Acta Zool. Mex. (n.s.) 76: 85-102 (1999)

HOST TRACKING OR RESOURCE TRACKING? THE CASE OF *PERIGLISCHRUS* WING MITES (ACARINA: SPINTURNICIDAE) OF LEAF-NOSED BATS (CHIROPTERA: PHYLLOSTOMIDAE) FROM MICHOACAN, MEXICO

Lorinda L. SHEELER-GORDON[1] and Robert D. OWEN[2]

[1] The Institute for Environmental and Human Health. Texas Tech University
P.O. Box 41163, Lubbock, TX, U.S.A. E-mail: lsheeler@ttacs.ttu.edu

[2] Department of Biological Sciences, Texas Tech University P.O. Box 43131
Lubbock, TX U.S.A. E-mail: bcrdo@ttacs.ttu.edu

RESUMEN

Las hipótesis de seguimiento del huesped (host tracking) versus seguimiento de recursos (resource tracking) fueron analizadas en ácaros spinturnícidos del genero *Periglischrus*, parásitos asociados a los murciélagos de la familia Phyllostomidae. Diferentes líneas de evidencia sugieren que estos ácaros siguen a los huespedes, es decir, que no responden a factores ambientales más alla del cuerpo de los mismos. Con una sola excepción, cada especie huesped fue infectada por una sola especie de ácaro. En algunos casos, una especie de ácaro infectó más de una especie de murciélago, pero siempre estos huespedes fueron especies estrechamente relacionadas, componiendo un grupo monofilético dentro de nuestra muestra. Por último, se usaron análisis por sistema de información geográfica (GIS) para evaluar los efectos de precipitación anual, vegetación, clima y suelos en la distribución de los ácaros dentro de la distribución de sus huespedes en Michoacán. Aquellas asociaciones con un tamaño de muestra adecuado resultaron no significativas, indicando que las distribuciones de los ácaros no varían con respecto a factores ambientales. Datos y análisis adicionales son necesarios para poner a prueba estos resultados, así como para evaluar otros factores ambientales no analizados en este estudio y que pudieran ser de importancia en la determinación de la distribución de los ácaros.

Palabras Clave: Ectoparásitos, murciélagos, Phyllostomidae, Spinturnicidae, Michoacán.

ABSTRACT

We examined the issue of host tracking versus resource tracking in spinturnicid wing mites of the genus *Periglischrus*, which are associated with bats of the family Phyllostomidae. Several lines of evidence suggest that these mites are host tracking, that is they do not respond to environmental factors beyond the body of their host. With one exception only, each host species was infested by only one mite species. In some cases, a mite species infested more than one bat species, but these hosts were always closely related, composing a monophyletic group within our sample. Finally, GIS analyses were used to evaluate the effects of annual precipitation, vegetation, climate, and soils on mite distributions within their host distributions in Michoacán. Those associations having an adequate sample size resulted in non-significance, indicating that the mite distributions did not vary with respect to environmental factors. Additional data and analyses are needed to test each of these findings, as well as to evaluate other environmental factors not tested in this study which may be of importance to mite distribution.

Key Words: Ectoparasites, bats, Phyllostomidae, Spinturnicidae, Michoacán

INTRODUCTION

Mites of the family Spinturnicidae are intimately associated with chiropterans; more specifically the spinturnicid genus *Periglischrus* Kolenati 1857 has been reported almost exclusively on bats of the family Phyllostomidae (Rudnick, 1960; Machado-Allison, 1967; Furman, 1966; Dusbabek, 1968; Herrin and Tipton, 1975). Spinturnicid mites are exclusively ectoparasites of bats during all active life stages, and their habitats are principally the wing membranes and occasionally the tail membrane of the bat (Rudnick, 1960).

Continuous existence on the host is reflected in adaptations in the mite's life cycle. The life cycle includes the egg, larva, protonymph, deutonymph, and adult stages, of which the egg and larval stages occur within the reproductive female. The female gives birth directly to the protonymph. Elimination of the independent larval stage is presumably an adaption that minimizes separation from the host, thereby maximizing survival of the spinturnicid (Rudnick, 1960).

The protonymph, deutonymph, and adult mites have sucking mouthparts, thus having the ability to feed only on body fluids of their hosts. Blood cells can be observed in the gut of engorged specimens, and it has been concluded that these mites feed primarily on blood of their hosts (Rudnick, 1960). However, it has been noted by Rudnick (1960) that the mites also would have the ability to feed on lymph.

Spinturnicid mites are specialized morphologically and behaviorally to inhabit bat wings during all of the active life stages. The body is relatively flat with thick legs (Fig. 1). The coxae are immovable and arranged radially; the tarsi have short pretarsi, large caruncles, and strong curved claws (Baker and Wharton, 1952). These modifications enable the mite to attach firmly to the hairless surface of the bat's wing membrane. When a mite is attached to the wing membrane, the legs may be spread out or bent under the body. Vitzthum (1932) suggested that these different leg positions allow the mite to compensate for rapid opening and closing of the bat wing during flight.

The strong claws and legs of *Periglischrus* mites enable the mite to avoid dropping off the bat host accidentally. Transfer of mites from bat to bat most likely occurs during close body contact, socially or maternally in roosts. In lab-rearing trials, mites did not survive more than 24 hours off their bat host (Rudnick, 1960). Thus, it is unlikely that a mite would freely leave a host in search of another. Although possible exceptions could include a mite deserting a dead bat to find a new host, or extreme populational pressures on a heavily infested host, neither of these situations would likely result in survival of the mite.

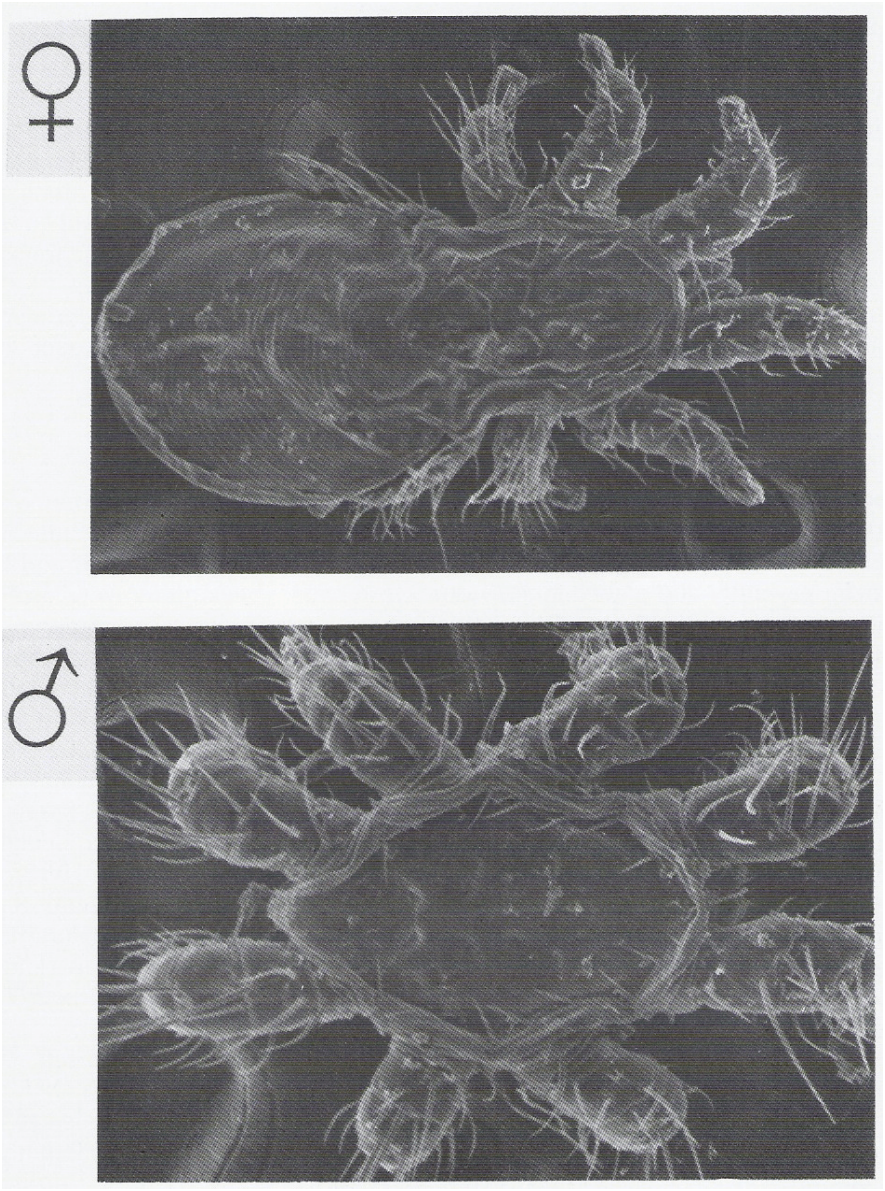


Figure 1
Female (80X) and male (110X) *Periglischrus iheringi* removed from *Artibeus hirsutus* (TTU 10635).

Bats and their ectoparasites were collected during January 1994 to January 1995 from 34 localities in Michoacán, México (Fig. 2). Our collection of phyllostomid bats in Michoacán includes 274 individuals of 22 species (13 genera, 4 subfamilies) and enables us to examine patterns of host fidelity in *Periglischrus* mites. In addition, geographic patterns were evaluated using Geographic Information System (GIS) to investigate the association of mite distributions with four selected environmental factors. Association of a mite species with one or more environmental factors might indicate a pattern of habitat or resource tracking, rather than a pattern of host tracking in a parasitic or phoretic species.

Moreover, we record the presence of *Periglischrus* mites previously unrecorded for the state of Michoacán, and summarize host distributions for each mite species.

MATERIAL AND METHODS

Geographic position of each of the 34 sites in Michoacán was recorded with a handheld Global Positioning System (GPS) receiver (Appendix 1). Bats were collected using mist nets and hand nets. The mist nets were attended, and bats removed promptly and placed in individual cloth bags. Precautions were taken to avoid exchange of arthropods among host individuals. To remove the ectoparasites, the host was etherized, and then brushed with a coarse toothbrush into the etherization bucket. The wing and tail membranes also were examined for ectoparasites, and any remaining parasites were removed by picking them individually with fine forceps. All parasites recovered from each host were placed in a vial containing 70 percent ethyl alcohol. The bucket and instruments were cleaned thoroughly before the next host was processed. Each host was preserved as a voucher specimen, enabling verification of host identification. Nomenclature of bats follows Owen, 1987, Baker *et al.* 1989, Van Den Bussche, 1992, and Ramírez-Pulido *et al.* 1996. Host specimens will be deposited in the Instituto de Biología, Universidad Nacional Autónoma de México; Universidad Autónoma Metropolitana-Iztapalapa; Universidad Michoacana de San Nicholas de Hidalgo; Universidad Autónoma del Edo. de Morelos; and the Museum of Texas Tech University.

Ectoparasites were stored in 70 percent ethyl alcohol until sorted. Mite specimens were cleared with lactophenol or potassium hydroxide (KOH), and mounted on glass slides in Hoyer's medium. A ring of glyptal was applied to seal the cover slip (Krantz, 1978). Specimens were examined with light microscopy, and identified using criteria from Dusbabek (1968), Furman (1966), Herrin and Tipton (1975), Machado-Allison (1964, 1965), and Rudnick (1960).

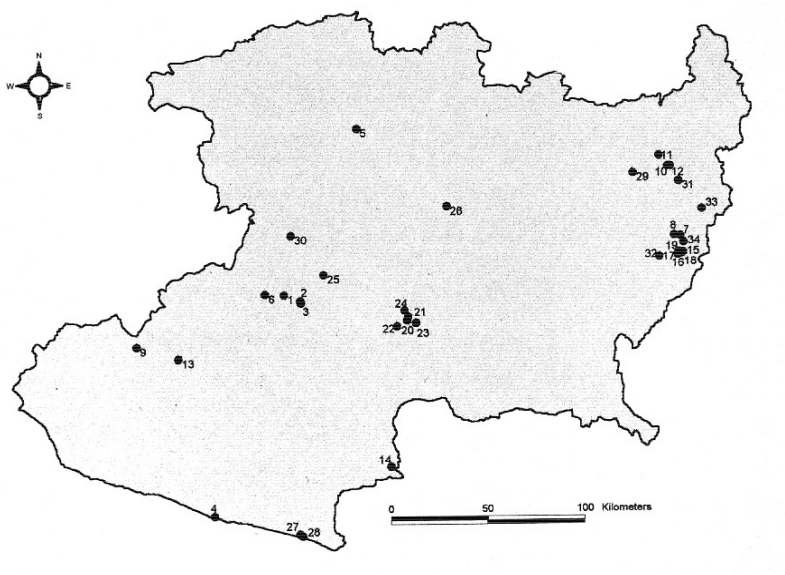


Figure 2
Collecting localities in Michoacán.

If the protonymphal or deutonymphal stage for a particular mite species has not been described, then the mite nymph was tentatively identified by association with the adult males and/or females present on the host. However, these specimens identified only by association were not included in any statistical tests of association. Arthropod specimens will be deposited in the Museum of Texas Tech University; Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional; and Universidad Nacional Autónoma de México.

Prevalence of spinturnicid mites was calculated as the number of infested bats divided by the total number of bats sampled for each species. Prevalences were calculated for the total sample of phyllostomid bats, and for each sex separately within species. Because sample sizes for some host species were small, which affects the confidence of obtaining an accurate prevalence estimate, 90 percent confidence intervals were calculated for the prevalence rates for each species (Sokal and Rohlf, 1981). Chi-square goodness-of-fit tests were performed to test for equal mite distribution among host species and genera, and within and between the two best represented host feeding guilds (frugivores and nectarivores). Chi-square tests also were performed where sample size permitted for comparison of mite distribution between males and females within each host

species, genus, feeding guild, between feeding guilds (frugivores and nectarivores), and within all bats pooled.

Maps (1:500,000, Nomenclator del Estado de Michoacán, 1985, Instituto Nacional de Estadística Geografía e Informática) describing environmental factors of annual precipitation, soils, climate, and vegetation were digitized using a 486 Dell PC, running ARC/INFO ver. 3.4.2b (Environmental Systems Research Institute, 1994), and a digitizing board (CalComp 9500, 36 x 48). The original maps included UTM coordinate labels that were incorrect by a reduced factor of 10. In addition, the division between UTM zones 13 and 14 was incorrectly labeled resulting in a numerical shift in zone 14 (600 km to the east). These problems were corrected to the extent possible, with ARC/INFO, before analyses were performed.

Collection locality and date, bat identification, mite identification, and relative numbers and life stages of mites were entered into dBase ver. 4.0 (Ashton-Tate, 1992). Utilizing the database, a GIS point coverage was created, which contained information on the bats and mites collected from each of the 34 localities. The point coverage and the four environmental coverages were merged with ARC/INFO, associating bats and wing mites with the corresponding environmental factors for each locality. The data were then examined for mite distributional patterns with respect to the four environmental factors using the chi-square goodness-of-fit test and the Yates' continuity-corrected chi-square (Sokal and Rohlf, 1981). The significance level for all chi-square goodness-of-fit tests was 0.05.

RESULTS

Twenty-two phyllostomid species (274 individual specimens) were captured in Michoacán, including representatives from 13 genera and 4 subfamilies (Table 1, Appendix 2). Of these 22 bat species, 17 species (9 genera, 3 subfamilies) included individuals that were infested with *Periglischrus* wing mites. Mites were not encountered on *Musonycteris harrisoni, Choeronycteris mexicana, Artibeus lituratus*, or *Carollia subrufa* perhaps due to small host samples. Additionally, mites were not encountered on *Micronycteris megalotis*, although 12 host individuals were collected from four different localities.

Seven species of *Periglischrus* wing mites were collected in Michoacán: *P. caligus* Kolenati 1857, *P. delfinadoae* Dusbabek 1968, *P. herrerai* Machado-Allison 1965, *P. iheringi* Oudemans 1902, *P. ojastii* Machado-Allison 1964, *P. paracaligus* Herrin and Tipton 1975, and *P. vargasi* Hoffman 1944 (Table 2). Four of these species (*P. delfinadoae, P. herrerai, P. ojastii*, and *P. paracaligus*) are reported here for the first time from Michoacán.

Table 1

Phyllostomid bats collected from Michoacán, México. Nomenclature follows Owen, 1987, Baker *et al*. 1989, and Van Den Bussche, 1992. M, the number of males; F, the number of females; Total, the total number of bats. Mites, presence (+) of spinturnicid mites on one or more host specimens, or absence (-) of spinturnicid mites.

Family Phyllostomidae	M	F	Total	Mites
Subfamily Desmodontinae				
Desmodus rotundus	8	7	15	+
Subfamily Macrotinae				
Macrotus waterhousii	14	1	15	+
Subfamily Micronycterinae				
Micronycteris megalotis	8	4	12	-
Subfamily Phyllostominae				
Tribe Glossophagini				
Leptonycteris nivalis	7	2	9	+
Leptonycteris curasoae	5	7	12	+
Glossophaga leachii	6	3	9	+
Glossophaga morenoi	7	8	15	+
Glossophaga soricina	13	5	18	+
Anoura geoffroyi	10	1	11	+
Musonycteris harrisoni	0	1	1	-
Choeronycteris mexicana	1	0	1	-
Tribe Stenodermatini				
Carollia subrufa	1	1	2	-
Sturnira lilium	13	26	39	+
Sturnira ludovici	5	10	15	+
Chiroderma salvini	0	1	1	+
Artibeus hirsutus	3	2	5	+
Artibeus jamaicensis	14	6	20	+
Artibeus lituratus	0	2	2	-
Artibeus intermedius	20	20	40	+
Dermanura azteca	3	9	12	+
Dermanura phaeotis	2	4	6	+
Dermanura tolteca	6	8	14	+

With one exception, each mite species was associated consistently with a monophyletic host taxon (species, genus, or genus-group). The exception was *Periglischrus herrerai* and *P. iheringi*, both of which were collected from the host *Desmodus rotundus*. This was the only host to have two associated mite species. This inconsistency is based on two *D. rotundus* specimens with eight total *P. iheringi*, and one *D. rotundus* specimen with one *P. herrerai*.

Table 2

Periglischrus wing mites associated with phyllostomid bats of Michoacán. M, the number of adult male mites collected; F, the number of adult female mites collected; N, the number of nymphal mites collected; Prev ± CI, prevalence (percentage) of hosts infested, with 90% confidence interval. *, new record for Michoacán, México.

Periglischrus	M	F	N	Total	Host species	Prev ± CI
caligus	3	1	0	4	*Glossophaga leachii*	0.33 ± 0.29
caligus	2	4	0	6	*Glossophaga morenoi*	0.27 ± 0.20
caligus	3	10	2	15	*Glossophaga soricina*	0.28 ± 0.18
*delfinadoae**	3	7	3	13	*Macrotus waterhousii*	0.33 ± 0.21
*herrerai**	0	1	0	1	*Desmodus rotundus*	0.07 ± 0.12
iheringi	1	6	2	9	*Artibeus hirsutus*	0.40 ± 0.47
iheringi	18	10	9	37	*Artibeus intermedius*	0.33 ± 0.13
iheringi	8	7	4	19	*Artibeus jamaicensis*	0.40 ± 0.19
iheringi	1	4	2	7	*Chiroderma salvini*	1.00 ± 0.00
iheringi	9	1	0	10	*Dermanura azteca*	0.33 ± 0.24
iheringi	0	5	0	5	*Dermanura phaeotis*	0.17 ± 0.31
iheringi	4	7	3	14	*Dermanura tolteca*	0.36 ± 0.23
iheringi	4	0	4	8	*Desmodus rotundus*	0.13 ± 0.15
*ojastii**	15	6	2	23	*Sturnira lilium*	0.33 ± 0.13
*ojastii**	7	8	0	15	*Sturnira ludovici*	0.40 ± 0.22
*paracaligus**	11	16	7	34	*Leptonycteris curasoae*	0.75 ± 0.23
*paracaligus**	8	26	7	41	*Leptonycteris nivalis*	0.89 ± 0.19
vargasi	12	22	10	44	*Anoura geoffroyi*	0.91 ± 0.16

Prevalence rates for most of the phyllostomid species in Michoacán were similar to levels observed in other studies (Herrin and Tipton, 1975). In some cases, 90 percent confidence intervals were large, which is attributable in part to small host sample sizes (Table 2). Bat species with higher *Periglischrus* prevalence rates than previously had been reported were *Leptonycteris curasoae* (75 percent), *Leptonycteris nivalis* (89 percent), and *Anoura geoffroyi* (91 percent). Species with lower prevalence rates were *Desmodus rotundus* (20 percent), and *Micronycteris megalotis* (0 percent).

Nine species of bats had expected infestation values adequate to test for equality of mite distribution among species. Among these species, no differences were detected in mite distributions (χ^2=1.074, df=7, *P*=0.994). Because sample sizes for many bat species were minimal, data for each bat genus were pooled for testing mite distribution among hosts. Again, the test result was non-significant (χ^2=5.82, df=5, *P*=0.324), indicating that there were equal mite distributions among the phyllostomid genera sampled. Mite distributions among species within the frugivore and nectarivore guilds were also analyzed with chi-square goodness-of-fit tests. These tests indicated equal mite distribution among frugivore species

(χ^2=0.049, df=2, *P*=0.976), but unequal mite distribution among nectarivores (χ^2=9.3, df=1, *P*=0.002). However, the chi-square test between the frugivore and nectarivore guilds (χ^2=3.242, df=1, *P*=0.072) was non-significant.

Prevalence rates were calculated separately for males and females for each host species (Fig. 3). For most bat species, samples were inadequate to test the equality of mite distribution between the sexes with a chi-square goodness-of-fit test. However, for *Artibeus intermedius* a chi-square test was performed to determine whether or not mite distributions were equal between the sexes. In *A. intermedius* the chi-square test was significant (χ^2=4.708, df=1, *P*=0.030), with the females being more heavily infested. The results for chi-square goodness-of-fit tests for the equality of mite distribution between the sexes for all *Glossophaga* species pooled (χ^2=0.094, df=1, *P*=0.759), all *Artibeus* species pooled (χ^2=2.236, df=1, *P*=0.135), all *Sturnira* species pooled (χ^2=0.061, df=1, *P*=0.805), and all *Leptonycteris* species pooled (χ^2=0.059, df=1, *P*=0.808) were all non-significant. The results for chi-square goodness-of-fit tests for the equality of mite distribution between sexes for frugivores (χ^2=1.721, df=1, *P*=0.190), nectarivores (χ^2=0.028, df=1, *P*=0.867), and all bats pooled (χ^2=0.49, df=1, *P*=0.484) also were non-significant.

To assess patterns of mite distribution with respect to each environmental factor for each mite species (without regard to host association), chi-square goodness-of-fit tests with the Yates' correction factor were performed. *Periglischrus ojastii* had samples sufficient to test among soil types (χ^2=0.151, df=1, *P*=0.698). This test resulted in non-significance, indicating that mite distributions were equally distributed with respect to the different soils.

Periglischrus iheringi had an adequate sample size to test for equal mite distribution with respect to three of the four environmental factors. For annual precipitation (χ^2=0.512, df=1, *P*=0.474), vegetation (χ^2=0.786, df=1, *P*=0.375), and climate (χ^2=2.114, df=1, *P*=0.146) the chi-square tests failed to reject the null hypothesis (mite distributions are equal among the divisions for the particular environmental factor), indicating that *P. iheringi* is distributed without respect to annual precipitation, vegetation, or climate.

Finally, all mite species were pooled to examine mite distributional patterns with respect to the four environmental factors. For annual precipitation (χ^2=3.82, df=1, *P*=0.051), vegetation (χ^2=1.591, df=1, *P*=0.207), climate (χ^2=7.57, df=4, *P*=0.109), and soils (χ^2=7.202, df=5, *P*=0.206) the results indicated a marginal significance in annual precipitation only, with the other three environmental factors non-significant.

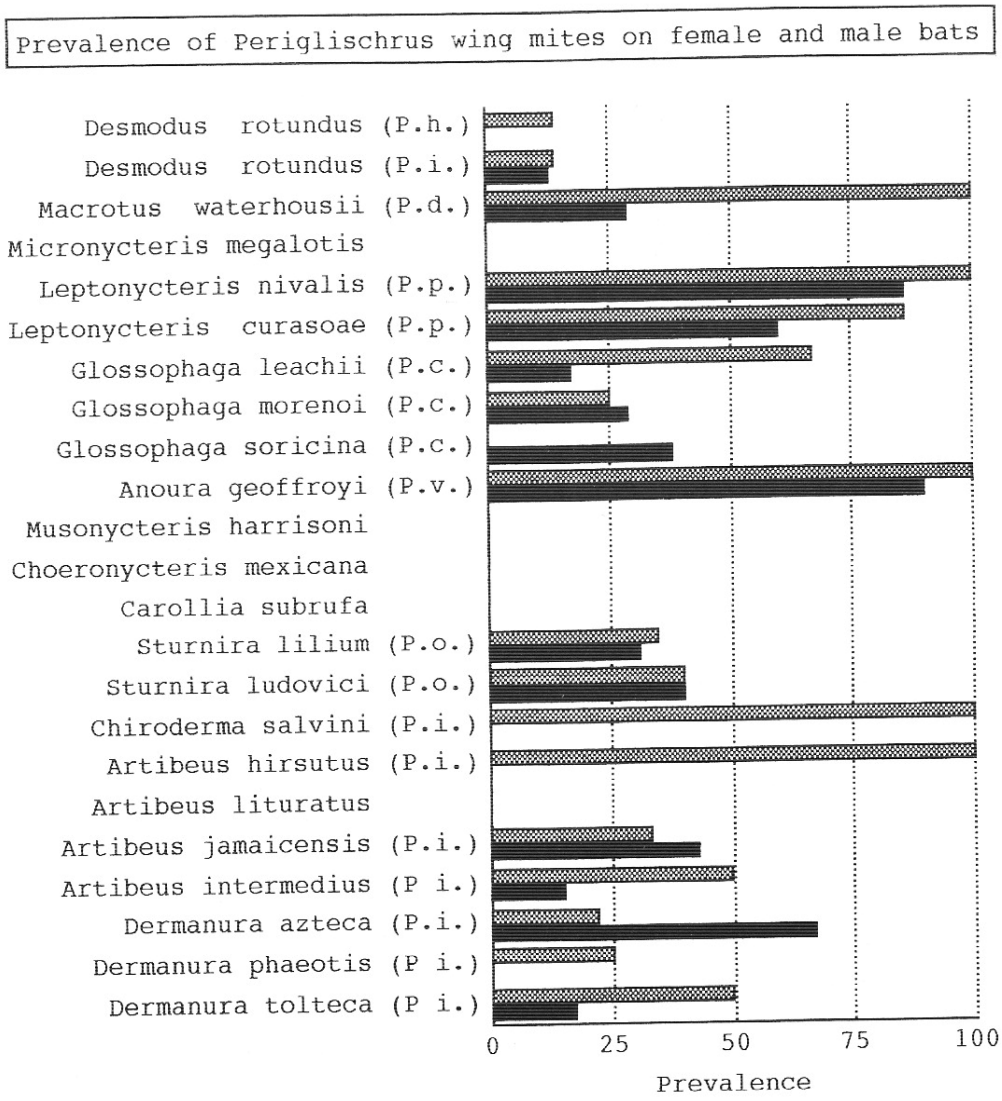


Figure 3

Prevalence (percentage) of *Periglischrus* wing mites on female (shaded bar) and male (solid bar) phyllostomid bats. Abbreviations for parasite names: P.h., *P. herrerai*; P.i., *P. iheringi*; P.d., *P. delfinadoae*; P.p., *P. paracaligus*; P.c., *P. caligus*; P.v., *P. vargasi*; P.o., *P. ojastii*.

DISCUSSION AND CONCLUSIONS

Host specificity is an avenue for investigation of the evolutionary, ecological, and geographical aspects of host-parasite relationships. The extent of parasite dependence influences the parasite's adaptive specialization, and as a result, one of two alternate patterns may emerge (Kethley and Johnston, 1975). One pattern is resource tracking, in which a parasite is associated consistently with a resource that is completely or partially independent of a particular host. Here, the expected pattern is incomplete congruence between parasite and host phylogenies. The other pattern is host tracking, in which a parasite species is obligatorily dependent on one or more aspects of the host animal. This pattern would be expected to result in congruence between the parasite and host phylogenies.

Mites of the genus *Periglischrus* (Family Spinturnicidae) are intimately associated with the chiropteran family Phyllostomidae (Rudnick, 1960; Machado-Allison, 1967; Furman, 1966; Herrin and Tipton, 1975). Previously, taxonomic relationships of spinturnicid mites have been used to discern or support phylogenetic relationships among the phyllostomid bats. Machado-Allison (1967), based on parasite-host relationships, suggested that the systematics of *Desmodus* and *Mormoops* be reevaluated. Smith (1972) applied many characters, including spinturnicid data, to present a new classification of the phyllostomid subfamily Chilonycterinae, elevating this group to familial status as the Mormoopidae. Based in part on these earlier works, current taxonomy of the phyllostomids includes the subfamily Desmodontinae and excludes the mormoopid species (Baker *et al.* 1989).

Kethley and Johnston (1975) stated that parasite and host phylogenies are expected to show congruence in lineages exhibiting host tracking. Currently, there is no proposed hypothesis of phylogenetic relationships among *Periglischrus* species. In addition, the taxonomy in this group has been very conservative, principally relying on host association. To evaluate the host tracking hypothesis thoroughly, a phylogenetic analysis of these mites will be necessary. However, to evaluate the parasite associations within the phyllostomid phylogeny, a phylogram (Fig. 4) reflecting the current proposed phylogeny of the phyllostomid bats, using only those bat species encountered in this study, was constructed following Baker *et al*. (1989), Owen (1987), and Van Den Bussche (1992). The host distribution of *Periglischrus* mite species is included with the dendogram to illustrate the taxonomic fidelity to the host lineages that is exhibited by the *Periglischrus* wing mites. Within this pattern, we observed three levels of parasite-host associations; a particular mite species was associated with: (1) a single host species, (2) a single host genus, or (3) multiple host genera. In each case but one, the mites exhibited taxonomic fidelity with reference to their hosts; i.e., there are no paraphyletic host taxa with respect to associated species of wing mites.

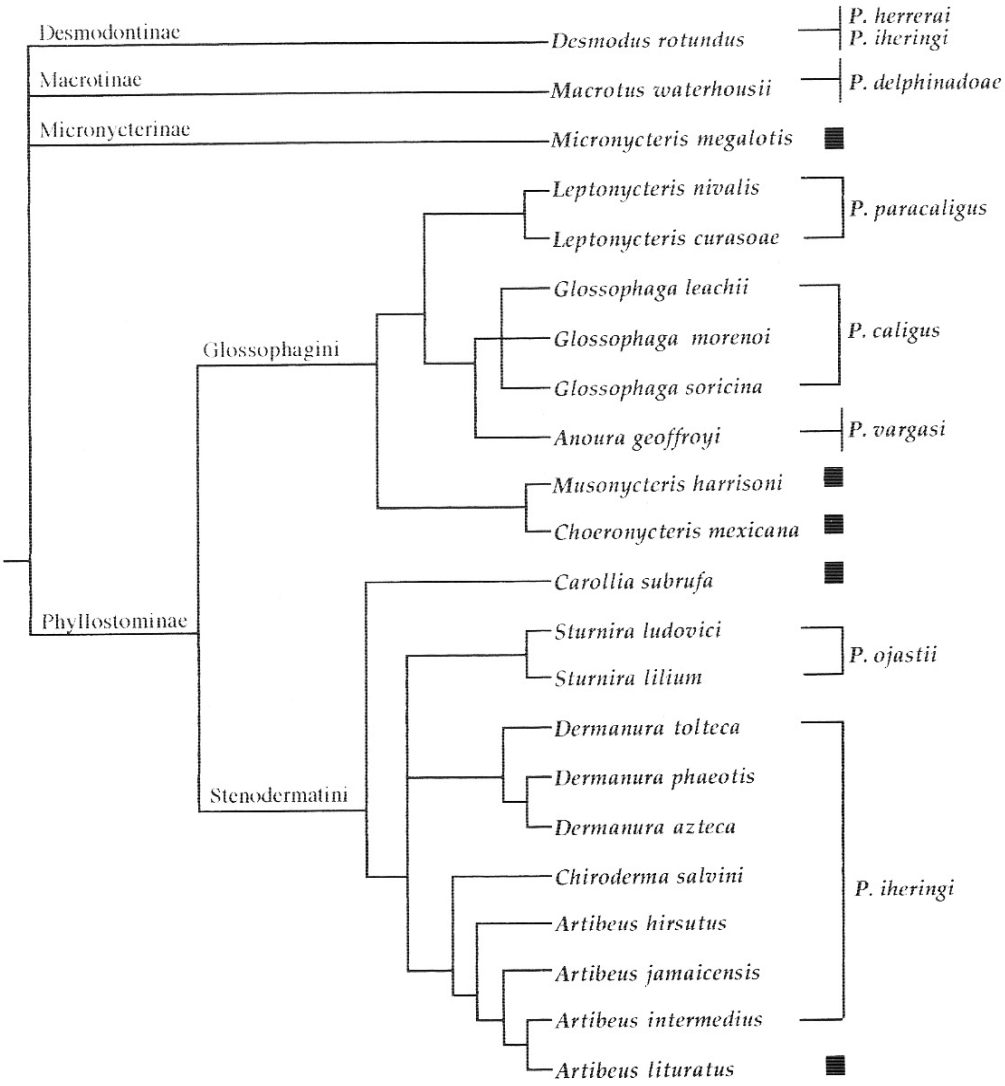


Figure 4

Phylogenetic relationships of phyllostomid bat species observed in Michoacán, with host associations of *Periglischrus* mite species. The current proposed phylogeny was constructed following Baker *et al*. (1989), Owen (1987), and Van Den Bussche (1992). ■; bat host with no mites reported.

The one exception was the mite species *Periglischrus iheringi* collected from *Desmodus rotundus*. This bat species is not a member of the clade containing *Artibeus, Dermanura*, and *Chiroderma*, with which *P. iheringi* is otherwise associated.

This exception consisted of eight *P. iheringi* specimens, which were collected from two *Desmodus rotundus* specimens. Some previous studies have reported only *P. herrerai* occurring on *D. rotundus* (Gettinger and Gribel, 1989; Machado-Allison, 1965). Other studies have indicated that *P. herrerai* is the mite most often found on the bat host, but *P. iheringi* also occurs on *D. rotundus* (Furman, 1966; Herrin and Tipton, 1975). *Periglischrus iheringi* and *P. herrerai*, although both previously reported from *D. rotundus*, have not been reported from the same host specimen (Furman, 1966; Herrin and Tipton, 1975; Machado-Allison, 1965). This pattern also was observed in Michoacán, with collection of *P. iheringi* and *P. herrerai* from different host individuals, although at the same locality. The association of *P. iheringi* with *D. rotundus* may represent a contamination incident or an accidental occurrence. However, eight *P. iheringi* mites from two individual bats, along with previous reports, are most likely sufficient to suggest an established association between *P. iheringi* and *D. rotundus*. Further investigation, including a broader geographic analysis of wing mites from *D. rotundus*, may provide some explanation for this pattern of alternate parasite species associations with this host.

Prevalence rates differed substantially among phyllostomid bat species, although the chi-square tests for mite distribution among bat genera and frugivore species were non-significant. The differences are particularly pronounced among the nectarivores. High prevalence rates were shown for *Leptonycteris nivalis* (89 percent), *Leptonycteris curasoae* (75 percent) and *Anoura geoffroyi* (91 percent). Previously, Herrin and Tipton (1975) reported a rate of 7.3 percent for *L. curasoae*, and 34.2 percent for *A. geoffroyi*. Further collection of mites from these and other glossophagine species would assist in obtaining a more confident estimate of the prevalence rate, and could lead to an understanding of the higher prevalence rates that were observed in this study. *Desmodus rotundus* had a lower rate than other phyllostomid bats. *D. rotundus* is known to perform social grooming and intensive self-grooming (Greenhall and Schmidt, 1988). It is possible that *D. rotundus* has lower prevalence rates as a result of this behavior.

Wing mites were not collected from *Micronycteris megalotis*. Furman (1966) described *Periglischrus micronycteridis* Furman 1966, found on *M. megalotis* and *M. minuta* from Panama. Herrin and Tipton (1975) reported *P. parvus* Machado-Allison 1964 on *M. hirsuta* and *M. nicefori*, and *P. micronycteridis* on *M. megalotis* and *M. minuta* from Venezuela. Machado-Allison (1965) reported *P. parvus* on *Micronycteris* sp. also from Venezuela. However, a sample of 12 *M. megalotis* specimens was collected in Michoacán from four different localities, and it is therefore likely that

the lack of association in this study was representative, at least for this host species in this region.

This study also reported no wing mites collected from *Carollia subrufa*, of which only two specimens were collected. The lack of association cannot be confirmed with such few host specimens. However, Machado-Allison (1965) noted that the bat subfamily Carolliinae (now considered a part of the tribe Stenodermatini) was not parasitized by Spinturnicidae. Herrin and Tipton (1975) reported prevalence rates to be less than one percent in the bat genus *Carollia* found in Venezuela, possibly indicating contamination or accidental occurrence. An intense study of the host genus *Carollia* is necessary to determine whether the bat genus is parasitized by spinturnicid mites.

Female *Artibeus intermedius* exhibited a higher prevalence rate than did males. Males had a 15 percent prevalence rate, and females had a 50 percent prevalence rate. The remaining bat species had inadequate samples to carry out the chi-square test for equal mite distribution between sexes. However, *Glossophaga, Artibeus, Sturnira*, and *Leptonycteris* were tested with chi-square and the results were non-significant, indicating equal mite distribution between sexes. The same is true for feeding guilds and all bats pooled.

There are no known comparable studies that have examined mite distributional differences between host sexes. Previous studies have shown that spinturnicid mites are unable to survive off hosts for longer than 24 hours (Rudnick, 1960). The transfer from one host to another is most likely from direct contact. *Periglischrus* wing mites have not been studied in detail, and very little is known about the biology of these mites. In addition, the behavior of the bat hosts is understood only anecdotally. For these reasons, it is not possible to infer why there are differences in prevalence due to the host's sex. However, it is necessary to test other species for equal mite distributions between the sexes to discern if this pattern is encountered among other species, and whether this pattern is related to social structure or other factors.

Investigation of the environmental aspects of parasite-host associations is an indirect means to evaluate host specificity. If mite distributions differ among species with respect to environmental factors, then the mite distribution can be limited by both biotic and abiotic factors. Using annual precipitation, vegetation, climate, and soils, GIS analyses can associate these factors with biological data to examine mite distribution within and among mite species. However, within this data set, sample sizes proved to be too small for statistical evaluations of most mite-environment associations.

Data from all mites pooled and from each of the mite species encountered was analyzed with chi-square. All tests were non-significant except the all-mites-pooled

test for annual precipitation, which was marginally significant. *Periglischrus ojastii* and *P. iheringi* followed the null hypothesis of equal mite distributions among the environmental factors. Therefore, the mite distributions apparently are not limited by these environmental factors. Rather, their distributions depend only on the presence of the appropriate host. This result, in addition to the phylogenetic fidelity of the *Periglischrus* mites also shown in our data, strongly suggests an invariable pattern of host tracking. Clearly, further collecting is needed to provide the additional data that are needed to confirm these findings, as well as to evaluate other environmental factors not tested in this study which may be of importance to mite distribution.

ACKNOWLEDGMENTS

This research was a partial requirement for the completion of the Master of Science degree by Lorinda Sheeler-Gordon. We thank Drs. E. Fish, D. Gettinger, and C. Jones for serving on the masters committee, and for their assistance in the development of this project. E. Fish made a substantial contribution by allowing the use of the GIS laboratory and advising the GIS portion of this project. D. Gettinger prepared the mite specimens and provided comments on the manuscript. C. Jones and two anonymous reviewers reviewed an earlier version of the manuscript. We also thank Guillermo D'Elía for translating the resumen. We thank C. Sánchez-Hernández, M. de L. Romero-Almaraz, R. López-Wilchis, A. Núñez-Garduño, and their colleagues and students for valuable assistance in collection and identification of bats. Mite specimens for SEM micrographs were removed from bats at The Museum of Texas Tech University, under the curatorial care of R.J. Baker. Financial support was provided for collaborative research investigating the mammals of Michoacán by the U.S. National Science Foundation (NSF grant INT-9301940, awarded to R. D. Owen); and by the Mexican Consejo Nacional de Ciencia y Tecnología (CONACyT grant 400-355-5-1361N, awarded to C. Sánchez-Hernández, and grant 1369-N9206, awarded to R. López-Wilchis).

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Recibido: 14 de julio 1998
Aceptado: 28 de octubre 1998

APPENDIX 1

Gazetteer of phyllostomid bat collection localities from Michoacán, México, January 1994 through January 1995. Collecting localities are listed in alphabetical order, then by date of collection period. A map with the localities numbered in accordance with this gazetteer is Fig. 2. Description of collection localities includes: Pueblo (town), Municipio (municipality); reference to nearby landmark or geographical feature; latitude (degrees, decimal minutes), longitude (degrees, decimal minutes), elevation (where available, meters); and first day of collection period (month/day/year). Collection periods were 1-3 nights in duration.

1. Apatzingan, Apatzingan; 5 km west, Lago de Chandio, La Concha . . . . . 19°5.62'N, 102°24.39'W, 250m; 1/05/95
2. Apatzingan, Apatzingan . . . . . 19°3.80'N, 102°19.64'W; 1/07/95
3. Apatzingan, Apatzingan; 5 km east . . . . . 19°3.40'N, 102°19.47'W, 200m; 1/09/95
4. Caleta de Campos, Lázaro Cárdenas; 2 km north, 2 km west 18°4.81'N, 102°45.81'W; 1/03/94
5. Carapan, Chilchota . . . . . 19°51.17'N, 102°1.96'W, 2050m; 1/04/95
6. Cenobio Moreno, Apatzingan . . . . . 19°5.92'N, 102°29.99'W, 525m; 1/09/95
7. Cerro Colorado, Juárez . . . . . 19°19.00'N, 100°27.80'W, 1350m; 10/25/94
8. Cerro Colorado, Juárez; 2 km west . . . . . 19°19.23'N, 100°29.50'W, 1113m; 10/27/94
9. Coalcomán, Coalcomán; 11 km northeast . . . . . 18°51.95'N, 103°8.07'W, 995m; 6/23/94
10. Ciudad Hidalgo, Hidalgo; Las Grutas . . . . . 19°38.36'N, 100°30.79'W, 1740m; 3/03/94
11. Ciudad Hidalgo, Hidalgo; Las Grutas . . . . . 19°41.49'N, 100°33.26'W; 6/12/94
12. Ciudad Hidalgo, Hidalgo; 6.5 km southeast, Las Grutas . . . . . 19°38.34'N, 100°30.10'W, 1690m; 10/29/94
13. Dos Aguas, Aguililla . . . . . 18°48.47'N, 102°55.73'W, 2293m; 7/01/94
14. Infiernillo, Arteaga; 1 km northwest . . . . . 18°17.32'N, 101°53.95'W, 200m; 1/1/94
15. Lajas del Bosque, Zitácuaro; 3.5 km northeast, Rancho Buena Vista . . . . . 19°14.29'N, 100°27.00'W, 1030m; 2/27/94
16. Lajas del Bosque, Zitácuaro; 4 km southeast, Minas Tiamaro . . . . . 19°13.72'N, 100°28.65'W, 1010m; 3/01/94
17. Lajas del Bosque, Zitácuaro; 4 km southeast, Mina 1;19°13.76'N, 100°28.68'W, 990m; 3/01/94
18. Lajas del Bosque, Zitácuaro; 2 km northeast, Rancho Buena Vista . . . . . 19°14.13'N, 100°27.53'W, 1100m; 6/08/94
19. Lajas del Bosque, Zitácuaro; Rancho Buena Vista . . . . . 19°14.55'N, 100°28.28'W; 8/01/94
20. La Huacana, Huacana; Arroyo La Huacana . . . . . 18°57.66'N, 101°48.33'W; 7/17/94
21. La Huacana, Huacana; 3 km northwest . . . . . 18°58.65'N, 101°48.03'W; 7/17/94
22. La Huacana, Huacana; 7 km southwest . . . . . 18°56.17'N, 101°51.36'W; 7/18/94
23. La Huacana, Huacana; Arroyo San Antonio . . . . . 18°56.93'N, 101°45.79'W, 387m; 8/07/94
24. La Huacana, Huacana; 8 km north . . . . . 19°0.39'N, 101°49.02'W; 8/08/94
25. Parácuaro, Parácuaro; 5 km north, El Aguage . . . . . 19°10.92'N, 102°12.61'W; 8/02/94
26. Pátzcuaro, Pátzcuaro; 5 km south, Los Tanques . . . . . 19°28.96'N, 101°36.02'W; 7/13/94
27. Playa Azul, Lázaro Cárdenas; 1 km north . . . . . 17°59.27'N, 102°21.07'W, 25m; 1/05/94
28. Playa Azul, Lázaro Cárdenas; 1 km east . . . . . 17°58.81'N, 102°20.25'W, 25m; 1/07/94
29. Presa Pucuato, Hidalgo; Centro Recreativo . . . . . 19°36.84'N, 100°41.09'W, 2500m; 11/03/94
30. Tancitaro, Tancitaro; 3 km north . . . . . 19°22.05'N, 102°21.97'W, 2122m; 7/05/94
31. Tuxpan, Tuxpan; 2 km west . . . . . 19°34.16'N, 100°27.75'W; 6/10/94
32. Tuzantla, Tuzantla; Rio del Puente Tuzantla . . . . . 19°13.33'N, 100°34.09'W, 700m; 8/04/94
33. Zitácuaro, Zitácuaro; 1 km southeast, Puente de San Juan Viajo . . . . . 19°26.26'N, 100°21.19'W, 1690m; 3/03/94
34. Zitácuaro, Zitácuaro; Kilometer 29 on road from Zitácuaro to Huetamo . . . . . 19°17.16'N, 100°26.88'W, 1240m; 6/10/94

APPENDIX 2

Numbers and localities of phyllostomid specimens examined. Species are listed in taxonomic order. Nomenclature follows Owen, 1987, Baker et al., 1989, Van Den Bussche, 1992, and Ramírez-Pulido et al., 1996. Number before the colon is locality number, as listed in Appendix 1. M, male specimens; F, female specimens; *, mites present on at least one individual of that sex at that collecting site. All specimens were examined for wing mites. For *Micronycteris megalotis, Musonycteris harrisoni, Choeronycteris mexicana, Carollia subrufra*, and *Artibeus lituratus*, no mites were encountered. For *Desmodus rotundus*, two mite species were recorded. For all other phyllostomid species, one mite species was encountered.

Subfamily Desmodontinae
Desmodus rotundus-7:1F; 8:1M; 12:6M*,4F*; 14:2F; 24:1M.
Subfamily Macrotinae
Macrotus waterhousii-1:1M; 3:1M; 14:2M*,1F*; 17:4M; 18:2M*; 19:3M; 25:1M*.
Subfamily Micronycterinae
Micronycteris megalotis-14:1M; 21:3M; 22:2M,1F; 24:2M,3F.
Subfamily Phyllostominae
Tribe Glossophagini
Leptonycteris nivalis-12:6M*,2F*; 29:1M.
Leptonycteris curasoae-4:1M*,4F*; 14:1F*; 18:2M; 23:1F*; 28:2M*,1F*.
Glossophaga leachii-2:1M; 4:1M*,1F*; 6:3M; 8:1M; 21:1F; 24:1F*.
Glossophaga morenoi-1:1F; 4:1F; 12:1M*; 14:4M*; 20:1M,1F; 21:1M,3F*; 22:1F; 32:1F.
Glossophaga soricina-4:2M*; 8:6M*,2F; 14:3M*; 18:1M; 19:2F; 22:1M*; 34:1F.
Anoura geoffroyi-12:10M*; 33:1F*.
Musonycteris harrisoni-14:1F.
Choeronycteris mexicana-16:1M.
Tribe Stenodermatini
Carollia subrufa-4:1M; 28:1F.
Sturnira lilium-7:1M,9F*; 8:1M,2F*; 9:1M,1F; 12:2F*; 15:1M; 25:7M*,8F*; 28:1F*;34:2M,3F*.
Sturnira ludovici-5:3M*,1F*; 12:2M,5F*; 13:1F; 30:3F.
Chiroderma salvini-8:1F*.
Artibeus hirsutus-1:1M; 12:1F*; 17:1M; 32:1M,1F*.
Artibeus jamaicensis-1:4M*,1F; 2:1M,1F; 7:2M*; 14:1M*,2F*; 19:2M*; 20:2M,1F; 25:1M*; 27:1F*; 28:1M.
Artibeus lituratus-7:1F; 27:1F.
Artibeus intermedius-1:3M,2F*; 2:2M,1F; 6:1M,1F; 7:6M*,9F*; 14:1M,1F*; 19:1F; 23:1F; 27:3M*,2F*; 28:2M,1F*; 33:2M,1F.
Dermanura azteca-10:7F*; 12:2M*,2F*; 33:1M.
Dermanura phaeotis-1:1F; 4:2F*; 8:2M,1F.
Dermanura tolteca-7:1M*; 8:4M,6F*; 9:2F; 19:1M.