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ECTOPARASITES OF THE OCCULT BAT, *MYOTIS OCCULTUS* (CHIROPTERA: VESPERTILIONIDAE)

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ABSTRACT.—Only a single previous study has examined ectoparasites of the occult bat (*Myotis occultus*), from which only 2 species of fleas were identified. For our study, we examined 202 individuals, 52 fresh hosts and 150 museum specimens, from New Mexico and southern Colorado for ectoparasites. We recorded 2158 ectoparasites, 634 from fresh hosts and 1524 from museum specimens. Ectoparasites belonged to 10 families and 13 genera of insect or acari and represent new host and locality records. In general, ectoparasites collected from fresh hosts and museum specimens were represented by 4 major species of mite: *Macronyssus crosbyi, Alabidocarpus calcaratus, Acanthophthirius lucifugus,* and *Alabidocarpus* nr. *eptesicus.* From our study, we found fresh hosts to have significantly greater prevalence values for *Myodopsylla gentilis* (flea), *Chiroptonyssus robustipes* (mite), and *Leptotrombidium myotis* (chigger), whereas museum specimens had significantly greater prevalence values for *A. calcaratus* (mite) and *A.* nr. *eptesicus* (mite). There were no significant differences between prevalence values for 4 mites including *M. crosbyi, A. lucifugus, Pteracarus* nr. *minutus,* and *Cryptonyssus* sp. Our study represents the only extensive study of ectoparasites on *M. occultus* and provides evidence for the importance of examining fresh hosts and museum specimens in future ectoparasite studies.

Key words: ectoparasites, Myotis occultus, *hosts, museum, specimen, Colorado, New Mexico.*

Few studies have reported on ectoparasites from species of *Myotis* in the southwestern United States. Krutzsch (1955) reported some of the earliest records of ectoparasites from *M. yumanensis, M. thysanodes, M. californicus,* and *M. ciliolabrum,* including Spinturnicidae and Macronyssidae (mites), Nycteribiidae (bat flies), Ischnopsyllidae (fleas), and Argasidae (ticks). Bradshaw and Ross (1961) reported on 20,000 bats from Arizona, documenting 23 species of ectoparasites from 14 species of bats, including *M. yumanensis, M. velifer, M. thysanodes, M. californicus,* and *M. ciliolabrum.*

Dooley et al. (1976) examined 60 bats of 12 species from western Texas and southern New Mexico but reported only 40 *Chiroptonyssus robustipes* from 7 individuals of *M. californicus.* Steinlein et al. (2001) conducted a thorough study on ticks of bats from New Mexico and documented *Ornithodoros kelleyi* from *M. velifer* and *M. thysanodes,* and *O. rossi* from *M. evotis.* Recently, Ritzi et al. (2001, 2002a, b) noted several ectoparasites, including smaller-sized ectoparasites (e.g., myobiid mites), from *M. ciliolabrum, M. thysanodes, M. velifer, M. volans,* and *M. yumanensis* from New Mexico and Texas.

The occult bat (*Myotis occultus*) is endemic to the southwestern United States (Barbour and Davis 1969, Hoffmeister 1986, Piaggio et al. 2002). The only known records of ectoparasites from this species were documented by Stager (1943). He examined 63 individuals from California and reported 2 species of fleas, *Myodopsylla collinsi* and *M. gentilis.* Our objective was to determine the presence and abundance of ectoparasites from *M. occultus* from New Mexico and southern Colorado and to compare the numbers and types of ectoparasites from fresh hosts to those of parasites remaining on museum specimens after preparation and drying.

METHODS

We examined 202 individuals of *M. occultus,* including adults and juveniles of both sexes from 10 counties in New Mexico and 2 in southern Colorado, for ectoparasites (Appendix). We captured 52 bats, which we refer to throughout as "fresh hosts," by hand at roost sites or in mist nets at drinking sites from 2003 to 2005. Forty-three of these individuals were kept as museum vouchers and are housed at

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the Museum of Southwestern Biology (MSB), University of New Mexico, Albuquerque. The remaining 150 bats examined were museum specimens in the MSB collected from 1959 to 2002. We followed techniques described by Whitaker (1988) and examined fresh hosts for ectoparasites immediately after euthanasia (or prior to release) and before preparation as museum vouchers under a 7–45X stereo-zoom Meiji microscope with fine-point forceps and probes. This technique included examining hairs (from tip to base), ears, wings, and tail membranes on ventral and dorsal sides of the bat. We used this same technique for museum specimens housed at MSB. Ectoparasites retrieved from specimens are also housed at MSB.

After locating ectoparasites, we counted them and placed them in vials of 95% ethanol, from which we mounted small individuals (e.g., mites and chiggers) onto microscope slides with PVA mounting medium and 12-mm round coverslips. After the medium dried, we sealed edges of coverslips with clear fingernail polish, and then we viewed the slides with a Leitz compound microscope to identify ectoparasites. In general, we kept larger ectoparasites such as bat flies (Nycteribiidae), fleas (Ischnopsyllidae), and bed bugs (Cimicidae) in vials of ethanol and later identified them in a watch glass with a stereo-zoom microscope. We identified ectoparasites to the lowest taxonomic level, usually to species, following species-specific dichotomous keys (Cooley and Kohls 1944, Rudnick 1960, Kohls et al. 1965, Radovsky 1967, Dusbabek 1973, Fain and Whitaker 1976, Brennan and Goff 1977, Lewis 1978, Whitaker 1982). We calculated prevalence percentages and mean intensities, following Bush et al. (1997), with the following formulas: prevalence = (individuals infested / total individuals examined) · 100; mean intensity = (parasites / individuals infested). To assess the general differences between prevalence values of ectoparasites observed on museum specimens and those of ectoparasites observed on fresh hosts, we used SAS 9.1.3, Service Pack 3, to perform a nonparametric Wilcoxon's 2-sample test with a 95% confidence interval.

RESULTS

Overall, we documented 44 of 52 (84%) fresh hosts and 125 of 150 (84%) museum specimens as parasitized. From these hosts, we retrieved 2158 ectoparasites belonging to 10 families and 14 genera of insect or acari (Table 1). The most abundant parasites collected from *M. occultus* were *Alabidocarpus* nr. *eptesicus* ($n = 756$), *Macronyssus crosbyi* ($n = 567$), *Alabidocarpus calcaratus* ($n = 427$), and *Acanthophthirius lucifugus* ($n = 242$; Table 1). Of 2158 ectoparasites, we obtained 634 from fresh hosts and 1524 from museum specimens (Table 1). Ectoparasites were documented from 10 counties in New Mexico and 2 counties in southern Colorado, all of which represent new locality records (Appendix). Also, all ectoparasites documented from *M. occultus,* except *Myodopsylla gentilis,* represent new host records, and 3 ectoparasites represent undescribed species (Appendix).

In comparing host types, we observed that most of the ectoparasites collected from fresh hosts were represented by 4 major species that included *M. crosbyi* (200 individuals recovered), *A. calcaratus* (138), *A. lucifugus* (105), and *A.* nr. *eptesicus* (102; Table 1). Likewise, all 4 species were frequently obtained from museum specimens, but *A.* nr. *eptesicus* contributed the greatest number of individuals collected with a total of 654, followed by *M. crosbyi* (367 individuals), *A. calcaratus* (289), and *A. lucifugus* (137; Table 1).

From fresh hosts, the most prevalent ectoparasite encountered was *M. crosbyi* (50%), followed by *A. lucifugus* (42%), *M. gentilis* (17%), *C. robustipes* (13%), *A. calcaratus* (12%), *P.* nr. *minutus* (12%), and *A.* nr. *eptesicus* (6%; Table 1). *Macronyssus crosbyi* (55%) also was the most prevalent species encountered on museum specimens, followed by *A. lucifugus* (36%), *A. calcaratus* (26%), and *A.* nr. *eptesicus* (26%; Table 1). From fresh hosts and museum specimens, *A.* nr. *eptesicus* had the greatest mean intensities at 34 and 16.76, respectively, followed by *A. calcaratus* (23, 7.40) and *M. crosbyi* (7.69, 4.48; Table 1). Interestingly, *P.* nr. *minutus* and *A. lucifugus* ranked fourth and fifth, respectively, for greatest mean intensities for fresh hosts (5 and 4.77), whereas the rankings were opposite for the same ectoparasites collected from museum specimens (2.54 and 2.45; Table 1). In the comparison of prevalence values of ectoparasites between fresh hosts and museum specimens, we found significant differences for *M. gentilis* ($P < 0.01$), *A. calcaratus* ($P = 0.03$), *C. robustipes* ($P < 0.01$), *A.* nr. *eptesicus* ($P <$

TABLE 1. Ectoparasites collected from fresh hosts ($n = 52$) and museum specimens ($n = 150$) of *M. occultus* occurring in New Mexico and southern Colorado. Values in parentheses denote results for museum specimens. Asterisks (*) denote significant differences ($P < 0.05$) at 95% CI for nonparametric Wilcoxon's 2-sample test of prevalence values.

Ectoparasite	No. of hosts infested	Prevalence (%)	Mean intensity	No. of ectoparasites recovered
ACARI: MESOSTIGMATA:				
MACRONYSSIDAE				
Macronyssus crosbyi	26 (82)	50 (55)	7.69 (4.48)	200 (367)
Chiroptonyssus robustipes *	7 (3)	13 (2)*	3.71 (1)	26 (3)
Cryptonyssus desultorius	1 (1)	(1)	(1)	1 (1)
Cryptonyssus sp.	3 (4)	6 (3)	1 (1.25)	3 (5)
ACARI: ASTIGMATA:				
CHIRODISCIDAE				
Alabidocarpus calcaratus *	6 (39)	12 (26)*	23 (7.40)	138 (289)
Alabidocarpus nr. eptesicus *	3 (39)	6 (26)*	34 (16.76)	102 (654)
ACARI: PROSTIGMATA:				
MYOBIIDAE				
Acanthophthirius lucifugus	22 (54)	42 (36)	4.77 (2.54)	105 (137)
Pteracarus nr. *minutus*	6 (22)	12 (15)	5 (2.45)	30 (54)
ACARI: MESOSTIGMATA:				
SPINTURNICIDAE				
Spinturnix americanus	2 (3)	4	1	2
ACARI: PROSTIGMATA:				
TROMBICULIDAE				
Leptotrombidium myotis *	2 (1)	4 (1)*	1.5 (1)	3 (1)
Unidentified Trombiculidae	1	2	1	1
SIPHONAPTERA:				
ISCHNOPSYLLIDAE				
Myodopsylla gentilis *	9 (6)	17 (4)*	1.66 (1)	15 (6)
HEMIPTERA: CIMICIDAE				
Cimex pilosellus	4	8	1	4
DIPTERA: NYCTERIBIIDAE				
Basilia forcipata	3	6	1.33	4
ACARI: METASTIGMATA:				
ARGASIDAE				
Ornithodoros sp.	(2)	(1)	(1.5)	(3)
ACARINA: ASTIGMATA:				
GLYCYPHAGIDAE				
Glycyphagus hypudaei	(1)	(1)	(1)	(1)
TOTAL				634 (1524)

0.01), and *Leptotrombidium myotis* ($P = 0.05$, chigger). Of these, we found significantly greater prevalence values for *M. gentilis*, *C. robustipes*, and *L. myotis* retrieved from fresh hosts, whereas prevalence values were greater for *A. calcaratus* and *A.* nr. *eptesicus* retrieved from museum specimens (Table 1).

Despite the ability of larger ectoparasites to readily leave dead hosts, we collected 3 larger species of ectoparasite from museum specimens. These included 6 individuals of *M. gentilis* (flea) and 3 each for *Spinturnix americanus* (wing mite) and *Ornithodoros* sp. (tick; Table 1). Specimens of *M. gentilis* were located within the fur and were easily removed, whereas those of *S. americanus* were found between folded wing membranes. The 3 larval ticks collected were attached to the skin of museum specimens and had to be forcibly pulled to remove them (Table 1). Because they were attached, one of the more critical features (i.e., the proboscis) for identifying the species was broken when the ticks were removed from hosts. Although it cannot be verified, it is likely that the ticks may be *O. kelleyi* or *O. yumatensis*, as those species have been reported from *M. velifer*, *M. yumanensis*, and *M. thysanodes* in the southwestern United States (Bradshaw and Ross 1961, Ritzi et al. 2001). Although these large ectoparasites were collected from museum specimens, other large ectoparasites, such as *Basilia forcipata*

(bat fly) and *Cimex pilosellus* (bed bug), were found only on netted individuals (Table 1).

We observed that smaller ectoparasites of *M. occultus* tend to remain on the host even after the host has been prepared as a museum specimen. *Alabidocarpus calcaratus* and *A.* nr. *eptesicus* were some of the smallest ectoparasites found on *M. occultus.* Interestingly, all specimens of *Alabidocarpus* (1182 individuals), with the exception of one, were collected from fresh hosts and museum specimens of *M. occultus* that occurred in montane areas found in Bernalillo, Catron, Cibola, Grant, Otero, and San Miguel counties of New Mexico and Saguache County of Colorado (Appendix). A single *A. calcaratus* was found on a host that was netted in the Rio Grande Valley, Sierra County, New Mexico (Appendix). We observed no other ectoparasites in this study with such a defined distributional pattern.

DISCUSSION

To date, our study represents the only extensive examination of ectoparasites from *M. occultus.* Interestingly, we discovered that examining fresh hosts and museum skins of *M. occultus* provided the same amount of overall infestation by ectoparasites, with 84% of the hosts infested. However, the 2 sampling methods represented the ectoparasitic community quite differently. Of the ectoparasites reported in this study and regardless of host type (i.e., fresh host or museum specimen), *M. crosbyi* was the most prevalent parasite on *M. occultus.* In general, this mite is one of the most frequently encountered ectoparasites on many vespertilionid bats and has been reported on several species of *Myotis* in the southwestern United States: *M. yumanensis, M. evotis, M. volans*, *M. californicus, M. ciliolabrum, M. thysanodes,* and *M. velifer* (Radovsky 1967, Ritzi et al. 2001, Ritzi et al. 2002a). This ectoparasite is capable of easily leaving its host and moving to another when hosts are in contact. Interestingly, there were no significant differences in the prevalence values for *M. crosbyi* between fresh hosts and museum specimens. This might have been due to the sample being largely composed of protonymphs, which have a different attachment to the host and thus lower mobility than their adult counterparts.

It is not surprising to find the next-largest prevalence values, after *M. crosbyi,* were for *Acanthophthirius, Alabidocarpus,* and *Pteracarus* retrieved from museum specimens. All 3 genera belong to families of mite that are host specific, and all 3 attach to individual hairs, usually at the base of the hair. Therefore, they are less likely to be lost when museum skins are handled or fresh hosts are groomed or prepared as voucher specimens. Of *Acanthophthirius, Alabidocarpus,* and *Pteracarus* collected from fresh hosts and museum specimens, *Acanthophthirius* had the highest prevalence for both host types. In a study on ectoparasites of *Myotis sodalis,* Ritzi et al. (2002b) noted that *Acanthophthirius lucifugus* never leaves its host, not even to lay eggs. Given the occurrence of *A. lucifugus* on *Myotis lucifugus* and *M. sodalis* (Ritzi et al. 2002b), it seems likely that *A. lucifugus* also parasitizes congeners when those hosts share a roost. Nevertheless, the high prevalence from fresh hosts and museum skins gives some indication of their attachment to a host, even when the host is dead.

Statistical analyses indicated significant differences in prevalence values for *M. gentilis, A. calcaratus, C. robustipes, A.* nr. *eptesicus,* and *L. myotis* collected from fresh hosts and museum specimens. We recognize that some of these differences may reflect variation in local infestation, localities sampled, time of sampling, or other variables. Despite this, it is important to note that certain host types are likely to have a greater presence of some ectoparasites. Overall, our analyses indicated that many of the larger parasites, capable of leaving their hosts readily, were found in greater numbers (or only) on fresh hosts. This is evident in the greater number of *M. gentilis* found on netted individuals versus museum specimens. Moreover, *B. forcipata* and *C. pilosellus* were only found on fresh hosts. We have observed *B. forcipata* crawling quickly and easily across the fur, often diving under the surface of the hair of the bat or crawling onto the hand of the person handling the bat. It is more than likely that their high vagility allows them to leave the host easily, especially when the host is prepared as a voucher specimen. Although *C. pilosellus* is a large ectoparasite and was found only on fresh hosts, it does not move as fast as *B. forcipata.* However, it does not aggressively attach to its host and likely leaves after the host is prepared as a voucher specimen.

Sampling museum specimens for ectoparasites may not provide accurate values of prevalence and mean intensity for many ectoparasites. Often this inaccuracy pertains to those ectoparasites that are capable of leaving their host prior to or even after the host has been prepared as a voucher specimen (e.g., fleas, wing mites, and bed bugs). Surprisingly, the only record of ticks, *Ornithodoros* sp., from *M. occultus* that are documented in this study were retrieved from museum specimens collected in 1962. Museum specimens also potentially harbor smaller ectoparasites, even if they have been examined for larger ectoparasites. For example, one museum specimen of *M. occultus* examined by Steinlein et al. (2001) did not harbor any ticks. However, upon closer examination, we found 4 individuals of *M. crosbyi,* 5 of *A. lucifugus,* and 1 of *Cryptonyssus* sp.

We believe that some of the ectoparasites from this study are specific to *M. occultus,* or at least to *Myotis.* Whitaker (1988) defined host-specific parasites as those that tend to occur on one or a few host species. In instances when a parasite has become host specific, it allows for the parasite to "evolve specifically to exploit the phenology and life history of its host" (Whitaker 1988: 461). Often these specializations are seen in parasites that are permanently on their hosts, as noted for the myobiid mites *Acanthophthirius* and *Pteracarus* (Fain 1994), both of which were found on *M. occultus.*

Although some ectoparasites on *M. occultus* occur on congeners, few are found on other genera of bats; those that are can likely be considered facultative parasites. For example, *C. robustipes* has been documented on several species of bats, but it is typically associated with *Tadarida brasiliensis* (Radovsky 1967). All but 3 specimens of *C. robustipes* were collected from fresh hosts located under a wooden bridge in the Rio Grande Valley, Sierra County, New Mexico. The hosts shared the same roost with a large colony of *T. brasiliensis,* thus providing additional evidence that *C. robustipes* is a facultative parasite.

Some ectoparasites found on *M. occultus* seem to have host specificity related to the geographic range of the host. For example, we found that all except one specimen of *A. calcaratus* and all *A.* nr. *eptesicus* came from hosts occurring only in montane areas. This trend seems to follow the similar geographic differences in *M. occultus,* as noted by Valdez (2006), who observed that large forms of *M. occultus* occurred only in montane areas, whereas smaller individuals were found only at lower elevations (i.e., Rio Grande Valley).

Herein, we document the presence of a single *Glycyphagus hypudaei* (mite) from a museum specimen. Like many *G. hypudaei* collected, our specimen was a hypopus (deutonymph). Hypopi are considered phoretic because they lack mouth parts but possess specialized clasping structures for attaching to fur, allowing them to be transported from one place to another (Whitaker and Wilson 1974, Whitaker et al. 2007). Interestingly, *G. hypudaei* is more common on terrestrial mammals (e.g., *Blarina brevicauda, Clethrionomys gapperi, Cryptotis parva, Peromyscus maniculatus,* and *Ondatra zibethicus*). *Myotis occultus* represents a unique host type for *G. hypudaei.*

We encourage others to examine both fresh hosts and museum specimens, when available. Researchers examining fresh hosts can obtain ectoparasites that are often lost after the host has been prepared as a museum specimen. However, examining museum specimens can clearly provide additional new information, especially for rare or extinct host species.

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APPENDIX. List of new state and county records for ectoparasites found on *Myotis occultus* in southern Colorado and New Mexico. Values represent number of ectoparasites retrieved from fresh hosts, whereas values in parentheses represent number of ectoparasites collected from museum specimens.

Colorado

GUNNISON COUNTY.—*Macronyssus crosbyi* (4); *Glycyphagus hypudaei* (1).

SAGUACHE COUNTY.—*Macronyssus crosbyi* 18; *Acanthophthirius lucifugus* 21; *Myodopsylla gentilis* 6; *Alabidocarpus calcaratus* 128; *Basilia forcipata* 4; *Alabidocarpus* nr. *eptesicus* 40, (125); *Cryptonyssus* sp. 1; Trombiculidae 1; *Leptotrombidium myotis* 3.

New Mexico

BERNALILLO COUNTY.—*Acanthophthirius lucifugus* (1); *Alabidocarpus* nr. *eptesicus* (2).

CATRON COUNTY.—*Macronyssus crosbyi* (85); *Acanthophthirius lucifugus* (34); *Alabidocarpus calcaratus* (129); *Pteracarus* nr. *minutus* (16); *Chiroptonyssus robustipes* (1); *Alabidocarpus* nr. *eptesicus* (209); *Cryptonyssus* sp. (3); *Spinturnix americanus* (2); *Leptotrombidium myotis* (1).

CIBOLA COUNTY.—*Macronyssus crosbyi* (40); *Acanthophthirius lucifugus* (18); *Pteracarus* nr. *minutus* (21); *Alabidocarpus* nr. *eptesicus* (70); *Cryptonyssus desultorius* (1).

COLFAX COUNTY.—*Macronyssus crosbyi* (1); *Acanthophthirius lucifugus* (2).

GRANT COUNTY.—*Macronyssus crosbyi* (87); *Acanthophthirius lucifugus* (24); *Alabidocarpus calcaratus* (18); *Pteracarus* nr. *minutus* (7); *Chiroptonyssus robustipes* (1).

OTERO COUNTY.—*Macronyssus crosbyi* 12, (100); *Acanthophthirius lucifugus* 15, (44); *Myodopsylla gentilis* 3; *Alabidocarpus calcaratus* 9, (109); *Pteracarus* nr. *minutus* (6); *Chiroptonyssus robustipes* (1); *Cimex pilosellus* 1; *Alabidocarpus* nr. *eptesicus* 62, (248); *Cryptonyssus* sp. 2, (2); *Spinturnix americanus* (1).

SANDOVAL COUNTY.—*Pteracarus* nr. *minutus* (1).

SAN MIGUEL COUNTY.—*Acanthophthirius lucifugus* (6); *Alabidocarpus calcaratus* (33); *Pteracarus* nr. *minutus* (1).

SIERRA COUNTY.—*Macronyssus crosbyi* 143; *Acanthophthirius lucifugus* 63; *Myodopsylla gentilis* 6; *Alabidocarpus calcaratus* 1; *Pteracarus* nr. *minutus* 27; *Chiroptonyssus robustipes* 26; *Cimex pilosellus* 3; *Spinturnix americanus* 2.

SOCORRO COUNTY.—*Macronyssus crosbyi* 27, (50); *Acanthophthirius lucifugus* 6, (8); *Myodopsylla gentilis* (6); *Pteracarus* nr. *minutus* 3, (2); *Cryptonyssus desultorius* 1; *Ornithodoros* sp. (3).