

# Public Veterinary Medicine: Public Health

**R**abies is primarily a disease that affects and is maintained by wildlife populations in the United States and other developed nations (**Figure 1**). During 2003, wild animals accounted for more than 91% of all cases of rabies reported to the CDC. The most frequently

canine variant that reemerged in south Texas during the late 1970s and early 1980s have substantially reduced or eliminated the spread of this variant, which is maintained in coyotes (*C latrans*) and historically transmitted to unvaccinated dogs, as well as a second canine variant found mainly in gray foxes (*Urocyon cinereoargenteus*) in west and central Texas. Regulations now in place in Texas and other states that prohibit translocation of certain wild animal species for hunting and other restocking purposes have substantially reduced the likelihood of accidental introductions of rabies virus variants into unaffected areas.<sup>1-3</sup>

Various public health activities, including vaccination of domestic livestock and companion animals, vaccination programs targeting wildlife, and ongoing education programs, have contributed to the reduction of transmission of rabies virus from terrestrial animals to human beings.<sup>4</sup> However, an ever-increasing number of rabies cases in human beings has resulted from infection with variants of the rabies virus that are associated with bats,<sup>5,6</sup> a wildlife group difficult to target for rabies control by conventional methods. Prevention of rabies resulting from infection with bat-associated variants is further challenged by the frequent absence of exposure histories involving a bat bite. Since 2000, 8 of 9 cases of indigenously acquired rabies were associated, as determined by genetic analysis, with variants of the rabies virus maintained by bats. Only 2 of these

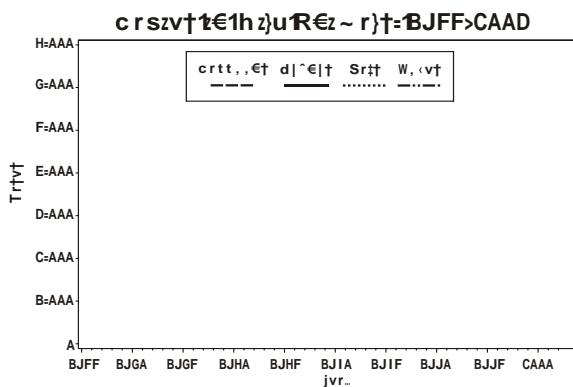
cases involved a report of a definite history of animal bite.<sup>2,6</sup> The most likely route of infection with rabies virus remains transmission by a bite that either was unnoticed or ignored and subsequently forgotten during seemingly insignificant interaction with a bat.

Rabies infections of terrestrial animals in most areas of the United States occur in geographically definable regions where virus transmission is primarily between members of the same species. Spillover infection from these species to other animal species occurs but rarely initiates sustained intraspecific transmission. Once established, virus transmission within a species can persist enzootically for decades or even centuries.

Variants of the rabies virus can be identified by reaction with panels of monoclonal antibodies<sup>7</sup> or by patterns of nucleotide substitution determined by genetic analysis.<sup>1,8</sup> The spatial boundaries of enzootic rabies in a reservoir species are temporally dynamic (Figure 3). Affected areas may expand and contract through virus transmission and population interactions.<sup>9,10</sup> Population increases and emigration result in expansion of rabies-infected areas, whereas natural barriers, such as mountain ranges and bodies of water, that restrict animal movements or result in low population densities can slow the spread of rabies. Unusual animal dispersal patterns and human-mediated translocation of infected animals have resulted in more rapid and unexpected introductions of rabies into new areas.<sup>1-3,8-10</sup>

Raccoons (*Procyon lotor*) have been recognized as a reservoir for rabies in the southeastern United States since the 1950s. An outbreak that began during the late 1970s in the mid-Atlantic states was attributed to the translocation by humans of infected raccoons from the Southeast.<sup>11</sup> Although identifiable as separate foci prior to 1994, the mid-Atlantic and southeastern foci have merged, and raccoon rabies is now enzootic in all of the eastern coastal states, as well as Alabama, Ohio, Pennsylvania, Vermont, and West Virginia.

Three variants of rabies virus are responsible for disease in skunks (primarily *Mephitis mephitis*) in California and the north central and south central states. A long-standing reservoir for rabies virus exists in red and arctic foxes (*Vulpes vulpes* and *Alopex lagopus*, respectively) in Alaska. Rabies spread during the



1950s to affect foxes across Canada and, intermittently, foxes in adjoining areas of the New England states. Rabies persists in foxes in Alaska, whereas reports of rabid foxes have declined in Canada. Two variants of

Rabies in the United States, 2003

State (City)	Domestic animals										Wild animals						Human beings	Change\$ 2002 %
	All animals	Domestic	Wild	Dogs	Cats	Cattle	Horses/ mules	Sheep/ goats	Swine	Other domestic*	Skunks	Foxes	Bats	Raccoons	Rodents and lagomorphs†	Other wild‡		
AL	68	4	64	—	3	—	1	—	—	—	3	27	33	—	1 <sup>a</sup>	—	78	-12.82
AK	9	1	8	1	—	—	—	—	—	—	8	—	—	—	—	—	27	-66.67
AZ	75	0	75	—	—	—	—	—	—	8	18	44	—	—	5 <sup>a</sup>	—	143	-47.55
AR	69	5	64	2	1	2	—	—	—	—	—	—	—	—	—	—	131	-47.33
CA	218	3	214	1	2	—	—	—	—	—	42	10	162	—	—	—	253	-13.83
CO	43	1	42	1	—	—	—	—	—	—	—	—	42	—	—	—	59	-27.12
CT	188	4	184	—	2	1	—	1	—	—	57	3	112	—	1 <sup>a</sup>	—	331	-43.20
DC	5	0	5	—	—	—	—	—	—	—	—	—	1	4	—	—	11	-54.55
DE	65	6	59	—	6	—	—	—	—	9	4	5	39	2 <sup>b</sup>	—	—	55	18.18
FL	193	17	176	2	15	—	—	—	—	—	28	20	127	—	1 <sup>c</sup>	—	181	6.63
GA	402	29	373	3	20	1	4	—	1	—	68	43	16	242	—	4 <sup>a</sup>	411	-2.19
HI	0	0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	0	—
ID	15	0	15	—	—	—	—	—	—	—	—	—	15	—	—	—	38	-60.53
IL	24	0	24	—	—	—	—	—	—	—	—	—	24	—	—	—	31	-22.58
IN	31	0	31	—	—	—	—	—	—	—	—	—	31	—	—	—	32	-3.13
IA	106	20	86	6	8	3	3	—	—	—	38	—	47	—	1 <sup>a</sup>	—	79	34.18
KS	166	30	136	3	10	12	4	1	—	—	124	2	9	1	—	—	154	7.79
KY	39	7	32	5	1	1	—	—	—	—	20	4	7	1	—	—	28	39.29
LA	4	0	4	—	—	—	—	—	—	—	1	—	3	—	—	—	6	-33.33
ME	82	2	80	1	—	—	1	—	—	—	26	5	9	37	2 <sup>c</sup>	1 <sup>a</sup>	67	22.39
MD	371	27	344	2	21	1	1	—	1	1 <sup>a</sup>	16	37	10	269	11 <sup>d</sup>	1 <sup>a</sup>	396	-6.31
MA	216	8	208	2	6	—	—	—	—	—	86	13	23	81	3 <sup>a</sup>	2 <sup>a</sup>	303	-28.71
MI	48	1	47	—	1	—	—	—	—	—	2	—	45	—	—	—	46	4.35
MN	48	13	35	4	4	5	—	—	—	—	23	—	12	—	—	—	47	2.13
MS	4	0	4	—	—	—	—	—	—	—	—	—	4	—	—	—	4	0.00
MO	43	2	41	1	1	—	—	—	—	—	4	—	37	—	—	—	46	-6.52
MT	22	0	22	—	—	—	—	—	—	—	11	—	11	—	—	—	21	4.76
NE	99	20	79	3	7	6	3	1	—	—	69	5	5	—	—	—	27	266.67
NV	6	0	6	—	—	—	—	—	—	—	—	—	6	—	—	—	17	-64.71

bats, foxes, and raccoons decreased 13.2%, 11.7%, 10.2%, and 8.9%, from 2002 totals, respectively.

**Raccoons**—The 2,635 cases of rabies in raccoons (*P lotor*) reported in 2003 represented a 5-year low for this species (Figures 2 and 4). Decreases in numbers of

rabid raccoons during 2003 were reported by 10 of the 20 eastern states in which raccoon rabies has been enzootic, including Connecticut (38.8% decrease; 183 cases in 2002 to 112 in 2003), Georgia (2.0%; 247 to 242), Maryland (1.1%; 272 to 269), Massachusetts (4.7%; 85 to 81), New Hampshire (57.7%; 26 to 11),





beavers (*Castor canadensis*), 2 rabbits (*Oryctolagus cuniculus*), 1 badger (*Taxidea taxus*), 1 black bear (*Ursus americanus*), 1 guinea pig (*Cavea porcellus*), 1 rat (*Rattus* sp), 1 ringtail (*Bassariscus astutus*), and 1 gray squirrel (*Sciuris carolinensis*).<sup>24,25</sup> All cases of rabies in rodents and lagomorphs (primarily groundhogs, 31/38 cases) were reported by states in which rabies is epizootic in raccoons.<sup>25</sup> No cases of rabies in coyotes

Oklahoma (n = 16), South Dakota (14), Kansas (12), Texas (10), and Virginia (10) reported the largest numbers of rabid cattle. No other states reported > 6 cases of rabies in cattle. The 63 cases of rabies reported in horses and mules (including donkeys) in 2003 represented an 8.6% increase over the 58 cases reported during 2002. Other reported cases of rabies in domestic animals included 1 ferret, 11 goats, 1 sheep, and 2 swine.

#### Seasonal Trends

The frequency of reported cases of rabies in skunks was highest in March, with only slight decline to June. This was followed by a slight increase in September and October and a rapid decline to a December low (**Figure 14**). The frequency of reporting for rabid raccoons showed a peak in March and April, followed by a decline into the summer months, a small increase in September and October, and a gradual decline into December. Reports of rabid bats increased through the spring and early summer months to a sharp peak in August followed by a steep decline. Reports of rabid foxes increased gradually from March to a broad summer high (May through August), followed by a drop in September and gradual further decline to a low in November.

Following a January through March winter lull, reports of rabid cats rose steeply to a peak in July and then dropped precipitously in August and September (**Figure 15**). This decline was followed by an increase

to a lower October reporting peak and then a second sharp decline to a November low. Reports of rabies cases in dogs plateaued broadly from January to June before declining to an August low. Reports then increased sharply in September before a gradual decline to a December low. Reported cases in cattle increased to an April peak prior to an undulating decline to an August low, before rising again slightly during the remainder of the year (**Figure 15**).

#### Rabies in Human Beings

Two cases of rabies in human beings were reported in the United States, and 1 case was reported in Puerto Rico during 2003 (**Table 2**).



was that associated with rabies in raccoons (*P lotor*) in the eastern United States; this was the first infection of a human being by the raccoon rabies variant that has ever been documented. The case was diagnosed retrospectively, and the man's friends and relatives could not recall a history of animal bite or exposure.<sup>26</sup>

On June 5, 2003, a 64-year-old man residing in Canovanas Municipio, Puerto Rico, died of rabies. The variant of the rabies virus that caused this infection was identified as that maintained by mongooses (*H javanicus*) and unvaccinated dogs (*C lupus [familiaris]*) in Puerto Rico. The man had a history of dog bite, but did not receive rabies postexposure prophylaxis until after onset of symptoms. This was the first case of human rabies reported by Puerto Rico since a case con-

and > 638,000 additional doses of ORV baits were distributed during the late summer through fall of 2003 over a total of > 3,100 square miles in 9 eastern Ohio counties extending along the Pennsylvania and West Virginia borders from Lake Erie to the Ohio River.<sup>31,32,b</sup> Also during the fall of 2003, ORV baits were distributed in Alabama, Georgia, Pennsylvania, Tennessee, Virginia, and West Virginia, thereby expanding and interconnecting existing ORV barriers or initiating new barriers in regions along and ahead of the front of the raccoon rabies enzootic as determined by active and passive rabies surveillance.<sup>31</sup> These ORV programs during 2003 served to maintain and expand a continuous immune corridor (augmented by geographic barriers such as lakes, rivers, and mountains), extending from the shore of Lake Erie south to extreme northeastern Tennessee. This "cordone sanitaire" will be extended further south and moved eastward over time in an attempt to contain and reduce the area of enzootic rabies in raccoons.<sup>33</sup> Concerns regarding vaccine safety, efficacy, ecologic impact, and physical bait variables, which were raised during earlier trials, continue to be assessed.<sup>19,20,34-36</sup>

Reports of rabid skunks in 2003 decreased by 13.2% from those reported in 2002, and in a reversal of increases in reporting observed in 2002, 24 of 35 states that reported rabid skunks in 2002 or 2003 reported decreases in numbers of rabid skunks in 2003. However, sheer numbers of rabid skunks reported by Kansas (n = 124), Nebraska (69), Oklahoma (147), South Dakota (86), and Texas (620) in 2003 stand out, especially those in Nebraska, a state that reported only 3 rabid skunks during the previous year. Although surveillance changes have taken place in Nebraska, historically a reporter of relatively few rabid skunks and other rabid species, ongoing surveillance clearly demonstrates enzootic transmission of skunk rabies variants in all of these Central Plains states. In Arizona, 1 rabid skunk infected with Arizona gray fox variant of the rabies virus was reported from the Flagstaff area, previously the site of a focal outbreak of rabies in skunks (Coconino County, 2001) resulting from apparent enzootic transmission of a bat rabies variant of the rabies virus. Texas again reported the greatest number of rabid skunks during 2003; however, the 620 cases reported were 120 fewer than those reported in 2002. Although 13 states reported increases in numbers of rabid skunks in 2003, with the exception of those states already addressed, other increases were unremarkable. Only 2 states (Alabama and Wisconsin) that reported rabid skunks in 2002 did not report rabid skunks in 2003. Massachusetts (n = 86) and Rhode Island (34) each reported more rabid skunks than rabid raccoons for the seventh consecutive year. However, most rabid skunks in these and other states enzootic for raccoon rabies are presumed to be infected with the raccoon variant of the rabies virus as determined on the basis of those that have been further tested to determine variant type. Studies have been unable to demonstrate evidence of adaptation, circulation, and maintenance of the raccoon variant of the rabies virus in skunks.<sup>37</sup> States in which the raccoon-associated variant of the rabies virus is enzootic reported > 40%

of the cases of rabies in skunks; thus, it may be that < 60% of all reported skunks (those reported rabid in skunk rabies reservoir areas previously defined) are infected with skunk variants of the rabies virus.

Cases of rabies in foxes in 2003 decreased 10.2% from numbers for 2002. Rabies resulting from the red fox variant of the rabies virus in Canada and New England has been controlled; most cases of rabies in foxes reported by eastern states were probably caused by the rabies virus variant associated with raccoons. This presumption has been supported by those samples further subjected to rabies virus variant analysis. Rabies in gray foxes in Arizona and Texas is usually the result of infection with gray fox variants found in each of those states. Reduced success in preventing infections resulting from the Texas gray fox variant of the rabies virus via the use of an ORV in baits targeted at gray foxes observed during 2002 continued in 2003; however, no infections occurred outside the boundaries of the original containment area.<sup>c</sup> Eighteen states reported decreases in numbers of cases of rabies in foxes. Although decreases were usually small, Alaska (n = 8), Arizona (18), Georgia (43), New York (19), and Texas (28) reported decreases of  $\geq 15$  cases. In contrast, 12 states reported increases in numbers of rabid foxes; however, these increases were also usually small. Maryland, New Jersey, Nebraska, New Hampshire, and Ohio reported increases of 7, 3, 2, 2, and 2 cases, respectively; only North Carolina and South Carolina, with 29 and 17 more cases than in 2002, respectively, reported increases of > 7 cases.

The occurrence of rabies in various species of bats fluctuates by geographic region. The continued and increasing association of bat rabies virus variants with human rabies infections in the United States during recent years has brought increased publicity and changes in public health recommendations proposed for rabies exposures potentially involving bats.<sup>38,39</sup> Rabies among rodents and lagomorphs reflects spillover infection, predominantly from regional terrestrial reservoir species. Reported cases among rodents occur primarily in groundhogs in areas of the country affected by the raccoon-associated variant of the rabies virus.<sup>25</sup> Rabies is occasional

location. Rapid responses to these events may have prevented establishment and spread of the involved variants.

Rabies in domestic animals increased 3.7% in 2003. Reported cases of rabies in dogs (n = 117) and cats (321) increased 18.2% and 7.4%, respectively, whereas cases in cattle (98) decreased 15.5%. The number of cases of rabies reported in cats was more than 3 times that reported for cattle, more than twice (2.7) the number reported for dogs, and more than the

initiated in 1995, almost 22.7 million doses of V-RG vaccine have been distributed over > 321,000 square miles in Texas.<sup>c</sup>

During February 2004, a man in Florida, who had recently arrived from Haiti with a history of a dog bite, died of rabies associated with a canine variant of the rabies virus.<sup>f</sup> On May 4, 2004, an organ donor in Arkansas with a history of bat bite died of bat-associated rabies. Four persons who received organs and tissues from this donor subsequently became infected and died from rabies in May and June.<sup>51,52</sup> On October 19, 2004, rabies was diagnosed at the CDC in samples from a teenage girl from Fond du Lac County, Wis.<sup>g</sup> She had been bitten by a bat 1 month earlier. This case is currently under investigation.

These latest cases (n = 7) bring the total number of cases of rabies diagnosed in human beings in the United States since 1990 to 44 (1 case in 2003 was diagnosed in Puerto Rico). Thirty-six (and 1 pending) of these individuals were infected with variants of the rabies virus indigenous to the United States. Monoclonal antibody analysis and genetic sequencing indicated that 34 of these 36 (94.4%) persons were infected with variants of the rabies virus associated with bats (12 of 13 since 2000). Only 5 of these cases involved a report of a definite history of animal bite.

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<sup>a</sup>Departamento de Salud, San Juan, Puerto Rico: Notifiable disease report, 2003.

<sup>b</sup>Smith KA, Krogwold R, Collart M, Ohio Department of Health, Columbus, Ohio: Personal communication, 2004.

<sup>c</sup>Wilson PJ, Texas Department of Health, Austin, Tex: Personal communication, 2004.

<sup>d</sup>Fadden D, Massachusetts Department of Public Health, Boston, Mass: Personal communication, 2004.

<sup>e</sup>Lasater R, Tennessee Department of Health, Nashville, Tenn: Personal communication, 2004.

<sup>f</sup>Blackmore C, Florida Department of Health Services, Tallahassee, Fla: Personal communication, 2004.

<sup>g</sup>Kazmierczak J, Wisconsin Department of Health and Family Services, Madison, Wis: Personal communication, 2004.

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37. Guerra MA, Curns AT, Rupprecht CE, et al. Skunk and raccoon rabies in the eastern United States: temporal and spatial analysis. *Emerg Infect Dis* 2003;9:1143–1150.
38. National Association of State Public Health Veterinarians Committee. Compendium of Animal Rabies Prevention and Control, 2004. *J Am Vet Med Assoc* 2004;224:216–222.
39. CDC. Human rabies prevention—United States, 1999. Recommendations of the Advisory Committee on Immunization Practices (ACIP; Erratum published in *MMWR Morb Mortal Wkly Rep* 1999;48:16). *MMWR Recomm Rep* 1999;48(RR-1):1–21.
40. CDC. Rabies in a beaver—Florida, 2001. *MMWR Morb Mortal Wkly Rep*