged and listed in the Supplementary data; geographical coordinates were obtained with a Global Positioning System. The specimens examined are included in Table II.

RESULTS AND DISCUSSION

Our intensive four-year study of the Peruvian Amazon has increased knowledge about the ectoparasitic insect fauna of bats. We studied parasitic species from the families Diptera (Streblidae) and Siphonaptera (Ischnopsyllidae) found on 35 species of bats (approximately 40% of the total of species from Iquitos): 30 Phyllostomidae (112 specimens), two Noctilionidae (5 specimens), one Molossidae (1 specimen) and two Vespertilionidae (2 specimens) (Tables I, II). We studied 246 ectoparasitic dipterous belonging to 26 bat fly species (Streblidae) and one species of flea (Ischnopsyllidae) represented by one specimen (Table II).

Four new species of parasitic insects are added to the fauna of Peru: *Neotrochobius ectophyllae* Wenzel, *Strebla galindoi* Wenzel, *Strebla paramirabilis* Wenzel (Diptera, Streblidae) and *Myodopsylla wolffsohni wolffsohni* (Rothschild) (Siphonaptera, Ischnopsyllidae).

Sixteen species of Streblidae (including 8 Streblinae and 8 Trichobiinae) are here cited for the first time for Loreto. With respect to the species of Streblinae, *Metelasmus pseudopterus* Coquillett and *Strebla guajiro* (García and Casal) were previously known from the departments of Madre de Dios and Pasco (Guerrero 1996a, b), *Strebla curvata* Wenzel, *Strebla kohlsi* Wenzel and *Strebla machadoi* Wenzel were known from Madre de Dios (Guerrero 1996a), *Strebla hertigi* Wenzel from Huanuco and Piura (Wenzel 1970) and *Strebla tonatie* (Kessel) from Cusco. On the other hand, *Strebla obtusa* Wenzel, a rare species according to Guerrero (1996b), was only known from three localities in Venezuela and from one undetermined locality in Peru. With respect to the species of Trichobiinae, *Aspidoptera falcata* Wenzel was known from Cusco, Lima, Madre de Dios and Pasco (Guerrero 1995, 1996a, Claps et al. 2005), *Aspidoptera phyllostomatis* (Perty) from Madre de Dios and Pasco (Guerrero 1996a), *Megistopoda aranea* (Coquillet) has been cited in five departments of Peru (Lima, Huanuco, Lambayeque, Madre de Dios and Pasco), but exact localities were known only in two of them, Lima and Madre de Dios (Wenzel 1970, Guerrero 1994, 1996a, Claps et al. 2005). *Megistopoda proxima* (Séguy) was cited in only one precise locality within Madre de Dios and from Pasco, but without a specific locality (Wenzel

TABLE I

Host specificity of insects ectoparasitic on bats: observed associations from this study and previous records from Peru

	Records in this study		Previous records from Peru	
Ectoparasite species	Bat species	HS	Bat species	HS
Diptera: Streblidae				
Streblinae				
Metelasmus pseudopterus	*Artibeus planirostris*, *Artibeus* sp. (Phyll.)	O	*A. planirostris*, *Artibeus lituratus* (Phyll.)	O
Strebla consocia	*Lophostoma brasiliense*, *Lophostoma silvicolum*, *Phyllostomus hastatus*, *Phyllostomus elongatus*, *Platyrrhinus brachycephalus* (Phyll.)	Pl	*P. hastatus*, *P. elongatus* (Phyll.)	O
Strebla curvata	*Carollia brevicauda* (Phyll.)	M	*Glosophaga commissarisi* (Phyll.)	M
Strebla galindoi	*Tonatia saurophila* (Phyll.)	M	-	-
Strebla guajiro	*Carollia perspicillata*, *Carollia* (*castanea* group), *Glossophaga soricina* (Phyll.)	Pl	*C. brevicauda*, *C. perspicillata* (Phyll.)	O
Strebla hertigi	*Phyllostomus discolor*, *P. elongatus*, *C. brevicauda* (Phyll.)	Pl	Host unknown	-
Strebla kohlsi	*G. soricina* (Phyll.)	M	*L. silvicolum*, *Phylloderma stenops* (Phyll.)	Pl
Complex kohlsi-mirabilis	*P. hastatus*, *Trachops cirrhosus* (Phyll.)	Pl	-	-
Strebla machadoi	*Mimon crenulatum* (Phyll.)	M	*Micronycteris minuta* (Phyll.)	M
Strebla obtusa	*Trinycteris nicefori* (Phyll.)	M	Host unknown	-
Strebla paramirabilis	*L. silvicolum* (Phyll.)	M	-	-
Strebla tonatie	*Micronycteris megalotis* (Phyll.)	M	Host unknown	-
Strebla wiedemanni	*Desmodus rotundus* (Phyll.)	M	*D. rotundus*, *Sturnira tildae* (Phyll.)	Pl
Trichobiinae				
Aspidoptera falcata	*Sturnira lilium*, *S. magna*, *Sturnira* sp., *Rhinophylla pumilio* (Phyll.)	Pl	*C. perspicillata*, *S. lilium*, *S. tildae* (Phyll.)	Pl
Aspidoptera phyllostomatis	*A. planirostris* (Phyll.)	M	*A. planirostris*, *A. lituratus*, *A. obscurus* (Phyll.)	O
Mastoptera minuta	*P. hastatus* (Phyll.)	M	*C. brevicauda, L. silvicolum*, *P. elongatus*, *P. hastatus* (Phyll.)	Pl
Megistopoda aranea	*A. planirostris, B. P. brachycephalus* (Phyll.)	Pl	*D. rotundus*, *Artibeus jamaicensis*, *A. lituratus*, *Uroderma bilobatum* (Phyll.)	Pl
Megistopoda proxima	*S. lilum*, *S. tildae*, *Sturnira* sp. (Phyll.)	O	*S. lilium*, *S. tildae* (Phyll.)	O
Neotrichobius delicatus	*Noctilio albiventris* (Noc.), *Molossus rufus* (Mol.), *Dermanura gnomus*, *D. anderseni*, *Rhinophylla fischerae* (Phyll.)	Po	*R. pumilio* (Phyll.)	M
Neotrichobius ectophyllae	*Mesophylla macconnelli* (Phyll.)	M	-	-
Noctiliostrebla aitkeni	*Noctilio leporinus* (Noc.)	M	*N. leporinus* (Noc.)	M
Paradyschiria fusca	*N. albiventris, N. leporinus* (Noc.)	O	Host unknown	-
Paradyschiria parvula	*N. albiventris* (Noc.), *Myotis simus* (Vesp.)	Po	*N. albiventris*, *Noctilio* sp.	O
Paratrichobius dunni	*P.brachycephalus*, *U. bilobatum*, *Vampyriscus bidens* (Phyll.)	Pl	*U. bilobatum* (Phyll.)	M
Paratrichobius longicrus	*A. lituratus*, *C. perspicillata* (Phyll.)	Pl	*A. lituratus* (Phyll.)	M
Pseudostrebla ribeiroi	*L. silvicolum* (Phyll.)	M	*L. silvicolum* (Phyll.)	M
Siphonaptera: Ischnopsyllidae				
Myodopsylla w. wolffsohni	*Myotis albescens* (Vesp.)	M	-	-

HS: host specificity; M: monoxenous; Mol: Molossidae; Noc: Noctilionidae; O: oligoxenous; Pl: pleioxenous; Phyll: Phyllostomidae; Po: polyxenous; Vesp: Vespertilionidae.

TABLE II

Species name, number of individuals examined by sex, collection number, host species, collecting date and collecting locality of ectoparasites (flies and fleas) collected on bats at Iquitos, Loreto, Peru

Species	Sex	Collection	Host	Date	Locality
Order Diptera					
Family Streblidae					
Subfamily Streblinae					
Metelasmus pseudopterus[a]	1 F	MMD 1435	*Artibeus planirostris*	20 May 2003	31
	1 M	MMD 3286	*A. planirostris*	7 May 2004	10
	1 F	MMD 2344	*Artibeus* sp.	26 Sep 2003	23
Strebla consocia	2 M, 1 F	MMD 2287	*Lophostoma brasiliense*[d]	23 Sep 2003	24
	1 M	MMD 2281	*Lophostoma silvicolum*[d]	23 Sep 2003	24
	1 M	MMD 3403	*L. silvicolum*	15 Jun 2004	35
	1 F	MMD 2600	*Phyllostomus elongatus*	24 Nov 2003	22
	4 M	MMD 4172	*P. elongatus*	28 Jan 2005	8
	3 M	MMD 4916	*P. elongatus*	21 Jul 2005	43
	1 M	MMD 2141	*Phyllostomus hastatus*	04 Sep 2003	12
	1 M	MMD 2507	*P. hastatus*	24 Oct 2003	30
	1 M	MMD 4058	*P. hastatus*	6 Dec 2004	29
	2 M, 1 F	MMD 4156	*P. hastatus*	26 Jan 2005	8
	1 M, 1 F	MMD 4160	*P. hastatus*	26 Jan 2005	8
	1 F, 1 U	MMD 4717	*P. hastatus*	18 May 2005	1
	1 F	MMD 3363	*Platyrrhinus brachycephalus*[d]	27 May 2004	20
Strebla curvata[a]	1 F	MMD 4435	*Carollia brevicauda*	11 Mar 2005	14
Strebla galindoi[b]	2 M, 1 F	MMD 1375	*Tonatia saurophila*[e]	14 May 2003	32
	3 M, 2 F	MMD 4015	*T. saurophila*	6 Dec 2004	29
	2 M, 2 F	MMD 4028	*T. saurophila*	6 Dec 2004	29
	2 M	MMD 4134	*T. saurophila*	26 Jan 2005	8
	3 M, 1 F	MMD 4726	*T. saurophila*	18 May 2005	1
Strebla guajiro[a]	1 F	MMD 2759	*Carollia perspicillata*	21 Jan 2004	26
	1 M, 2 F	MMD 3439	*C. perspicillata*	17 Jun 2004	35
	2 F	MMD 3906	*C. perspicillata*	22 Nov 2004	2
	1 F	MMD 3972	*C. perspicillata*	26 Nov 2004	2
	1 F	MMD 4129	*C. perspicillata*	24 Jan 2005	8
	1 F	MMD 4140	*C. perspicillata*	26 Jan 2005	8
	1 F	MMD 4149	*C. perspicillata*	26 Jan 2005	8
	1 M, 1 F	MMD 4678	*C. perspicillata*	26 May 2005	1
	1 F	MMD 2083	*Carollia* sp. (*castanea* group)	25 Aug 2003	41
	1 M	MMD 4145	-	26 Jan 2005	8
	1 F	MMD 2449	*Glossophaga soricina*	20 Oct 2003	31
Strebla hertigi[a]	1 F	MMD 3632	*Carollia brevicauda*	02 Sep 2004	39
	2 M	MMD 2375	*Phyllostomus discolor*	29 Sep 2003	25
	1 M	MMD 2378	*P. discolor*	29 Sep 2003	25
	1 M	MMD 2544	*P. discolor*	28 Oct 2003	32
	1 M	MMD 2646	*P. discolor*	26 Nov 2003	22
	1 F	MMD 3553	*P. discolor*	16 Aug 2004	33
	2 F	MMD 3660	*P. discolor*	06 Sep 2004	4
	1 F	MMD 3661	*P. discolor*	06 Sep 2004	4
	2 M, 7 F	MMD 3712	*P. discolor*	17 Sep 2004	7
	1 M, 1 F	MMD 3725	*P. discolor*	22 Sep 2004	7
	1 F	MMD 4937	*P. discolor*	25 Jul 2005	6
	1 M, 1 F	MMD 4941	*P. discolor*	25 Jul 2005	6
	1 M	MMD 5016	*P. discolor*	20 Sep 2004	38
	1 F	MMD 959	*P. discolor*	04 Feb 2003	24
	1 M	MMD 4243	*P. elongatus*[e]	03 Feb 2005	34
Strebla kohlsi[a]	1 F	MMD 4009	*G. soricina*[d]	2 Dec 2004	29

↳

Species	Sex	Collection	Host	Date	Locality
Strebla kohlsi-mirabilis complex[f]	1 M	MMD 2391	*P. hastatus*	01 Oct 2003	25
	3 M	MMD 4011	*P. hastatus*	2 Dec 2004	29
	1 M	MMD 4056	*P. hastatus*	6 Dec 2004	29
	1 M	MMD 2042	*Trachops cirrhosus*	22 Aug 2003	40
Strebla machadoi[a]	1 F	MMD 2784	*Mimon crenulatum*[d]	21 Jan 2004	26
Strebla obtusa[g]	1 F	MMD 4672	*Trinycteris nicefori*	16 May 2005	1
Strebla paramirabilis[b]	1 M	MMD 901	*L. silvicolum*	31 Jan 2003	25
Strebla tonatie[a]	1 M, 1 F	MMD 5135	*Micronycteris megalotis*[d]	23 Aug 2006	1
Strebla wiedemanni	1 M	MMD 2524	*Desmodus rotundus*	27 Oct 2003	32
	2 M	MMD 2535	*D. rotundus*	27 Oct 2003	32
	2 M, 1 F	MMD 5035	*D. rotundus*	18 Oct 2005	21
	3 M	MMD 990	*D. rotundus*	7 Feb 2003	23
Subfamily Trichobiinae					
Aspidoptera falcata[a]	1 M	MMD 2120	*Rhinophylla pumilio*[d]	28 Aug 2003	42
	3 M, 3 F	MMD 4201	*Sturnira* cf. *lilium*	1 Feb 2005	34
	1 F	MMD 4596	*S.* cf. *lilium*	18 Apr 2005	3
	2 M, 2 F	MMD 3962	*S. lilium*	16 Nov 2004	2
	1 F	MMD 4150	*S. lilium*	26 Jan 2005	8
	1 U	MMD 4211	*S. lilium*	1 Feb 2005	34
	2 F	MMD 4421	*S. lilium*	11 Mar 2005	14
	2 F	MMD 4436	*S. lilium*	11 Mar 2005	14
	1 M	MMD 4589	*S. lilium*	18 Apr 2005	3
	1 M, 1 U	MMD 4246	*Sturnira magna*[e]	3 Feb 2005	34
	2 M, 1 F	MMD 4701	*S. magna*	16 May 2005	1
	1 M	MMD 2907	*Sturnira* sp.	12 Feb 2004	27
	1 M, 1 F	MMD 3025	*Sturnira* sp.	11 Mar 2004	28
	1 M	MMD 3026	*Sturnira* sp.	11 Mar 2004	28
	5 M, 4 F	MMD 4441	*Sturnira* sp.	11 Mar 2005	14
	1 F	MMD 4569	*Sturnira* sp.	15 Apr 2005	3
	1 F	MMD 2329	*Sturnira tildae*	23 Sep 2003	23
Aspidoptera phyllostomatis[a]	1 F	MMD 1551	*A. planirostris*	3 Jun 2003	21
	1 F	MMD 3614	*A. planirostris*	23 Aug 2004	13
Mastoptera minuta[h]	3 M, 3 F	MMD 2877	*P. hastatus*	11 Feb 2004	27
	1 F	MMD 4011	*P. hastatus*	2 Dec 2004	29
	4 F, 1 U	MMD 4079	*P. hastatus*	8 Dec 2004	29
Megistopoda aranea[a]	1 M, 1 F	MMD 1136	*A. planirostris*	24 Mar 2003	37
	2 M, 2 F	MMD 1235	*A. planirostris*	1 Apr 2003	36
	1 M	MMD 1237	*A. planirostris*	1 Apr 2003	36
	2 M	MMD 1315	*A. planirostris*	12 May 2003	32
	1 F	MMD 1523	*A. planirostris*	30 May 2003	30
	2 M, 1 F	MMD 3695	*P. brachycephalus*[e]	13 Sep 2004	9
Megistopoda proxima[a]	1 M	MMD 4209	*S. lilium*	1 Feb 2005	34
	2 M, 1 F	MMD 4211	*S. lilium*	1 Feb 2005	34
	1 F	MMD 2140	*Sturnira* sp.	4 Sep 2003	12
	2 M, 4 F	MMD 4436	*Sturnira* sp.	11 Mar 2005	14
	1 M	MMD 4443	*Sturnira* sp.	11 Mar 2005	14
	1 M, 2 F	MMD 4138	*Sturnira tildae*	26 Jan 2005	8
Neotrichobius delicatus[a]	1 M	CML 7662	*Dermanura anderseni*	4 Sep 2003	12
	1 M	CML 7671	*Dermanura gnomus*	26 Jan 2005	8
	1 F	MMD 4351	*Molossus rufus*[c]	4 Mar 2005	15
	1 M	MMD 1718	*Noctilio albiventris*[c]	30 Jun 2003	16
	1 F	MMD 4404	*Rhinophylla fischerae*[e]	9 Mar 2005	14
	1 F	MMD 4414	*R. fischerae*	9 Mar 2005	14
Neotrichobius ectophyllae[b]	1 M, 1 F	MMD 4597	*Mesophylla macconnelli*	18 Apr 2005	3

Species	Sex	Collection	Host	Date	Locality
Noctiliostrebla aitkeni	3 M, 4 F	MMD 2809	*Noctilio leporinus*	22 Jan 2004	26
Paradyschiria fusca[a]	2 M	MMD 1718	*Noctilio albiventris*	30 Jun 2003	16
	1 M, 1 F	MMD 2809	*N. leporinus*	22 Jan 2004	26
Paradyschiria parvula[a]	1 F	MMD 3623	*Myotis simus*[c]	25 Aug 2005	5
	3 M, 5 F	CML 7625	*N. albiventris*	22 Sep 2004	16
	5 M	CML 7629	*N. albiventris*	8 Feb 2005	7
	1 M, 1 P	MMD 1715	*N. albiventris*	30 Jun 2003	16
	3 M	MMD 1718	*N. albiventris*	30 Jun 2003	16
	6 M, 4 F	MMD 4265	*N. albiventris*	8 Feb 2005	7
Paratrichobius dunni[a]	1 M	MMD 3695	*P. brachycephalus*[d]	13 Sep 2004	9
	1 F	MMD 3909	*Uroderma bilobatum*	22 Nov 2004	2
	1 M	MMD 4700	*Vampyriscus bidens*[d]	16 May 2005	1
Paratrichobius longicrus[h]	1 M	MMD 1618	*Artibeus lituratus*	13 Jun 2003	18
	1 M	MMD 2727	*A. lituratus*	9 Dec 2003	19
	1 M	MMD 3233	*A. lituratus*	6 May 2004	11
	1 M	MMD 2527	*C. perspicillata*	27 Oct 2003	32
Pseudostrebla ribeiroi[h]	1 M	MMD 4739	*L. silvicolum*	20 May 2005	1
Order Siphonaptera					
Family Ischnopsyllidae					
Myodopsylla w. wolffsohni[b]	1 F	MMD 4870	*Myotis albescens*	5 Jul 2005	17

a: new record for the department of Loreto; *b*: new record for Peru. The new records of the parasites for the hosts are indicated as follows: *c*: new for the family; *d*: new for the genus; *e*: new for the species of bat; *f*: as the males of the species *S. kohlsi* and *S. mirabilis* are indistinguishable, they were all included under this complex; *g*: first known precise locality and identified host for this species in Peru; *h*: first known precise locality for this species in Loreto. The number of each locality corresponds to those listed in the Supplementary data. CML: Colección Mamíferos Lillo; F: female; M: male; MMD: catalogue of María Mónica Díaz; U: sex undetermined, specimen with damaged abdomen.

1970, Guerrero 1994, 1996a), *Neotrochobius delicatus* (Machado Allison) and *Paradyschiria fusca* Speiser were previously known from Pasco (Guerrero 1994, 1995), *Paradyschiria parvula* Falcoz from Cusco and Madre de Dios (Guerrero 1995, 1996a) and *Paratrichobius dunni* (Curran) from Madre de Dios (Guerrero 1994, 1996a).

Paratrichobius longicrus (Miranda Ribeiro) and *Pseudostrebla ribeiroi* Costa Lima were already cited for Loreto, but without precise collecting sites (Wenzel 1970); thus, our data define localities for the distribution of these species in Loreto.

The finding of *N. delicatus* on bats of the families Molossidae (*Molossus rufus* É. Geoffroy St.-Hilaire) and Noctilionidae (*Noctilio albiventris* Desmarest), as well as the finding of *P. parvula* on a species of Vespertilionidae (*Myotis simus* O. Thomas), are remarkable. For *Neotrichobius delicatus*, we recorded a new association with the Phyllostomid bat *Rhinophylla fischerae* D.C. Carter and the association with species of bats belonging to families where this parasite was not previously recorded as are *N. albiventris* (family Noctilionidae) and *M. rufus* (family Molossidae). As these are very rare and previously unknown associations, it is necessary to add that the specimens of *Noctilio* and *Molossus* were the first collected each respective netting night and that their parasites were removed and fixed in alcohol prior to collecting other species of bats. This makes it unlikely that there was accidental infection by manipulation.

P. parvula, known primarily as a parasite of bats of the family Noctilionidae and only occasionally of Phyllostomidae, Molossidae and Emballonuridae (Marinkelle & Grose 1981, Guerrero 1995, Graciolli & Carvalho 2001), was not previously observed on vespertilionid bats. However, we collected a specimen *P. parvula* on a specimen of the bat *M. simus*, representing the first report of this parasite with the family Vespertilionidae.

Wenzel (1976) suggested that the presence of *P. parvula* on bats others than members of the family Noctilionidae could be considered accidental or transitory infections. However, we found *P. parvula* on a specimen of *M. simus*, a member of the family Vespertilinidae, which was not collected simultaneously with any specimens of *Noctilio*, suggesting that it was not an accidental infection. Also, we captured a specimen of *N. albiventris* (MMD 1718) that was parasitised by three species of Streblidae (*P. parvula*, *P. fusca* and *N. delicatus*).

We have found the following new host-parasite associations: *S. galindoi-Tonatia saurophila*, *Strebla kolshi-Glossophaga soricina* Pallas, *A. falcata-Sturnira magna* de la Torre, *A. falcata-Rhinophylla pumilio* W. Peters, *M. aranea-Platyrrhinus brachycephalus* (Rouk and Carter), *P. dunni-P. brachycephalus* and *P. dunni-Vampyriscus bidens* (Dobson).

Although *Strebla consocia* Wenzel is considered typical for *Phyllostomus hastatus* (Pallas) and *Phyllostomus elongatus* (É. Geoffroy St.-Hilaire), we report here its association with *P. brachycephalus*, *Lophostoma brasiliense* W. Peters and *L. silvicolum*. None of these bats was collected along with any *Phyllostomus*. Therefore, we dismiss the possibility of accidental infection posited by other authors (Dick 2006, Dick & Patterson 2007a).

S. machadoi was known only as a parasite of bats of the genus *Micronycteris*, but we add here another genus and species of bat, *Mimon crenulatum* (É. Geoffroy St.-Hilaire), as a host of this species. *S. hertigi* is reported herein for *P. elongatus*; this species was known as a typical parasite of the bats *P. hastatus* and *Phyllostomus discolor* (J.A. Wagner) (Guerrero 1996b). With respect to *S. tonatie*, it was previously known as a common parasite of the genus *Tonatia* (that now includes genus *Lophostoma*) but also cited for *Sturnira lilium* (Guerrero 1996b). Here, we add the bat *Micronycteris megalotis* (Gray), which represents a new genus and species of host for this parasite.

Coincident with what was observed by Guerrero (1996a), our samples showed a male-biased sex ratio (54% males, 46% females). Some authors suggest that this is most likely due to the fact that the females leave the host every ~10 days to make a prepupal deposition in the refuges of the host (Overal 1980, Marshall 1982, Fritz 1983). However Dick and Patterson (2007b) mention that traditional explanations for male-biased sex ratio, such as sampling effects, unequal longevity between sexes and differential dispersal capability are refuted in favour of an alternative hypothesis. They suggest 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 1981b) and evaluations based on short-term or limited surveys may provide an incomplete picture. According to Dittmar et al. (2011), specific data on bat fly sex-ratios are rare and, at times, confounding.

With respect to fleas, only one specimen of the species, *M. wolffsohni wolffhsoni*, was recorded on the bat *Myotis albescens* (É. Geoffroy St.-Hilaire) (family Vespertilionidae); thus, the proportion of sexes cannot be analysed.

Host-ectoparasite specificity - Host-ectoparasite specificity can be influenced by several factors, including host isolation, climate, competition, depredation, morphological characteristics and physiological adaptation (Marshall 1976). According to Dick and Patterson (2007a), it relies on a set of intrinsic biologic proprieties of the host and ectoparasite as well as ecological and evolutionary relationships. The degree of specificity among arthropod ectoparasites and the methodology used to evaluate specificity are still disputed (Poulin 2007). Some studies conclude that the fleas do not present a high degree of specificity to the hosts, most likely because many species of bats usually roost together and share a common pool of parasites (Theodor 1957). In fact, the bat fleas of family Ischnopsyllidae are unique in that all genera are pleioxenous (Jamerson 1985).

In this study, we found 14 (54%) monoxenous, seven (27%) pleioxenous, three (11%) oligoxenous and two (8%) polyxenous species (Table I). However, when we compared our observations to previous Peruvian records, we found varied information (Table I), possibly due to accidental infections or lack of surveys. Thus, species recorded in this study as monoxenous, including *S. kohlsi*, *Strebla wiedemanni*, *A. phyllostomatis* and *Mastoptera minuta* (Costa Lima), were recorded by other authors as oligoxenous (Guerrero 1995, 1996b) or pleioxenous (Guerrero 1995, 1996b). *N. delicatus*, *P. dunni* and *P. longicrus* (Guerrero 1994, 1996a) were recorded as monoxenous in other studies, but we found them on different species and even different families of bats. In this study, *S. consocia* and *S. guajiro* were found to be pleioxenous and *P. parvula* oligoxenous, though the two first species have been recorded as oligoxenous (Guerrero 1996a) and the last one as polyxenous (Guerrero 1995) in the literature. Graciolli and Dick (2004) also considered *M. pseudopterus* as oligoxenous, with the primary hosts being *Artibeus jamaicensis* Leach, *Artibeus fimbriatus* Gray and *Artibeus planirostris* (Spix). *S. curvata*, recorded as monoxenous, was usually found on bats of the genus *Glossophaga* (Wenzel 1976, Dick & Gettinger 2005, Dick et al. 2007), but we collected this species on a specimen of *Carollia brevicauda* (Schinz). *S. wiedemanni* Kolenati was found parasitising several species of bats (Marinkelle & Grose 1981, Guerrero 1996b, Graciolli & Carvalho 2001, Rios et al. 2008, Rojas et al. 2008), but we only found it on *Desmodus rotundus* (É. Geoffroy St.-Hilaire) (monoxenous), which is considered its primary host (Aguiar & Antonini 2011). *Noctiliostrebla aitkeni* Wenzel is known mainly as a parasite of *Noctilio leporinus* (Linnaeus) and recorded as monoxenous, but we found this species in sympatry with *P. fusca* on one specimen of *N. leporinus* (MMD 2809), an association also observed by Graciolli and Carvalho (2001).

ACKNOWLEDGEMENTS

To Joseph Vinetz, principal investigator, of the grants that supported the fieldwork, to INRENA, Ministerio de Agricultura of Peru, for the permits to capture and collect the specimens, to Yesenia Doris Chillitupa Campos, Victor Linares, Sixto Mananita, Harold Portocarrero, Cesar Ahuanari, Rubi Angulo and students of the Universidad Nacional de San Marcos, for their help in lab and fieldwork, and to Nofre Sánchez and IVITA, for his help with the preparation of ectoparasites in lab.

REFERENCES

Aguiar LMS, Antonini Y 2011. Descriptive ecology of bat flies (Diptera: Hippoboscoidea) associated with vampire bats (Chiroptera: Phyllostomidae) in the *cerrado* of Central Brazil. *Mem Inst Oswaldo Cruz 106*: 170-176.

Autino AG 1996. *Contribución al conocimiento de la sistemática y biología de los murciélagos de las Yungas de la Argentina y sus insectos ectoparásitos*, Doctoral Thesis, Universidad Nacional de Tucumán, Tucumán, 310 pp.

Autino AG, Claps GL 2008. Streblidae. In G Debandi, LE Claps, S Roig-Juñent (eds.), *Biodiversidad de artrópodos argentinos*, vol. II, SEA Ediciones Especiales, Tucumán, p. 293-304.

Claps GL, Autino AG, Barquez RM 2005. Streblidae de murciélagos de Lima: dos citas nuevas para Perú. *Rev Soc Entomol Argent 64*: 95-98.

Del Ponte E 1977. Notas sobre suctoria argentinas. VIII. Revisión de las familias Hystrichopsyllidae, Stephanocircidae e Ischnopsyllidae (Ceratophylloidea). *Rev Mus Argent Cienc Nat "B Rivadavia" Inst Nac Investig Cienc Nat Entomol 5*: 1-141.

Díaz MM, Flores DA, Barquez RM 1998. Instrucciones para la preparación y conservación de mamíferos. PIDBA (Programa de Investigaciones de Biodiversidad Argentina). *Publicaciones Especiales 1*: 13-18.

Dick CW 2006. The Streblid bat flies (Diptera: Streblidae) of Guatemala. In EB Cano, *Biodiversidad de Guatemala*, vol. I, Universidad del Valle de Guatemala, Guatemala, p. 441-452.

Dick CW, Gettinger D 2005. A faunal survey of Streblid flies (Diptera: Streblidae) associated with bats in Paraguay. *J Parasitol 91*: 1015-1024.

Dick CW, Gettinger D, Gardner SL 2007. Bolivian ectoparasites: a survey of bats (Mammalia: Chiroptera). *Comp Parasitol 74*: 372-377.

Dick CW, Graciolli G 2007. Cheklist of world Streblidae (Diptera: Hippoboscoidea). Available from: fm1.fieldmuseum.org/aa/Files/cdick/Streblidae_Checklist_2oct06.pdf.

Dick CW, Patterson BD 2007a. Against all odds: explaining host specificity in dispersal-prone ectoparasites. *Int J Parasitol 37*: 871-876.

Dick CW, Patterson BD 2007b. An excess of males: skewed sex ratios in bat flies (Diptera: Streblidae). *Evol Ecol 22*: 757-769.

Dittmar K, Morse S, Gruwell M, Mayberry J, DiBlasi E 2011. Spatial and temporal complexities of reproductive behavior and sex ratios: a case from parasitic insects. *PLoS ONE 6*: e19438.

Fritz GN 1983. Biology and ecology of bat flies (Diptera: Streblidae) on bats in the genus *Carollia*. *J Med Entomol 20*: 1-10.

Gardner AL 2008. *Mammals of South America - Marsupials, xenarthrans, shrews and bats*, vol. 1, The University of Chicago Press, Chicago, 669 pp.

Graciolli G 2003. Nova espécie de Anatrichobius Wenzel, 1966 (Diptera, Streblidae) do Brasil meridional. *Rev Bras Entomol 47*: 55-58.

Graciolli G, Carvalho CJ 2001. Moscas ectoparasitas (Díptera, Hippoboscoidea) de morcegos (Mammalia, Chiroptera) do Estado do Paraná. II. Streblidae. Chave pictórica para gêneros e espécies. *Rev Bras Zool 18*: 907-960.

Graciolli G, Dick CW 2004. A new species of *Metelasmus* (Diptera: Streblidae: Streblinae) from southern South America. *Zootaxa 509*: 1-8.

Guerrero R 1994. Catálogo de los Streblidae (Díptera: Pupipara) parásitos de murciélagos (Mammalia: Chiroptera) del Nuevo Mundo. IV. Trichobiinae con alas desarrolladas. *Bol Entomol Venez 9*: 161-192.

Guerrero R 1995. Catálogo de los Streblidae (Díptera: Pupipara) parásitos de murciélagos (Mammalia: Chiroptera) del Nuevo Mundo. V. Trichobiinae con alas reducidas o ausentes y misceláneos. *Bol Entomol Venez 10*: 135-160.

Guerrero R 1996a. Streblidae (Diptera: Pupipara) parásitos de murciélagos de Pakitza, Parque Nacional Manu (Perú). In DE Wilson, A Sandoval, *Manu: the biodiversity of Southeastern Perú*, Smithsonian Institution, Washington D.C., p. 627-641.

Guerrero R 1996b. Catálogo de los Streblidae (Diptera Pupipara) parásitos de murciélagos (Mammalia: Chiroptera) del Nuevo Mundo. VI. Streblinae. *Acta Biol Venez 12*: 1-25.

Guerrero R 1997. Catálogo de los Streblidae (Diptera: Pupipara) parásitos de murciélagos (Mammalia: Chiroptera) del Nuevo Mundo. VII. Lista de especies, hospedadores y países. *Acta Biol Venez 17*: 9-24.

Hopkins GH, Rothschild M 1953. An illustrated catalogue of Rothschild collection of fleas (Siphonaptera) in the British Museum (Natural History), vol. I, *Tungidae and Pulicidae,* British Museum (Natural History), London, 361 pp.

Hopkins GH, Rothschild M 1956. An illustrated catalogue of Rothschild collection of fleas (Siphonaptera) in the British Museum (Natural History), vol. II, *Cotopsyllidae, Vermipsyllidae, Stephanocircidae, Ischnopsyllidae, Hypsophthalmidae and Xiphiopsyllidae*, British Museum (Natural History), London, 445 pp.

Jameson EW 1985. Pleioxenous host-restriction in fleas. *J Nat Hist 19*: 861-876.

Jobling B 1947. On *Speiseria ambigua* Kessel and *Synthesiostrebla amorphochili* Townsend with redescription of the latter (Diptera, Streblidae). *Proc Royal Entomol Soc London (B) 16*: 39-42.

Johnson PT 1957. A classification of the Siphonaptera of South America. *Mem Entomol Soc Wash 5*: 1-298.

Koepcke J 1987. *Okologische studien an einer Fledermaus-arrengemeinschaft im tropischen Regenwald von Peru*, PhD Thesis, Ludwig Maximilians Universität, München, 439 pp.

Lewis RE 1998. Resumé of the Siphonaptera (Insecta) of the world. *J Med Entomol 35*: 377-389.

Marinkelle CJ, Grose ES 1981. A list of ectoparasites of Colombian bats. *Rev Biol Trop 29*: 11-20.

Marshall AG 1976. Host-specificity amongst arthropods ectoparasitic upon mammals and birds in the New Hebrides. *Ecol Entomol 1*: 189-199.

Marshall AG 1981a. *The ecology of ectoparasitic insects*, Academic Press, London, 459 pp.

Marshall AG 1981b. The sex ratio in ectoparasitic insects. *Ecol Entomol 6*: 155-174.

Marshall AG 1982. Ecology of insects ectoparasitic on bats. In TH Kunz, *Ecology of bats*, Plenum Press, New York, p. 369-401.

Overal WL 1980. Host-relations of the batfly *Megistopoda aranea* (Diptera: Streblidae) in Panamá. *Univ Kansas Sci Bull 52*: 1-20.

Pacheco V 2002. Mamíferos del Perú. In G Ceballos, J Simonetti, *Diversidad y conservación de los mamíferos neotropicales*, CONABIO-UNAM, México DF, p. 503-550.

Poulin R 2007. *Evolutionary ecology of parasites*, 2nd ed., Princeton University Press, New Jersey, 332 pp.

Rios GFP, Sá-Neto RJ, Graciolli G 2008. Fauna de dípteros parasitas de morcegos em uma área de Caatinga do Nordeste do Brasil. *Chiropt Neotrop 14*: 339-345.

Rojas A, Jiménez A, Vargas M, Zumbado M, Herrera MV 2008. Ectoparasites of the common vampiro bat (*Desmodus rotundus*) in Costa Rica: parasitism rates and biogeographic trends. *Mastozool Neotrop 15*: 181-187.

Simmons NB 2005. Order Chiroptera. In DE Wilson, DM Reeder, *Mammal species of the world - A taxonomic and geographic reference*, 3rd ed., Johns Hopkins University Press, Baltimore, p. 312-529.

Solari S, Hoofer SR, Larsen PA, Brown AD, Bull RJ, Carrera JA, Guerrero JA, Ortega J, Carrera JP, Bradley RD, Baker RJ 2009. Operational criteria for genetically defined species: analysis of the diversification of the small fruit-eating bats, *Dermanura* (Phyllostomidae: Stenodermatinae). *Acta Chiropt 11*: 279-288.

ter Hofstede HM, Fenton MB, Whitaker Jr JO 2004. Host and host-site specificity of bat flies (Diptera: Streblidae and Nycteribiidae) on Neotropical bats (Chiroptera). *Can J Zool 82*: 616-626.

Theodor O 1957. Parasitic adaptation and host-parasite specificity in the pupiparous Diptera. In E Mayr, *First symposium on host*

specificity among parasites of vertebrates Institut de Zoologie, Université de Neuchâtel, Neuchâtel, p. 50-63.

Townsend CHT 1913. Preliminary characterization of the vector of verruga, *Phlebotomus verrucarum* sp. n. *Ins Ins Mens 1*: 107-109.

Wenzel RL 1970. Family Streblidae. In N Papavero, *A catalogue of the Diptera of the Americas South of the United States*, Museu de Zoologia da Universidade de São Paulo, São Paulo, p. 1-25.

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 bat flies of Panamá (Diptera: Calypterae: Streblidae), In RL Wenzel, VJ Tipton, *Ectoparasites of Panama*, Field Museum of Natural History, Chicago, p. 405-675.

Whitaker Jr. JO 1988. Collecting and preserving ectoparasites or ecological study. In T Kunz, *Ecological and behavioral methods for the study of bats*, Smithsonian Inst Press, Washington, p. 459-474.

Whiting MF, Whiting AS, Hastriter MW, Dittmar K 2008. A molecular phylogeny of fleas (Insecta: Siphonaptera): Origins and host associations. *Cladistics 24*: 677-707.