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Source: Journal of Wildlife Diseases, 43(2) : 291-299

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-43.2.291

Journal of Wildlife Diseases, 43(2), 2007, pp. 291–299

Rabies in Bats from Alabama

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ABSTRACT: Data on rabies virus infection in bats that were submitted to the Alabama Department of Public Health from 1995–2005 were analyzed. Demographic factors, such as species and sex, and temporal aspects, such as yearly and monthly trends, were investigated. Thirteen species of bats were submitted, and of those, individuals from seven species were rabid; prevalence was highest in *Lasiurus borealis* and *Pipistrellus subflavus* and lowest in *Eptesicus fuscus* and *Nycticeius humeralis*. There was no difference in prevalence of rabies between sexes or years. Statistically, more rabid bats were submitted in August, September, and November; and fewer were submitted in March, June, and July. Results were similar to those from other regions of North America; these data from Alabama can help to present a more complete view of rabies in bats in North America.

Key words: Alabama, bats, Chiroptera, Molossidae, rabies, *Rhabdoviridae*, Vespertilionidae.

Most cases of rabies in the United States occur in wildlife (>91% in 2004), because most domestic animals are vaccinated (Krebs et al., 2005). Raccoons (*Procyon lotor*) are most frequently infected (37.5%), followed by skunks (27.1%; primarily the striped skunk, *Mephitis mephitis*), and bats (19.9%). Bats included at least 21 rabid species from 1993–2000 (Mondul et al., 2003; Krebs et al., 2005); other wildlife species contributed <10% of all cases of rabies in 2004 (Krebs et al., 2005).

Rabies virus was first identified in bats from the United States in the northern yellow bat (*Lasiurus intermedius*) from Florida in 1953 (Venters et al., 1954). Since that time, rabies has been detected in bats across the contiguous United States (Krebs et al., 2005). Prevalence of rabies in bats from the United States and Canada range from 2.4% to 15% (Table 1). These prevalence estimates may not accurately reflect the occurrence of rabies in these populations because they are derived from submissions to state health departments (Parker et al., 1999). Typically, <2% of free-flying bats are rabid (Venters et al., 1954; Girard et al., 1965; Trimarchi and Debbie, 1977; Constantine, 1988; Yancey et al., 1997).

Solitary species of bats frequently have a higher prevalence of rabies than colonial species (Table 1). Various explanations for this observation have been proposed, including sampling bias, aggressive behavior by solitary species, difference in genetic variant of rabies virus, and migrational stress (Rosatte, 1985; Childs et al., 1994; Parker et al., 1999). Evidence to support these hypotheses is somewhat contradictory in that the species with the second greatest prevalence, the Brazilian free-tailed bat (*Tadarida brasiliensis*), is a colonial species that is migratory throughout most of its range (Mondul et al., 2003). In addition, aggressive behavior by rabid individuals has been noted in a colonial species, the big brown bat (*Eptesicus fuscus*), whereas a solitary species, the eastern red bat (*Lasiurus borealis*) seems to be less aggressive than other species (Baer and Smith, 1991; Parker et al., 1999; Mondul et al., 2003). Although the observed prevalence of rabies in solitary species submitted for rabies examination is consistently greater than in colonial species, most cases of chiropteran rabies in the United States and Canada are found in *E. fuscus* (Pybus, 1986; Mondul et al., 2003).

Bats infected with rabies virus can infect humans if contact occurs. Although humans in the United States rarely are infected with rabies virus from any source, 28 of 31 cases of human rabies acquired in

TABLE 1. Total number of bats by family and genus or species, number of bats that tested positive for rabies virus, and prevalence of rabies virus in 1,389 bats tested in Alabama, 1995–2005.

Family	Species	Prevalence in Alabama	Prevalence reported in literature
Vespertilionidae	*Corynorhinus rafinesquii*[a]	0/2 (0%)	Arkansas (0%)[c], Florida (0%), South Carolina (0%)
	Eptesicus fuscus[a]	22/372 (5.9%)	Alberta (9.7%), British Columbia (25%), Arkansas (4.1%), Colorado (17%), Florida (0%), Georgia (0%), Illinois (3%), Indiana (3.7%), Manitoba (0%), Michigan (5.1%), Minnesota (3.2%), New York (6.3%), Oklahoma (10.8%),Ontario (11.4%), Pennsylvania (4.7%), Saskatchewan (3%), South Carolina (5%), Texas (7.1%)
	Lasiurus borealis[b]	51/300 (17.0%)	Arkansas (17.4%), Colorado (12%), Florida (5.9%), Georgia (15%), Illinois (5%), Indiana (7.1%), Manitoba (0%), Michigan (12.5%), Minnesota (0%), New York (4.8%), Oklahoma (8.8%), Ontario (20%), Pennsylvania (6.8%), South Carolina (18%), Texas (6.7%)
	Lasiurus cinereus[b]	0/18 (0%)	Alberta (24%), Arkansas (28%), Colorado (40%), Florida (16.6%), Georgia (20%), Illinois (11%), Indiana (19.6%), Manitoba (67%), Michigan (10%), Minnesota (20%), New York (10%), Oklahoma (37.5%), Ontario (33%), Pennsylvania (50%), South Carolina (13%), Texas (26.3%)
	Lasiurus intermedius[b]	0/2 (0%)	Florida (14.1%), South Carolina (0%), Texas (9.2%)
	Lasiurus seminolus[b]	23/201 (11.4%)	Florida (6.3%), Georgia (11%), South Carolina (13%), Texas (14.3%)
	Lasiurus spp.[b]	3/36 (8%)	
	Lasionycteris noctivagans[b]	0/6 (0%)	Alberta (2%), Arkansas (0%), Colorado (5%), Florida (0%), Georgia (0%), Illinois (4%), Indiana (0%), Manitoba (25%), Michigan (20%), Minnesota (50%), New York (8%), Ontario (0%), Pennsylvania (0%), South Carolina (5%), Texas (0%)
	Myotis austroriparius[a]	0/6 (0%)	Arkansas (0%), Florida (1.7%), Georgia (16.6%), South Carolina (0%), Texas (0%)
	Myotis grisescens[a]	4/40 (10%)	Arkansas (8.3%), Georgia (0%), Oklahoma (0%)
	Myotis septentrionalis[b]	0/2 (0%)	Alberta (0%)

TABLE 1. Continued.

Family	Species	Prevalence in Alabama	Prevalence reported in literature
	Myotis spp.	0/9 (0%)	
	Nycteceius humeralis[a]	2/175 (1.1%)	Arkansas (2.7%), Georgia (1.2%), Illinois (2%), Indiana (0%), Michigan (0%), Oklahoma (0%), South Carolina (3%), Texas (0.7%)
	Pipistrellus subflavus[b]	12/55 (22%)	Arkansas (14.3%), Florida (3.9%), Georgia (0%), Indiana (12.5%), Manitoba (0%), New York (20%), Oklahoma (22.2%), Ontario (25%), Pennsylvania (20%), South Carolina (7%), Texas (0%)
Molossidae	*Tadarida brasiliensis*[a]	20/165 (12.1%)	Arkansas (3.6%), Colorado (12%), Florida (7.9%), Georgia (1.3%), Oklahoma (0%), South Carolina (9%), Texas (16.4%)
	Total solitary	89/620 (14.4%)	Alberta (8.3%), Florida (12.2%), Georgia (14%), Michigan (13%), Minnesota (20%), South Carolina (15.3%)
	Total colonial	48/760 (6.3%)	Alberta (3.8%), Florida (3.1%), Georgia (1.3%), Michigan (4.5%), Minnesota (2.5%), South Carolina (4.5%)
	Total	137/1,389 (9.9%)	Alberta (4.6%), Arkansas (9.8%), Arizona (2.4%), British Columbia (9.7%), Colorado (15%), Florida (10.3%), Georgia (6.7%), Illinois (6%), Indiana (5.1%), Kansas (10.8%), Michigan[d] (6.2%), Minnesota (3.1%), New York (4.6%), Oklahoma (8.1%), Ontario (5.9%), Pennsylvania (3.9%), Saskatchewan (2.9%), South Carolina (9%), Texas (11%)

[a] Colonial species.

[b] Solitary species.

[c] References unless otherwise indicated: Alberta (Rosatte, 1985), Arizona (Dean et al., 1960), Arkansas (Heidt et al., 1991), British Columbia (Pybus, 1986), Colorado (Pape et al., 1999), Florida (Bigler et al., 1975), Georgia (Richardson et al., 1966), Illinois (Burnett, 1989), Indiana (Whitaker and Miller, 1973), Kansas (Birney and Rising, 1967), Manitoba (Beauregard, 1969), Michigan (Kurta, 1979), Minnesota (Steece et al., 1982), New York (Childs et al., 1994), Oklahoma (Caire, 1998), Ontario (Beauregard, 1969), Pennsylvania (Wampler and Kirkland, 1981), Saskatchewan (Pybus, 1986), South Carolina (Parker et al., 1999), Texas (Rohde et al., 2004).

[d] (Feller et al., 1997).

the United States from 1990 to 2003 were linked to genetic variants of rabies virus from bats (Krebs et al., 2004). Most of these cases (17/24 cases during1990–2000) were related to a specific variant found in silver-haired bats (*Lasionycteris noctivagans*) and eastern pipistrelles (*Pipistrellus subflavus*; Messenger et al., 2002; Mondul et al., 2003). Rabid bats of all species were most likely detected in autumn, but *L. noctivagans* and *P. subflavus* were more likely to be rabid if collected in summer (Mondul et al., 2003). In contrast, when sources of rabies infections of domestic

animals in the United States were investigated, none of the 78 dogs and only 1 of 230 cats in 1999 had genetic variants of rabies virus that came from bats (McQuiston et al., 2001); the variant of rabies virus infecting the single cat was determined to be from *E. fuscus* (McQuiston et al., 2001).

Fifteen species of bats are native to Alabama, including: *E. fuscus*, *L. noctivagans*, *L. borealis*, *Lasiurus cinereus*, *L. intermedius*, *Lasiurus seminolus*, *Myotis austroriparius*, *Myotis grisescens*, *Myotis lucifugus*, *Myotis septentrionalis*, *Myotis sodalis*, *Nycticeius humeralis*, *P. subflavus*, *Corynorhinus rafinesquii*, and *T. brasiliensis* (Best, 2004). Individuals from 12 of these species, excluding *M. septentrionalis*, *M. sodalis*, and *C. rafinesquii*, have tested positive for rabies virus in the United States (Constantine, 1988). In this study, data from bats provided to Auburn University by the Alabama Department of Public Health from 1995 through 2005 were studied to elucidate epidemiology of chiropteran rabies in Alabama.

Bats submitted for rabies diagnosis to the Alabama Department of Public Health were provided to the authors with results of fluorescent antibody tests for rabies virus and dates of submission. Bats that were reported as not suitable for rabies diagnosis were excluded from this study. Species and sex identification were determined by one of the authors (TLB), and all bats were deposited in the museum of Auburn University. In most cases, *L. borealis* and *L. seminolus* could be identified, but 32 individuals were difficult to distinguish and were categorized as *Lasiurus* spp. For nine specimens of *Myotis*, it was not possible to determine species; thus, these were categorized as *Myotis* spp. Data were evaluated to detect possible relationships between infection by rabies virus and demographic and temporal aspects in populations of bats. Contingency tables were produced using SPSS statistical software (SPSS, 2004) to investigate trends in rabies in bats by year, month, sex, and species. Adjusted residual (AR) absolute values of >1.96 were used to indicate a statistically significant difference using Pearson Chi-Squared values. Missing data for some specimens caused them to be removed from statistical analyses, but in all cases the sample consisted of $\geq 94\%$ of submitted bats.

From 1995 through 2005, 1,389 bats were obtained by Auburn University from the Alabama Department of Public Health, which included 13 of 15 native species (Table 1); 137 were rabid, for an overall prevalence of 9.86%. The most commonly submitted bats were *E. fuscus* (26.8%) and *L. borealis* (21.6%).

There was no significant difference in number of bats with rabies virus that were submitted during 1995–2005 ($P>0.05$; Fig. 1). However, there was a significant difference in number of rabid bats submitted during different months of the year (Fig. 2). Numbers of rabid bats submitted in March (AR$=-2.3$), June (AR$=-5.2$), and July (AR$=-2.4$) were lower than predicted by the total number of submissions ($P<0.01$). Additionally, more rabid bats were submitted in August (AR$=6.0$), September (AR$=8.2$), and November (AR$=2.6$; $P<0.01$). Seasonal trends for individual species did not differ from the combined species trends.

Of the bats for which sex was determined, there were 689 females and 618 males; of those, 61 females and 69 males were rabid. A difference in prevalence of rabies between sexes was not detected ($P>0.05$) for the total sample or for individual species. However, there was a significant difference in rabies prevalence among species (Fig. 3). Prevalence of rabies in *E. fuscus* (5.9%, AR$=-3.0$) and *N. humeralis* (1.1%, AR$=-4.1$) was lower ($P<0.01$) than prevalence for all bats. Conversely, prevalence was higher ($P<0.01$) for *L. borealis* (17.0% rabid, AR$=4.7$) and *P. subflavus* (22% rabid, AR$=3.0$); *L. borealis* represented 37.2% of all rabid bats. When pooled, prevalence of rabies in noncolonial species (14.4%)

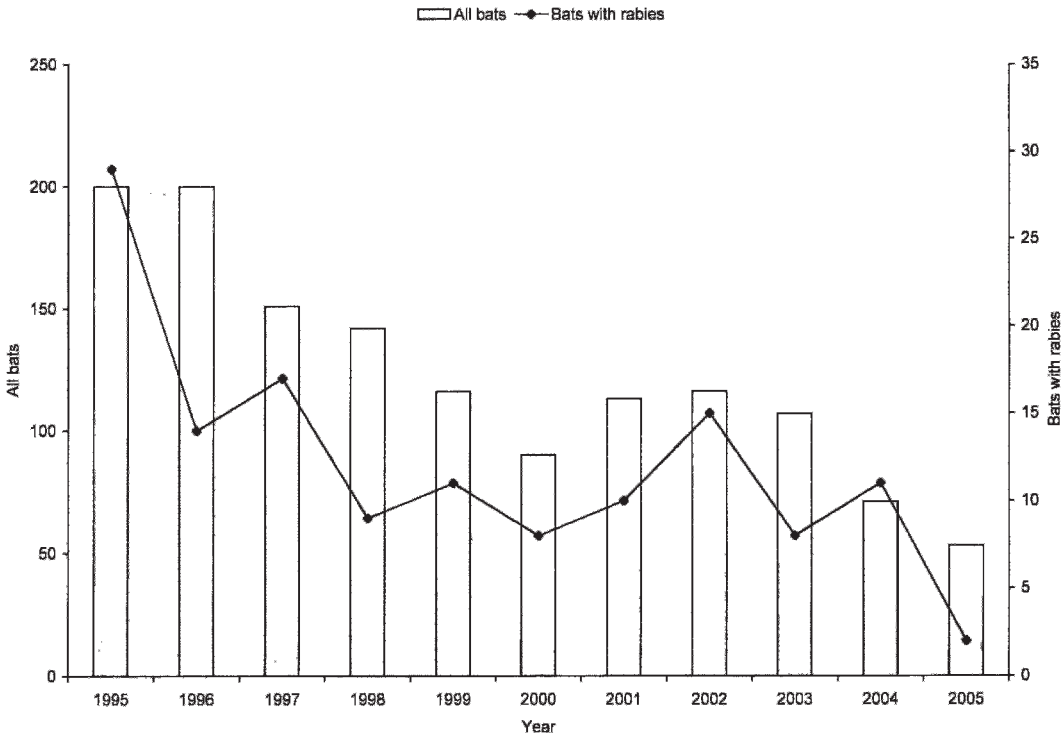

FIGURE 1. Annual distribution of submissions of bats and number of bats that tested positive for rabies virus in Alabama, 1995–2005.

was more than twice that of colonial species (6.3%).

Prevalence of rabies in Alabama is similar to those reported from other states and Canadian provinces (Table 1). Prevalence was <10% although bats were submitted based on a suspicion of rabies. Nationally, *Myotis yumanensis* and *M. lucifugus* had the lowest reported prevalences (1.7% for both species; Mondul et al., 2003). In the present study, *N. humeralis* (1.1%) had the lowest prevalence, which is similar to results from other states (Table 1). Nationally, prevalences of rabies in *L. cinereus* and *T. brasiliensis* were greatest (38.2 and 31.8%, respectively; Mondul et al., 2003). In Alabama, however, *T. brasiliensis* did not have significantly higher (or lower) prevalence of rabies than other species and no rabid *L. cinereus* was detected. However, only 18 *L. cinereus* was submitted in our study over the 11-yr period (Table 1).

Alabama differs from other southeastern states in that *E. fuscus* was the most frequently submitted species ($n=372$), whereas *L. borealis* comprised the majority of submissions of bats in other southeastern states, including Arkansas, Georgia, and South Carolina (Richardson et al., 1966; Heidt et al., 1991, Parker et al., 1999). *Eptesicus fuscus* was submitted most often from other regions and the observed prevalence of rabies (5.9%) was similar to the national prevalence (5.8%; Mondul et al., 2003; Table 1). Prevalence of rabies virus for *L. borealis* in Alabama (17.0%) was greater than the national average (9.0%; Mondul et al., 2003; Table 1).

Prevalence of rabies was highest for noncolonial species, such as *L. borealis*; this result is consistent with results from other studies (Table 1). Likewise, for two solitary species, *P. subflavus* and *L. seminolus*, prevalences in Alabama (22%

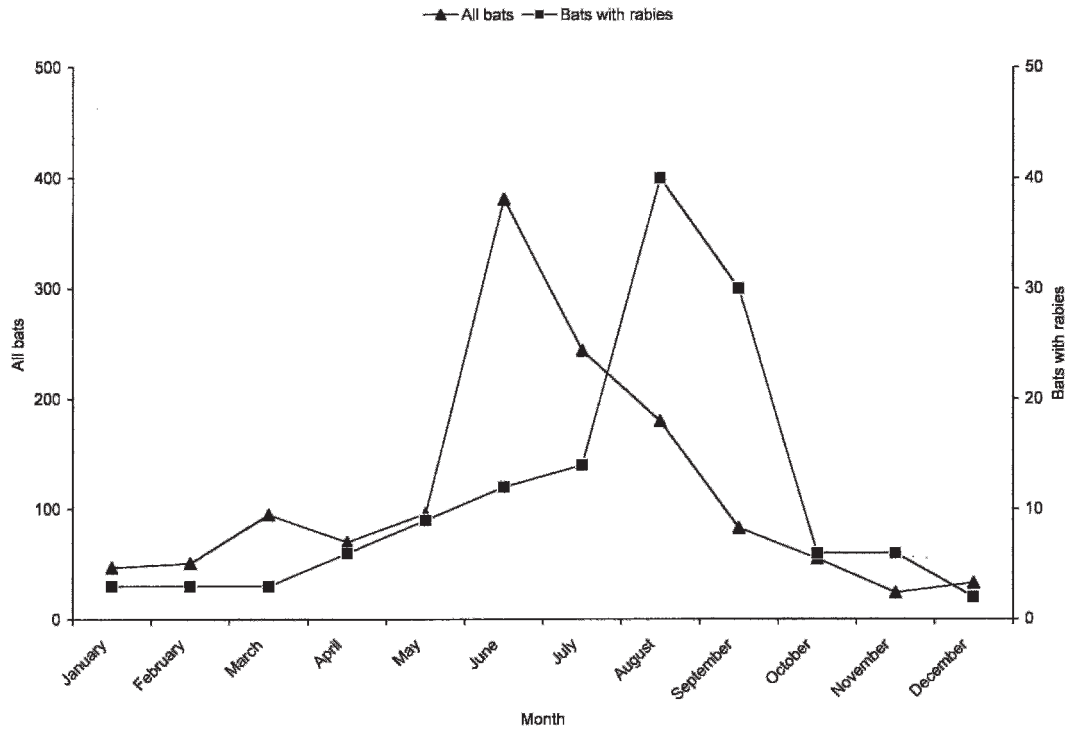

FIGURE 2. Monthly distribution of submissions of bats and number of bats that tested positive for rabies virus in Alabama, 1995–2005.

and 11.4%, respectively) were higher than reported for these species in other states (Table 1). For *P. subflavus*, prevalence also was higher than the national average (17.1%; Mondul et al., 2003). Two colonial species, *M. grisescens* and *T. brasiliensis* (10% and 12.1%, respectively in Alabama), also had prevalences greater than those reported from other states (Table 1), but prevalence for *T. brasiliensis* was lower than the national average (31.8%; Mondul et al., 2003).

In Alabama and New York, *P. subflavus* had the greatest prevalence, but in New York and other studies *P. subflavus* was considered a colonial species (Richardson et al., 1966; Bigler et al., 1975; Childs et al., 1994). The roosting behavior of *P. subflavus* is more comparable with solitary species such as members of the genus *Lasiurus*. *Pipistrellus subflavus* hibernates singly, and in summer, males and nonreproductive females roost singly in trees. The maternity colonies of reproductive females consist of few individuals, unlike typical colonial species such as *E. fuscus* (Fujita and Kunz, 1984; Veilleux et al., 2003; Veilleux and Veilleux, 2004). Treating *P. subflavus* as a colonial species in analysis of solitary versus colonial pooled prevalence would not change the overall result. Reasons for the greater prevalence of rabies in solitary species are not clear, and a combination of factors such as sampling bias, behavioral differences, and genetic variants of rabies virus probably are responsible.

For the two species considered epidemiologically most important in transmission of rabies virus to humans, only *P. subflavus* tested positive in Alabama, but *L. noctivagans* was represented by only six individuals over 11 yr. These species are associated with a unique variant of rabies virus and with cases of rabies in humans where exposure to possible rabid animals was denied by the human (Mondul et al., 2003). Bat bites were reported in only one

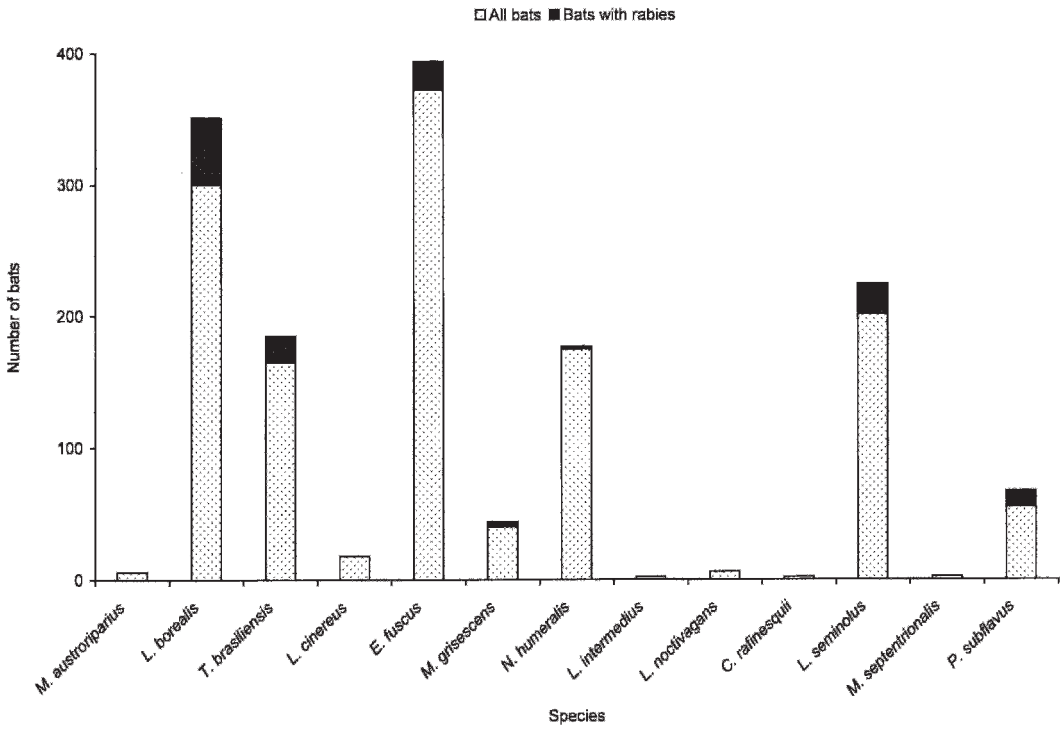

FIGURE 3. Total number of each species of bat submitted for diagnosis and number of bats with rabies virus in Alabama, 1995–2005.

of 22 cases of human rabies from 1981–98 where the virus variant was linked to bats (Krebs et al., 2000; Messenger et al., 2002). This variant of rabies virus might be able to replicate in epidermal tissue at a lower temperature, allowing minute amounts of virus associated with a scratch or bite to become established in a human host (Morimoto et al., 1996). The natural history of *P. subflavus* and *L. noctivagans*, and the fact that they comprise a minority of specimens submitted in Alabama (4.0% and 0.4% of total submissions, respectively), suggests that they rarely come into contact with humans (Mondul et al., 2003).

Absence of a statistically significant difference in percentage of rabid bats between years (1995–2005) in this study implies that levels of rabies in bats remains stable in Alabama; this appears to be the case in other areas (Kurta, 1979; Steece et al., 1982; Olnhausen and Gannon, 2004; Rohde et al., 2004). However, temporal distribution of rabid bats throughout the year varies among studies. A higher prevalence in autumn, as observed in Alabama, also was reported by other states, but in Illinois, Georgia, and South Carolina, an additional increase in cases of rabies was seen in spring (Richardson et al., 1966; Whitaker and Miller, 1973; Bigler et al., 1975; Kurta, 1979; Steece et al., 1982; Rosatte, 1985; Burnett, 1989; Childs et al., 1994; Parker et al., 1999). These increases most likely reflect behavioral patterns of common bat species with stress due to migration or newly volant young contributing to seasonal patterns. The lack of prevalence differences between sexes in Alabama was consistent with results reported from Alberta, Florida, and Minnesota, but contrasted with results from studies in New York and Illinois where females had greater prevalence of rabies and Oklahoma, where males had a higher prevalence (Bigler et al., 1975; Steece et al., 1982; Rosatte,

1985; Burnett, 1989; Childs et al.,1994; Caire, 1998).

Analysis of rabies in bats from Alabama has provided a more complete picture of the status of rabies in the United States. These results could help to shape future management plans for bats in the state, and provide information as to precautions for chiropterologists working in Alabama, as well as the general public. Although the risk of encountering a rabid bat in Alabama generally is <10%, biologists should exercise caution when working with bats, especially during autumn months. Additionally, data from submissions of bats not only provides information on rabies in Alabama but also the distribution of bats. Submission of two *L. intermedius* included in this study doubled the known specimens for the species in Alabama. Most importantly, work is needed to ensure that fear of rabies from bats does not endanger conservation efforts for these important mammals.

We thank personnel of the Alabama Department of Public Health for providing specimens and associated data, the numerous students who aided in recording data from specimens, and C. A. Sundermann, R. S. Lishak, and two anonymous reviewers for providing comments on drafts of the manuscript. This project was partially funded by the Alabama Agricultural Research Station, Auburn University.

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Received for publication 3 March 2006.