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BAT RABIES IN SOUTH CAROLINA, 1970–90

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ABSTRACT: This retrospective study examines the geographic and temporal distribution of bat species submitted for rabies testing in South Carolina (USA) from 1970 to 1990. Histories of human or animal exposures to rabid and nonrabid bats submitted during this time period were compared. Two hundred and thirty-one bats were found to be rabid from the 2,657 bats submitted over this 20 yr period. The two species most frequently submitted for testing were *Lasiurus borealis* with 785 specimens (30% of the total) and *Nycticeius humeralis* with 607 specimens (22% of the total). *Lasiurus borealis* also had the highest prevalence of rabies (18%) while *N. humeralis* had the lowest prevalence (3%). Fifty-one percent (1,259) of the bats received for testing were submitted from June through August. The majority (54%) of rabid bats were received from August through October.

Key words: Bats, *Lasionycteris noctivagans*, rabies, retrospective study, survey.

The Centers for Disease Control and Prevention (CDC, Atlanta, Georgia, USA) reported in January, 1998 that 58% (21/36) of the human rabies cases occurring in the United States since 1980 were caused by bat-associated rabies virus variants. Fifteen of the 21 were variants of the rabies virus associated with *Lasionycteris noctivagans* and *Pipistrellus* spp. (Anonymous, 1998). These human cases renewed interest in the epidemiology of rabies in bats. Two recent articles have examined bat rabies, one in the north central state of Michigan (USA) (Feller et al., 1997) and the other in the northeastern state of New York (USA) (Childs et al., 1994). This study focuses on bats found in a southeastern state.

All animals to be tested for rabies in South Carolina (USA) are submitted to the Bureau of Laboratories (State Public Health Laboratory) located in Richland County (Columbia, South Carolina, USA) and all bat submissions from the public are accepted for rabies testing. From 1970 to 1990, 93% of the 2,657 bats submitted for testing were speciated. Information on the submitting county, date of submission, species of bat, type of human or animal exposure to the bat, and test results were compared for significant differences between rabid and nonrabid bats in this population. All statistical tests were done using SAS (Statistical Analysis Systems, Inc., Cary, North Carolina, USA). The *P*-values for the *t*-tests were calculated using the normal probability function PROBNORM in SAS. Significance was determined at $P \leq 0.05$.

In 1963, the first rabid bat in South Carolina was identified and by the end of the year five of the 16 bats submitted for testing had been reported positive for the rabies virus. From 1963 to 1971, 11% of the 288 bats submitted for rabies testing were rabid. There were no other rabid animals reported in the state during these 8 yr. In 1972, the anticipated northward migration of the raccoon epizootic that began in Florida (USA) reached South Carolina. Six rabid raccoons and one rabid fox were reported from 1972 to 1976 from Beaufort, Hampton, and Jasper counties in the southeast corner of South Carolina (Fig. 2). In 1977, 15 of the 50 raccoons submitted from these counties and two raccoons, a fox and a dog submitted from the adjoining county of Colleton were identified as being rabid. This dog was the first case of rabies diagnosed in a domestic animal since 1963. In 1978 raccoon rabies spread

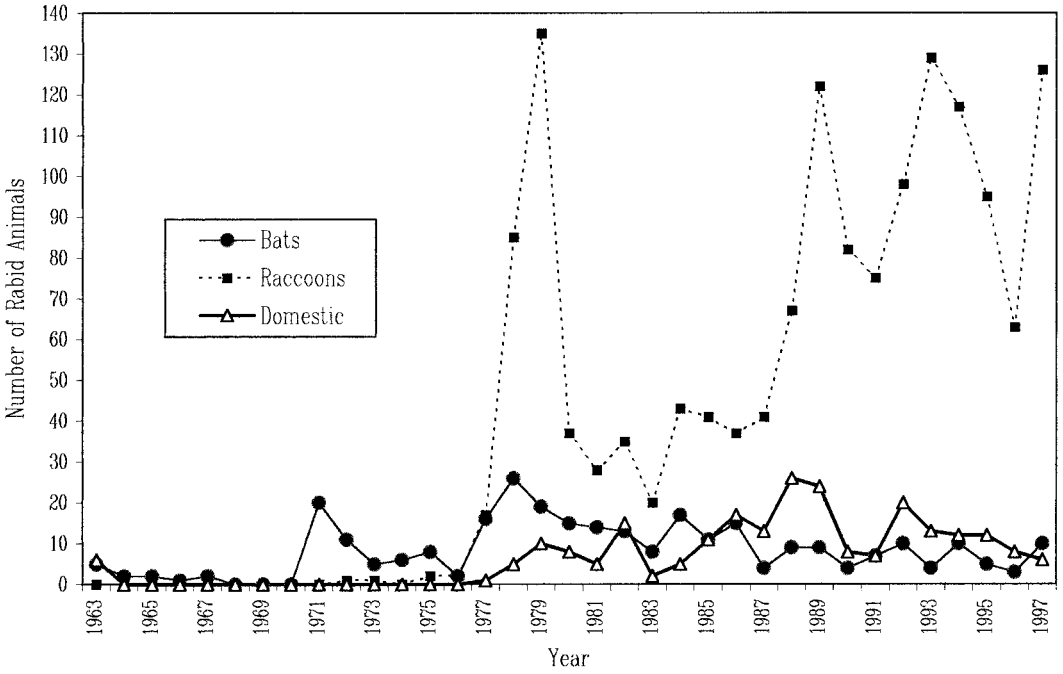

FIGURE 1. Rabies in raccoons, bats, and domestic animals in South Carolina from 1963 to 1997.

to the contiguous counties of Barnwell, Aiken, Edgefield, Bamberg, Orangeburg, Dorchester, and Lexington. Thirty-nine % of the 216 raccoons submitted for testing that year were positive for the rabies virus. All six of the rabid domestic animals, but only one of the 23 rabid bats, were submitted from counties with rabid raccoons. Rabies in domestic animals in South Carolina reappeared with the raccoon epidemic occurring in counties with rabid raccoons. Monoclonal antibody analysis of rabies virus isolates from domestic animals have demonstrated that most domestic animals are infected with variants from the dominant terrestial wildlife reservoir in the area (Smith and Baer, 1988). The pattern of rabies in raccoons, bats, and domestic animals in South Carolina strongly supports the idea that bats are neither effective transmitters of rabies virus to feral animals nor are they commonly infected by these reservoirs (Fig. 1).

Seventeen species, belonging to the families Vespertilionidae and Molossidae (Webster et al., 1985) comprise the resident bats found in North and South Carolina, Virginia, and Maryland. Eight of these species were represented among the rabid bats submitted to the laboratory during the study. Seventy-three percent of the bats received in the laboratory belonged to three species: *Lasiurus borealis* (the red bat), *Nycticeius humeralis* (the evening bat), and *Eptesicus fuscus* (the big brown bat). Table 1 summarizes the species examined and the number of each positive for rabies. Healthy bats avoid human contact whenever possible, but bats submitted to the laboratory for testing are usually sick or dead when found by the submitter. Therefore, the percentage (9%) of positive bats in this study population is higher than if a random sample of bats were tested. (Brass, 1994). This prevalence, which is also higher than that found by Childs et al. (1994), is probably increased by the species of bat submitted for testing in South Carolina. Solitary species made up less than 3% of the population of the New York study, but 39% of the bats in this study came from species considered to be

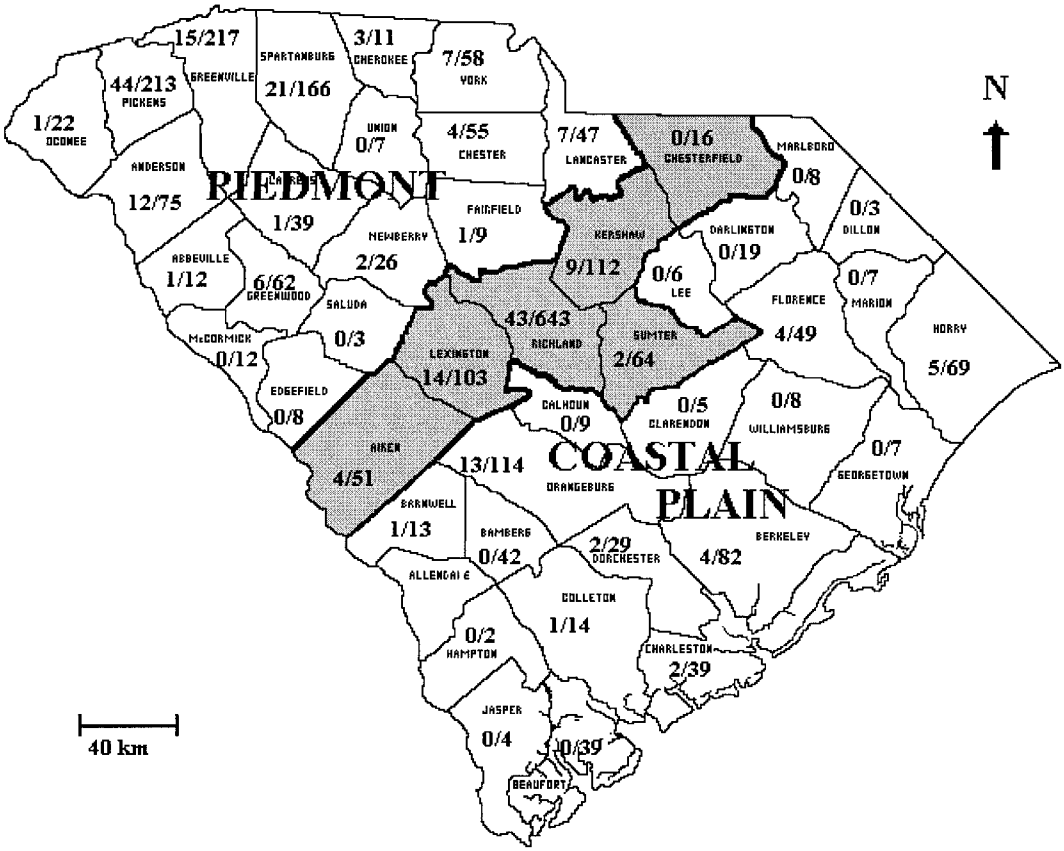

FIGURE 2. Total number (Rabid/Total) and rabid bats by county in South Carolina 1970–90. The shaded counties are in a transition zone known as the Sandhills.

solitary (*L. borealis, L. seminolus, L. cinereus*) in which a higher prevalence of rabies has been reported (Brass, 1994).

Based on the number of *L. borealis, N. humeralis*, and *E. fuscus* submitted for testing, the observed number of rabid bats in these species was significantly different from what would be expected (Table 2). The prevalence of rabies in *L. borealis* was significantly higher than expected and the prevalence in *H. humeralis* and *E. fuscus* was significantly lower than expected. The big brown bat roosts in relatively large colonies in buildings (Barbour and Davis, 1969), where it may frequently come into contact with humans. This can result in groups of multiple specimens of healthy bats from a single site being collected and submitted to the laboratory reducing the prevalence of rabies in this species. There were 33 negative big brown bats received in three large groups in this study, but subtracting these bats from the total did not change the prevalence of rabies in this species. Large groups of evening bats were not submitted; but specimens were sometimes received in small batches of two to four from a group of bats occupying a building. In Richland County where there was a high number of submissions of both the red bat and the evening bat, 19% (22/118) of the red bats were rabid and only 3% (6/232) of the evening bats were rabid. Subtracting bats submitted in groups for both of these species in this county did not change the prevalence in either species. The expected and observed prevalence of rabies did not differ significantly for any of the other species.

South Carolina can be divided into

TABLE 1. Total number of bats examined and rabies positive bats by species in South Carolina (1970–90).

Species	Total	Positive (%)
Lasiurus borealis	785	137 (18)
Nycticeius humeralis	607	16 (3)
Eptesicus fuscus	537	25 (5)
Tadarida brasiliensis	221	20 (9)
Lasiurus seminolus	122	15 (13)
Not identified	177	1 (<1)
Lasiurus cinereus	94	12 (13)
Lasionycteris noctivagans	66	3 (5)
Pipistrellus subflavus	29	2 (7)
Lasiurus intermedius	5	0 (0)
Plecotus rafinesquii	3	0 (0)
Myotis austroriparius	3	0 (0)
Myotis spp.	4	0 (0)
Other	4	0 (0)
Total	2,657	231 (9)

three geographical regions; these are, the Piedmont, the Sandhills, and the Coastal Plain. The Piedmont contains the Blue Ridge region which is mountainous, ranging in elevation from about 427 to 1,067 m. This small area of 1,554 km^2 includes the northwestern portions of Oconee, Pickens, and Greenville Counties. The Piedmont, covering the northwestern one–third (28,749 km^2) of the state, has a rolling topography with an elevation ranging from about 91 m at the fall-line to 366 m at the foothills of the Blue Ridge. The Sandhills are a narrow, discontinuous northeast-southwest trending band of rolling hill topography situated in portions of Aiken, Lexington, Richland, Kershaw, Sumter and Chesterfield counties. The Coastal Plain is the largest region in South Carolina extending 193 to 241 km from the Sandhills to the Atlantic ocean and covering about 51,800 km^2 with elevations ranging from sea level to about 91 m at the edge of the Sandhills (Kovacik and Winberry, 1987). One thousand and forty-two bats or 40% of the total were submitted from the Piedmont, 989 bats or 38% from the Sandhills, and 590 bats or 23% from the Coastal Plain (Table 3). The prevalence of rabid bats in each region area varied from 12% in the Piedmont, 7% in the Sandhills, and 6% in the Coastal plain. There was a significant difference in the numbers of specimens submitted and the prevalence of rabies between the Piedmont and the Coastal Plain, but not between the Sandhills and the Piedmont or the Coastal Plain (Simultaneous *t*-test using a Bonferroni approach to control the experiment-wise error rate). Generally the more densely populated counties submit more bats and the more bats submitted the more rabid bats that are found. Greenville, Spartanburg, and Pickens counties are listed by the U.S. Bureau of the Census of 1996 (U.S. Bureau of the Census, Population Division, Washington, D.C. USA) as three of the five most densely

TABLE 2. Number of observed rabid bats versus expected cases by species in South Carolina, 1970–90.

	Observed		Expected		Chi-Square		
Species	Number	(%)	Number	(%)	Df[d]	Value	*P*
Lasiurus borealis[a]	137	(60)	68	(30)	1	89.405	0.001
Nycticeius humeralis[b]	16	(7)	53	(23)	1	42.817	0.001
Eptesicus fuscus[b]	25	(11)	47	(22)	1	17.835	0.001
Tadarida brasiliensis	20	(9)	19	(8)	1	0.025	0.874
Lasiurus seminolus	15	(7)	11	(5)	1	1.318	0.251
Lasiurus cinereus	12	(5)	8	(4)	1	1.349	0.245
Lasionycteris noctivagans	3	(1)	6	(3)	1	1.845	0.174
Pipistrellus subflavus[c]	2	(<1)	3	(1)	1	0.208	0.649

[a] $P < 0.05$, observed greater than expected.
[b] $P < 0.05$, observed less than expected.
[c] 25% of the cells have expected counts less than 5. Chi-Square may not be a valid test.
[d] Degrees of freedom.

TABLE 3. Geographic distribution of bat species in South Carolina.

	Piedmont	Sandhills	Coastal Plain	Total
Population	1,238,980	681,132	1,201,708	3,121,820
Area	28,749 km^2	10,360 km^2	51,800 km^2	80,583 km^2
Total number bats	1,042	989	590	2,621
Rabid bats	125	72	33	230
% Rabid	12%	7%	6%	9%
Lasiurus borealis	385	254	146	785
Nycticeius humeralis	152	304	133	589
Eptesicus fuscus	311	184	39	534
Tadarida brasiliensis	5	87	127	219
Lasiurus seminolus	20	26	76	122
Lasiurus cinereus	38	34	21	93
Lasionycteris noctivagans	48	14	3	65
Pipistrellus subflavus	18	6	4	28

populated counties in the Piedmont. Fifty-seven % of the bats submitted from the Piedmont came from those three counties. The red bat, hoary bat, big brown bat, eastern pipistrelle, and silver-haired bat were more frequently submitted from the Piedmont than from any other area. The average temperature of this area of the Piedmont is about 10° cooler than that of the coast (Kovacik and Winberry, 1987) and these bats are able to tolerate the cooler climate. Fifty-two % (34/66) of the silver-haired bats (*L. noctivagans*), a solitary migratory bat, were submitted from the mountainous Piedmont counties of Oconee, Pickens, and Greenville. Three rabid silver-haired bats were reported in the study one each from Greenville (1978), Lexington (1980), and Pickens (1984) counties. Eighteen of 29 pipistrelles received for testing came from the Piedmont with rabid bats reported from Pickens County in August 1981 and Anderson County in August 1984.

Richland County (SC) is the second most densely populated county in South Carolina and is centrally located geographically. The presence of the state laboratory in this county may also make it easier for the public to submit bats. Twenty-four percent (643) of the bats submitted for testing came from Richland county. The evening bat (*N. humeralis*) with 607 specimens was the second most common species submitted for rabies testing and is distributed statewide; however, 52% were submitted from the Sandhills with 40% coming from Richland County. The evening bat has been found occasionally with *Tadarida brasiliensis* in old buildings in Richland County.

The free-tailed bat (*T. brasiliensis*) is the only resident member of the family Molossidae in South Carolina. Richland County with 66 and Berkeley County (SC) with 45 free-tailed bats submitted almost half of the specimens. Only five specimens of this species were received from the Piedmont. The majority of the free-tailed bats (58%) and 62% of the Seminole bats (*L. seminolus*) were received from the Coastal Plain. Although the Seminole bat is found in all areas of South Carolina (USA) the lower coastal plain has an abundance of Spanish moss which is the preferred roost of this species (Webster et al., 1985).

Fifty-nine percent of the bats reviewed and 63% of the rabid bats in this study were submitted in the months of June through September. Thirty-three rabid red bats were found in August and 39 in September representing 53% of the positives reported in this species. This increased incidence of rabid red bats during these months may be related to the greater activity of this normally solitary genus during the breeding season. The Seminole bat's seasonal distribution is identical to that of

the red bat. Unlike the other members of the genus *Lasiurus*, 71% of the hoary bats (*L. cinereus*) were received from December to March but four of the 12 rabid bats were found in May when this species is migrating (Webster et al., 1985). Only six hoary bats were submitted during the summer months. Seventy-seven % of the silver-haired bats were submitted from November through February and the only three silver-haired bats to test positive for rabies were submitted in November, December, and April. The silver-haired bat and the hoary bat probably migrate out of the state during the hot summer months. The prevalence of rabid bats was significantly different for the months of September, October, November, May, and June. Table 4 presents the data for the seasonal distribution by species of bat.

Finally, the reason a bat was submitted to the laboratory was compared in rabid and nonrabid bats (Table 5). The red bat (*L. borealis*) and the Seminole bat were twice as likely to have been in contact with dogs, cats, or other pets than the evening bat or the Brazilian free-tail bat. Cats were more likely to have been exposed to rabies negative bats than dogs, but dogs were 2.2 times more likely to have been exposed to a rabid bat. Thirty percent of the forms submitted with negative bats listed cats as the animal exposed to the bat with dogs listed on 16% of the forms. When the exposed animal was a cat the history was more likely to report that the bat was still alive than if the exposed pet was a dog.

Eighty percent of the rabies negative bats found in yards or buildings were colonial bats (evening bats, big brown bats, free-tail bats), but most of the rabid bats (77%) in this category were solitary bats. The same pattern existed with human contact or bites to humans. Rabies negative colonial bats accounted for 66% of the exposures and bites to humans but only 19% of the bites and exposures to humans by rabid bats involved colonial bats.

No consistent risk factor for rabies infection in a bat other than submission to

TABLE 4. Number of rabid bats/total number (% prevalence) of bats by month in South Carolina from 1971 to 1990.

	Lasiurus borealis	*Nycticeius humeralis*	*Eptesicus fuscus*	*Tadarida brasiliensis*	*Lasiurus seminolus*	*Lasiurus cinereus*	*Lasionycteris noctivagans*	*Pipistrellus subflavus*	Total for month
Jan	0/7 (0)	0/18 (0)	1/25 (4)	0/11 (0)	0/5 (0)	0/16 90)	0/7 (0)	0/0 (0)	1/89 (1)
Feb	1/11 (9)	0/17 (0)	0/19 (0)	0/16 (0)	0/1 (0)	2/28 (7)	0/19 (0)	0/0 (0)	3/111 (3)
Mar	2/30 (7)	0/12 (0)	0/36 (0)	5/94 (5)	0/2 (0)	1/11 (9)	0/4 (0)	0/2 (0)	8/191 (4)
Apr	10/73 (14)	2/25 (8)	3/49 (6)	1/11 (9)	1/9 (11)	1/5 (20)	1/4 (25)	0/9 (0)	19/185 (10)
May	10/68 (15)	0/29 (0)	1/34 (3)	4/8 (50)	1/3 (33)	4/6 (66)	0/3 (0)	0/3 (0)	20/154 (13)
Jun	8/142 (6)	4/142 (3)	6/81 (7)	2/4 (50)	0/20 (0)	0/1 (0)	0/1 (0)	0/3 (0)	20/394 (5)
Jul	10/142 (7)	4/197 (2)	3/101 (3)	1/5 (20)	2/38 (5)	0/3 (0)	0/0 (0)	0/2 (0)	20/488 (4)
Aug	33/119 (28)	1/98 (1)	10/122 (8)	1/17 (6)	5/17 (29)	0/2 (0)	0/0 (0)	2/2 (100)	52/377 (4)
Sep	39/94 (41)	3/21 (14)	1/29 (3)	5/13 (38)	4/16 (25)	1/4 (25)	0/0 (0)	0/4 (0)	53/181 (29)
Oct	16/56 (29)	0/19 (0)	0/17 (0)	0/16 (0)	2/6 (33)	2/2 (100)	0/3 (0)	0/4 (0)	20/123 (16)
Nov	8/36 (22)	2/13 (15)	0/13 (0)	1/5 (20)	0/3 (0)	0/4 (0)	1/10 (10)	0/0 (0)	12/84 (14)
Dec	0/7 (0)	0/15 (0)	0/12 (0)	0/21 (0)	0/2 (0)	1/12 (8)	1/15 (7)	0/0 (0)	2/84 (2)
Total	137/785	16/607	25/537	20/221	15/122	12/94	3/66	2/29	230/2,461 (9)

TABLE 5. Tabulation of types of exposure histories on laboratory forms submitted to the Bureau of Laboratories in South Carolina with five species of bats.

Species	*Lasiurus borealis*		*Lasiurus seminolus*		*Nycticeius humeralis*		*Eptesicus fuscus*		*Tadarida brasiliensis*	
Result	Negative	Rabid	Negative	Rabid	Negative	Rabid	Negative	Rabid	Negative	Rabid
Forms with histories[a]	204	71	29	9	108	8	162	6	40	4
Cats (% on forms)[b]	74 (36)	14 (20)	7 (24)	1 (11)	15 (14)	1 (13)	50 (31)	1 (17)	6 (15)	0 (00)
Dogs (% on forms)[b]	48 (24)	12 (17)	9 (31)	3 (33)	10 (09)	0 (00)	14 (09)	2 (33)	4 (10)	1 (25)
Pets (% on forms)[b]	16 (08)	13 (18)	0 (00)	1 (11)	4 (04)	1 (13)	4 (02)	0 (00)	0 (00)	0 (00)
Yards or buildings (%)[c]	23 (11)	16 (23)	1 (03)	1 (11)	32 (30)	1 (13)	51 (31)	1 (17)	15 (38)	3 (75)
Human exposure (%)[d]	21 (10)	6 (08)	3 (10)	0 (00)	27 (25)	3 (38)	18 (11)	1 (17)	10 (25)	0 (00)
Human bitten (%)[e]	22 (11)	10 (14)	9 (31)	3 (33)	20 (19)	2 (25)	25 (15)	1 (17)	5 (13)	0 (00)

[a] Histories on negative specimens taken from forms submitted from 1980 to 1990 and histories on rabid specimens taken from forms submitted from 1975 to 1990.
[b] Forms reported that animals were bitten by a bat or an animal killed or played with a bat.
[c] Buildings inlcuded homes, schools or stores.
[d] Exposure to a human was not counted unless the form specified that a person had handled the bat.
[e] Most bat bites reported as being to the hand, arm or leg.

the laboratory for testing was found in this study. Solitary bats such as red bats and Seminole bats are the species with the highest prevalence of rabies in South Carolina. However, the reason for this is not clear and the difference is probably not as wide as it appears. As noted previously, the evening bat, the big brown bat (*E. fuscus*), and the free-tailed bat are more likely to be submitted in groups of two to 14 as part of a large group of healthy bats who happen to be living in close proximity to humans. This may dilute the number of rabid bats found in these species. Healthy solitary species are less likely to come into contact with humans potentially increasing the percentage of sick bats being submitted in these species. Whether these factors are enough to cause the differences seen in this study is unknown. It has been speculated that solitary species may be more aggressive when rabid (Brass, 1994). Reports of attacks on humans by the red bat in this study do not support this conclusion. Rabies negative or positive red bats were equally as likely to have bitten a human and the percentage of human bites were lower in this species than any of the other species. Non-rabid red bats were involved in a bite exposure 11% (22/207) and rabid bats 12% (10/71) of the time. The Seminole bat may be a more aggressive bat. The data available in this study does show an increase in the percentages of a bite to a human by the rabies negative or positive Seminole bat (3/9 rabid bats and 9/29 nonrabid bats), but the number of bats were too low for this to be statistically significant. The percentage of evening bats having bitten or exposed a human was higher than any other species compared in Table 5, but the evening bat is commonly found in buildings, increasing the opportunity for contact with humans. Comparisons of the other two colonial bats (the big brown bat and the free-tail bat) in this study are limited because of the scarcity of rabid bats in both of these species.

Initially, it appeared that the big brown bat, the eastern pipistrelle, and the silver-

haired bat were more likely to be positive if submitted from the counties in the northern third of the state, but more bats of these species are submitted from these counties. The number of rabid bats appear to vary with the number of specimens submitted for testing not their location.

Some of the monthly variations of rabies prevalence appear to be related to months when a species is subjected the stress of breeding or migration. The time of year that the red bat, the hoary bat, and the free-tail bat have their highest prevalence are the months these species are breeding. The silver-haired bat appears to migrate in and out of South Carolina and the three rabid silver-haired bats were collected during the time this migration probably occurs. (April and November)

It is curious that the silver-haired bat variant of rabies has been incriminated in so many cases of human rabies. This bat, roosting in deep crevices of rocks, under the barks of trees, and in open outbuildings rather than attics (Barbour and Davis, 1969), is not likely to have contact with humans. Morimoto et al. (1996) have hypothesized that the silver-hair bat variant of rabies virus may have unique biological properties that enhance its transmissibility to humans. It appears that silver-haired bat variant of rabies virus may possess an unique cellular tropism and the ability to replicate at lower temperatures, allowing a more effective local replication in the dermis (Morimoto et al., 1996). Only 23% of the silver-haired bats submitted for testing in South Carolina had a history of exposing a human or a pet. Not only is this a rare bat in South Carolina but it is not found in the state during the summer months. By missing the season that people are most active in outdoor activities, the opportunities for human encounters with the silver-haired bat are further reduced.

Speciation of bats was discontinued in 1991 and reinstated in 1996. Since 1996 the laboratory has received 246 bats with 13 reported as rabid. The breakdown by species is *E. fuscus* ($n = 76$), *N. humeralis* ($n = 58$), *T. brasiliensis* ($n = 35$), *L. borealis* ($n = 32$), *L. seminolus* ($n = 17$), *P. subflavus* ($n = 4$), *L. cinereus* ($n = 3$), and *L. noctivagans* ($n = 1$). The rabid bats received since 1996 have been typed using the monoclonol test procedure developed by the CDC. These results are being collected as part of an ongoing study of rabid bats in South Carolina.

Bats were speciated by A. F. DiSalvo. The statistical work for Table 2 was provided by Terri Stephens. We thank all of the staff of the Virology Division who have been responsible for rabies testing in South Carolina for their technical expertise and dedication over the past 25 yr.

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