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Rabies surveillance in the United States during 2006

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Summary—During 2006, 49 states and Puerto Rico reported 6,940 cases of rabies in animals and 3 cases in humans to the CDC, representing an 8.2% increase from the 6,417 cases in animals and 1 case in a human reported in 2005. Approximately 92% of the cases were in wildlife, and 8% were in domestic animals. Relative contributions by the major animal groups were as follows: 2,615 raccoons (37.7%), 1,692 bats (24.4%), 1,494 skunks (21.5%), 427 foxes (6.2%), 318 cats (4.6%), 82 cattle (1.2%), and 79 dogs (1.1%). Compared with numbers of reported cases in 2005, cases in 2006 increased among all groups except cattle. Increases in numbers of rabid raccoons during 2006 were reported by 11 of the 20 eastern states where raccoon rabies was enzootic, and reported cases increased by 3.2% overall, compared with 2005.

On a national level, the number of rabies cases in skunks during 2006 increased by 6.1% from the number reported in 2005. Once again, Texas reported the greatest number (n = 351) of rabid skunks and the greatest overall state total of animal rabies cases (889). No cases of rabies associated with the dog/coyote rabies virus variant were reported. The last identified case of this canine rabies virus variant was identified in March 2004, along the US/Mexico border. With 2006 marking the second year of no apparent transmission of the dog/coyote variant, these findings from surveillance data support the contention that the canine rabies virus variant is no longer in circulation in the United States. Total number of cases of rabies reported nationally in foxes increased 13.6%, compared with 2005. Increases in the number of reported rabid foxes were attributable to greater numbers of foxes reported with the Arctic fox rabies virus variant in Alaska, the Texas gray fox rabies virus variant in Texas, and the raccoon rabies virus variant in Virginia. The 1,692 cases of rabies reported in bats represented a 14.5% increase, compared with numbers reported in 2005, making bats the second most reported rabid animal behind raccoons. Cases of rabies in cats, dogs, horses and mules, and sheep and goats increased 18.2%, 3.9%, 12.8%, and 22.2%, respectively, whereas cases reported in cattle decreased 11.8%. In Puerto Rico, reported cases of rabies in mongooses increased 9.2%, and rabies in domestic animals, presumably attributable to spillover infection from mongooses, increased 20%.

Three cases of human rabies were reported from Texas, Indiana, and California during 2006. The cases in Indiana and Texas were attributed to bat rabies virus variants, whereas the case in California was attributed to an exposure to a dog in the Philippines.

As in many developed countries, wild animals accounted for the majority (92%) of all rabies cases in the United States reported to the CDC during 2006. The most frequently reported rabid wildlife remain raccoons, bats, skunks, and foxes; however, their relative proportions have continued to fluctuate because of epizootics of rabies among animals infected with several distinct rabies virus variants.[1]

Abbreviations

ORV	Oral rabies virus vaccination
V-RG	Vaccinia-rabies glycoprotein
PAHO	Pan American Health Organization
DFA	Direct immunofluorescent antibody
PEP	Postexposure prophylaxis
USDA WS	USDA Wildlife Services
GAT	Georgia, Alabama, and Tennessee

Rabies virus infections of terrestrial animals in 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 animals occurs, but rarely initiates sustained transmission in other species. Once established, enzootic virus transmission within a species can persist regionally for decades or longer.

Rabies virus variants can be identified antigenically by reaction with panels of monoclonal antibodies[2] or by comparing patterns of nucleotide substitution determined by genetic analysis.[1,3] Spatial boundaries

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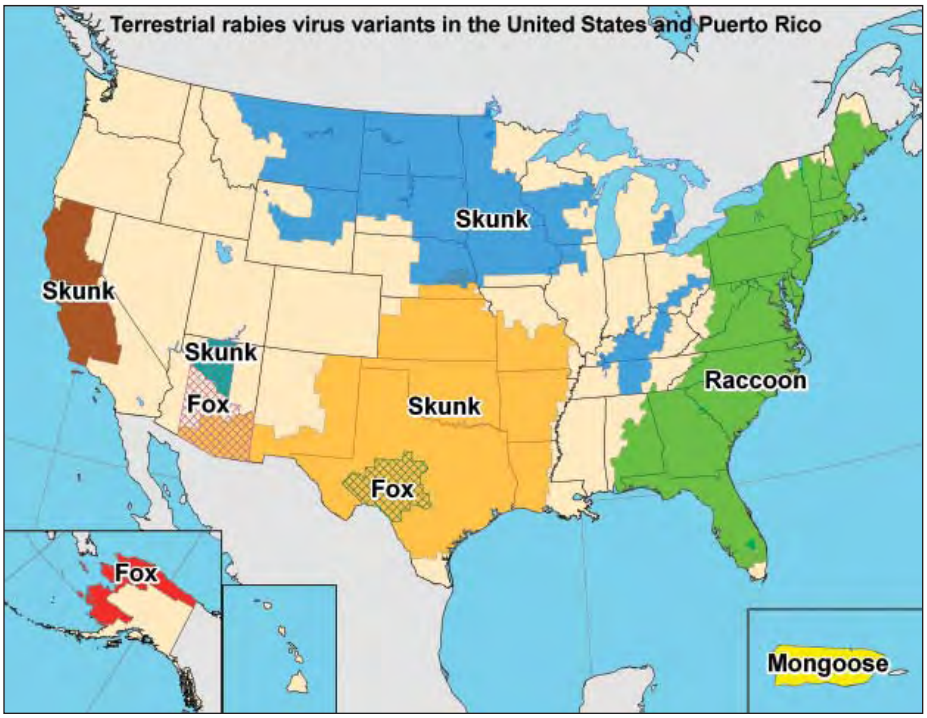

Figure 1—Distribution of major rabies virus variants among wild terrestrial reservoirs in the United States and Puerto Rico.

of enzootic rabies in reservoir species are temporally dynamic (**Figure 1**). Affected areas may expand and contract through virus transmission and population interactions.[4,5] Population increases and emigration result in the expansion of rabies-infected areas, whereas natural barriers, such as mountain ranges and bodies of water, may restrict animal movements or sustain lower population densities that 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.[1,3–7]

Rabies control programs, including extensive vaccination campaigns implemented during the 1940s and 1950s, resulted in a substantial decline of rabies in domestic animals in the United States and eliminated the circulation of the major canine variants of the rabies virus in dogs (*Canis lupus*) by the late 1960s (**Figure 2**). During the late 1980s, a canine rabies virus variant reemerged in southern Texas. This virus had been maintained historically in coyotes (*Canis latrans*) and transmitted to unvaccinated dogs. Oral rabies vaccination programs were initiated to interrupt transmission of this rabies virus variant. No cases of animals infected with this rabies virus variant have been reported since 2004.[8] After more than 10 years of oral vaccination, this variant has now been eliminated from the United States.[9–12] Rabies cases associated with a second canid rabies virus variant found mainly in gray foxes (*Urocyon cinereoargenteus*) in western and central Texas have similarly been reduced. Regulations in place in Texas and other states prohibiting the translocation of certain wild animal species for hunting and restocking purposes may have reduced the likelihood

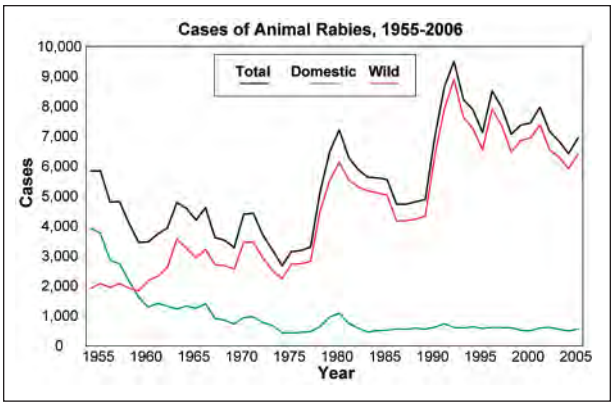

Figure 2—Cases of animal rabies in the United States, by year, 1955 to 2006.

of accidental introduction of rabies virus variants into unaffected areas.[1,6,7]

Raccoons (*Procyon lotor*) have been recognized as a major 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.[13] Although identifiable as separate foci prior to 1994, the mid-Atlantic and southeastern fronts merged in North Carolina in 1995. Raccoon rabies is now enzootic in all of the eastern coastal states as well as in Alabama, Ohio, Pennsylvania, Tennessee, Vermont, and West Virginia.

Three rabies virus variants are responsible for disease in skunks (primarily *Mephitis mephitis*) in California and the north central and south central United States. In Alaska, a long-standing reservoir for rabies

virus exists in red and arctic foxes (*Vulpes vulpes* and *Alopex lagopus*, respectively). Rabies spread during the 1950s among red foxes across Canada and, intermittently, to foxes in adjoining areas of the New England states. Although rabies persists in foxes in Alaska, reports of rabid foxes have declined in Canada, in part because of ORV programs.[14] Two rabies virus variants are in geographically limited populations of gray foxes (*U cinereoargenteus*) in Arizona and Texas. On the island of Puerto Rico, another wildlife rabies reservoir exists in mongooses (*Herpestes javanicus*).[15,16] Rabies virus maintained and circulated by mongooses is periodically transmitted to unvaccinated dogs and cats.[6]

Distribution of an oral V-RG recombinant vaccine targeting raccoons in the eastern United States[17–19] and gray foxes and coyotes in Texas[12] has had promise as an important adjunct to traditional rabies control methods (eg, parenteral vaccination of domestic animals). Products used in oral vaccination programs are self-replicating, and the unintentional exposure of nontarget species, including humans, must be minimized and monitored.[20,21]

There are multiple, independent reservoirs for rabies virus in several species of insectivorous bats, which overlay the patterns of rabies virus variants maintained among terrestrial mammals. Rabies virus transmission among bats appears to be primarily intraspecific, and distinct virus variants can be identified and associated with different bat species. In contrast to maintenance cycles in terrestrial animals, however, the greater mobility of bats precludes definitive range mapping of different variants, other than the geographic ranges of the implicated host bat species. Because bat species known to be reservoirs for rabies virus are found in all areas of the continental United States, every state except Hawaii is considered enzootic for rabies.

Although transmission of rabies virus from bats to terrestrial mammals occurs, such transmission rarely results in sustained, independent, intraspecific cycles among terrestrial animals. Such occurrences represent substantial shifts in host adaptation and the emergence of rabies virus variants in a new host species. In 2001, this rare phenomenon was determined by the adaptation of a rabies virus variant associated with big brown bats (*Eptesicus fuscus*) in Flagstaff, Ariz, to skunks (*M mephitis*) in an area previously naive for terrestrial rabies.[22] Prior genetic analysis indicated a net difference of 15% to 20% between rabies virus RNA sequences in bats, compared with those in terrestrial mammals. Thus, instances of spillover transmission of rabies virus from bats are readily detectable, as is sustained transmission of a bat-associated rabies virus variant in a terrestrial mammal population.

Various public health activities, including vaccination of companion animals, vaccination programs targeting wildlife, and ongoing education programs, have contributed to the reduction in transmission of rabies virus from terrestrial animals to humans.[23] However, most cases in humans have resulted from infection with rabies virus variants that are associated with bats.[24,25] Rabies control in bats is difficult by conventional methods. In humans, prevention of rabies resulting from infection with bat-associated rabies virus variants is further challenged by the frequent absence of documented exposure histories involving a bat bite.

This report is prepared annually to inform veterinarians and public health officials of the current status of rabies in the United States. Information is provided on the geographic distribution of rabies and long- and short-term temporal patterns for reported cases of rabies in various species. Long-term trends for reported cases of rabies in animals in the United States are generated by examining reports beginning in 1955. For this report, short-term trends were determined by comparing reported cases from 2006 with those from 2005 and by examining seasonal patterns for selected species.

Summaries of 2006 surveillance data are provided for Canada and Mexico because of common borders and frequent travel between the United States and these countries. A brief update on cases of rabies and other related activities reported to the CDC during 2007 is also included.

Collection of Data

Data collection procedures were similar to those described previously.[26] Between January 1 and December 31, 2006, all 50 states, New York City, the District of Columbia, and Puerto Rico reported, on a monthly basis, the number of cases of rabies in animals to the CDC by county of origin and type of animal. Typically, epidemiologic data are provided for all animals tested. During 2006, all states submitted data for all animals tested. County of origin for test-negative animals from the state of South Carolina and Oklahoma was not reported. Furthermore, because of changes in data collection procedures in Georgia and Iowa, submission data reported to the CDC for 2006 may not reflect complete numbers for animals submitted and testing negative for rabies. A total of 113,033 animals were reported to the CDC as tested in the United States during 2006.

State public health laboratories report rabies cases among most terrestrial mammals using the common name of these animals (usually identifiable to the taxonomic level of genus and often to the level of species). However, bats are frequently reported only to the taxonomic level of order (eg, *Chiroptera* = bats). Several states reported data by use of the Public Health Labora-

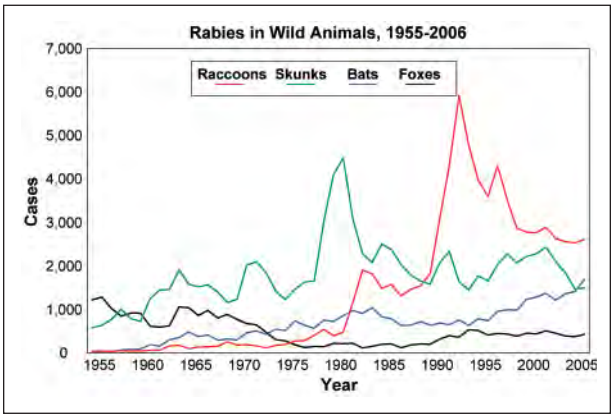

Figure 3—Cases of rabies in wild animals in the United States, by year and species, 1955 to 2006.

Table 1—Cases of rabies in the United States, by state and category, during 2006.

				Domestic animals						Wild animals									
State (city)	All animals	Domestic	Wild	Cats	Cattle	Dogs	Horses/ mules	Sheep/ goats	Other domestic*	Raccoons	Bats	Skunks	Foxes	Other wild†	Rodents and lagomorphs‡	Humans	% Positive 2006	2005 cases	Change (%)
AK	18	5	13	0	0	5	0	0	0	0	1	0	12	0	0	0	22.8	4	350.00
AL	82	2	80	2	0	0	0	0	0	56	17	0	7	0	0	0	3.4	78	5.13
AR	32	1	31	0	0	1	0	0	0	0	13	18	0	0	0	0	3.8	36	–11.11
AZ	140	1	139	1	0	0	0	0	0	0	96	16	22	5[d]	0	0	5.6	168	–16.67
CA	202	1	200	0	0	0	1	0	0	0	158	40	2	0	0	1	2.8	204	–0.98
CO	70	0	70	0	0	0	0	0	0	0	70	0	0	0	0	0	6.8	44	59.09
CT	208	6	202	5	0	1	0	0	0	112	23	53	3	3[e]	8[u]	0	7.6	210	–0.95
DC	40	0	40	0	0	0	0	0	0	26	12	0	2	0	0	0	10.9	33	21.21
DE	24	3	21	3	0	0	0	0	0	16	2	1	1	0	1[v]	0	9.9	38	–36.84
FL	176	15	161	10	0	2	3	0	0	111	20	1	27	2[f]	0	0	5.6	202	–12.87
GA	268	26	242	17	0	8	1	0	0	154	28	42	16	2[g]	0	0	16.6§	256	4.69
HI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	0.00
IA	57	16	41	7	4	2	3	0	0	0	28	13	0	0	0	0	10.1§	108	–47.22
ID	26	0	26	0	0	0	0	0	0	0	26	0	0	0	0	0	4.2	12	116.67
IL	46	0	46	0	0	0	0	0	0	0	46	0	0	0	0	0	1.0	51	–9.80
IN	13	0	12	0	0	0	0	0	0	0	12	0	0	0	0	1	0.7	12	8.33
KS	83	24	59	9	9	2	4	0	0	0	5	53	0	1[h]	0	0	6.8	80	3.75
KY	30	10	20	4	1	5	0	0	0	0	11	9	0	0	0	0	2.9	17	76.47
LA	7	0	7	0	0	0	0	0	0	0	5	2	0	0	0	0	1.0	7	0.00
MA	232	12	220	12	0	0	0	0	0	135	34	40	9	2[i]	0	0	8.4	329	–29.48
MD	414	19	395	15	2	0	2	0	0	272	44	27	41	1[j]	10[w]	0	8.5	386	7.25
ME	127	7	120	6	1	0	0	0	0	59	15	43	2	1[k]	0	0	15.6	61	108.20
MI	50	6	44	1	1	0	4	0	0	0	39	4	1	0	0	0	1.8	39	28.21
MN	42	5	37	1	3	0	1	0	0	0	17	20	0	0	0	0	1.8	71	–40.85
MO	66	3	63	0	1	0	2	0	0	0	55	8	0	0	0	0	2.6	73	–9.59
MS	9	0	9	0	0	0	0	0	0	0	9	0	0	0	0	0	2.6	6	50.00
MT	16	1	15	0	0	0	1	0	0	0	10	5	0	0	0	0	3.3	15	6.67
NC	521	30	491	19	2	8	0	0	1[a]	297	43	91	50	7[l]	3[x]	0	12.8	458	13.76
ND	32	14	18	5	5	4	0	0	0	0	1	17	0	0	0	0	7.7	36	–11.11
NE	34	15	19	5	7	0	3	0	0	1	3	15	0	0	0	0	3.6	60	–43.33
NH	48	2	46	2	0	0	0	0	0	19	4	17	6	0	0	0	8.2	12	300.00
NJ	265	23	242	20	2	0	0	0	1[b]	139	45	45	8	0	5[y]	0	8.1	241	9.96
NM	10	2	8	0	0	1	1	0	0	0	5	3	0	0	0	0	2.5	10	0.00
NV	8	0	8	0	0	0	0	0	0	0	8	0	0	0	0	0	2.9	17	–52.94
NY	612	34	578	25	6	1	2	0	0	320	127	95	31	1[m]	4[z]	0	7.3	563	8.70
NYC	44	4	40	4	0	0	0	0	0	36	2	2	0	0	0	0	5.3	28	57.14
OH	59	0	59	0	0	0	0	0	0	10	48	0	0	1[n]	0	0	1.4	70	–15.71
OK	69	16	53	4	6	1	5	0	0	0	3	50	0	0	0	0	5.5	79	–12.66
OR	25	0	25	0	0	0	0	0	0	0	23	0	2	0	0	0	9.4	8	212.50
PA	504	72	432	58	6	4	1	1	2[c]	283	41	62	32	8°	6[aa]	0	6.2	413	22.03
PR	78	12	66	1	0	8	3	0	0	0	0	0	0	66[p]	0	0	33.2	71	9.86
RI	30	1	29	1	0	0	0	0	0	16	4	7	2	0	0	0	8.0	29	3.45
SC	180	25	155	20	0	4	1	0	0	105	7	15	26	2[q]	0	0	7.7	220	–18.18
SD	38	11	27	5	4	1	1	0	0	0	2	25	0	0	0	0	5.9	68	–44.12
TN	131	7	124	3	2	2	0	0	0	3	19	98	4	0	0	0	3.5	48	172.92
TX	890	44	845	10	7	13	12	2	0	19	432	351	31	12[r]	0	1	6.5	741	20.11
UT	11	0	11	0	0	0	0	0	0	0	10	0	1	0	0	0	2.4	15	–26.67
VA	637	62	575	40	8	5	2	7	0	311	17	156	80	6[s]	5[bb]	0	15.5	496	28.43
VT	73	4	69	0	4	0	0	0	0	42	1	24	1	0	1[cc]	0	15.5	59	23.73
WA	15	0	15	0	0	0	0	0	0	0	15	0	0	0	0	0	3.1	15	0.00
WI	22	0	22	0	0	0	0	0	0	0	21	1	0	0	0	0	1.0	28	–21.43
WV	118	6	112	3	1	1	0	1	0	73	7	22	8	1[t]	1[dd]	0	9.4	75	57.33
WY	11	0	11	0	0	0	0	0	0	0	8	3	0	0	0	0	1.6	18	–38.89
Total	**6,943**	**547**	**6,393**	**318**	**82**	**79**	**53**	**11**	**4**	**2,615**	**1,692**	**1,494**	**427**	**121**	**44**	**3**	**6.1§**	**6,418**	**8.18**
% 2006	100.00	7.88	92.08	4.58	1.18	1.14	0.76	0.16	0.06	37.66	24.37	21.52	6.15	1.74	0.63	0.04			
% Positive 2006§	6.10	0.94	11.75	1.08	6.39	0.31	5.03	2.01	1.23	18.73	6.26	28.12	24.91	4.42	1.20	—			
Total 2005‡	6,418	494	5,923	269	93	76	47	9	0	2,534	1,478	1,408	376	98	29	1			
% Change§	8.18	10.73	7.94	18.22	–11.83	3.95	12.77	22.22	400.00	3.20	14.48	6.11	13.56	23.47	51.72	200.00			

*Other domestic includes: [a]1 ferret; [b]1 ferret; [c]1 ferret, 1 llama. †Other wild includes: [d]3 bobcats, 1 cougar, 1 coyote; [e]1 coyote, 1 deer, 1 opossum; [f]1 bobcat, 1 otter; [g]1 bobcat, 1 coyote; [h]1 coyote; [i]1 coyote, 1 otter; [j]1 deer; [k]1 wolf hybrid; [l]5 bobcats, 2 coyotes; [m]1 otter; [n]1 opossum; [o]4 deer, 2 coyotes, 1 bobcat, 1 fisher; [p]66 mongooses; [q]2 bobcats; [r]10 bobcats, 1 coyote, 1 ringtail; [s]6 bobcats; [t]1 bobcat. ‡Rodents and lagomorphs include: [u]8 groundhogs; [v]1 groundhog; [w]10 groundhogs; [x]3 groundhogs; [y]4 groundhogs, 1 rabbit; [z]4 groundhogs; [aa]6 groundhogs; [bb]5 groundhogs; [cc]1 groundhog; [dd]1 groundhog. §Because of changes in state data collection procedures, percent positive may be elevated because of incomplete reporting of submission data.

tory Information System or the Laboratory Information Tracking System.[27,28] To date, no unified electronic reporting system exists for rabies. Existing public health reporting systems were not designed for transmission of data involving diseases in animal populations and often lack designated fields for reporting vital information, such as animal species.[29,30] To facilitate consistent reporting, all states and territories are requested to submit finalized data by e-mail directly to the Poxvirus and Rabies Branch at the CDC. All year-end totals were confirmed by e-mail or telephone verification with state or territorial health department officials. Data from Canada were obtained from the Animal Health and Production Division, Canadian Food Inspection Agency, and data from Mexico were obtained from the PAHO Epidemiological Information System.

Diagnosis in animals suspected of having rabies was made by DFA staining of rabies viral antigen in brain material submitted to the state health laboratories as described in the standard DFA protocol for rabies.[31] Virus isolation in neuroblastoma cell cultures or mice, nucleic acid detection via the reverse transcriptase–polymerase chain reaction assay, and sequencing and genetic analysis were used to confirm some cases.

Calculations of percent positive are based on the total number of animals tested for rabies. Because most animals submitted for testing are selected because of abnormal behavior or obvious illness, the percent positive is not representative of the incidence of rabies in the general species population. Furthermore, because protocols for submitting animals vary by state, the percent positive for one species is not directly comparable with another species, and comparison of percent positive values between states is inappropriate. For comparison of percent positive to historical data, data from states lacking total submission data were excluded from calculations.

Geographic areas for different rabies virus reservoirs in the United States were produced by aggregating data from 2002 through 2006. If no cases of a particular variant were identified over the preceding 2 years, the variant is not represented. Counties in which cases were reported in the reservoir species over this period were selected and dissolved in a software program[a] to produce a polygon representing the distribution of that rabies virus variant. Reservoir maps are an estimate of the relative distribution of each major terrestrial rabies virus variant maintained by a particular reservoir species. Because of the paucity of samples tested at some localities and a lack of antigenic typing or genetic sequencing where reservoirs meet, defining precise viral fronts is difficult. Geographic location was provided only to the county level, and maps represent cases at this jurisdictional level. Submission data for South Carolina and Oklahoma were not provided with location data. Subsequently, maps showing rabies cases by species do not include counties in which testing occurred but no rabies cases were identified.

Rabies in Wild Animals

Wild animals accounted for 6,393 (92.1%) of the 6,940 reported cases of rabies in animals in 2006 (**Figure 3**). This number represents a nearly 8% increase from the 5,923 cases reported in 2005 (**Table 1**). Raccoons continued to be the most frequently reported rabid wildlife species (37.7% of all animal cases during 2006), followed by bats (24.4%), skunks (21.5%), foxes (6.2%), and other wild animals, including rodents and lagomorphs (2.4%). Numbers of reported cases in

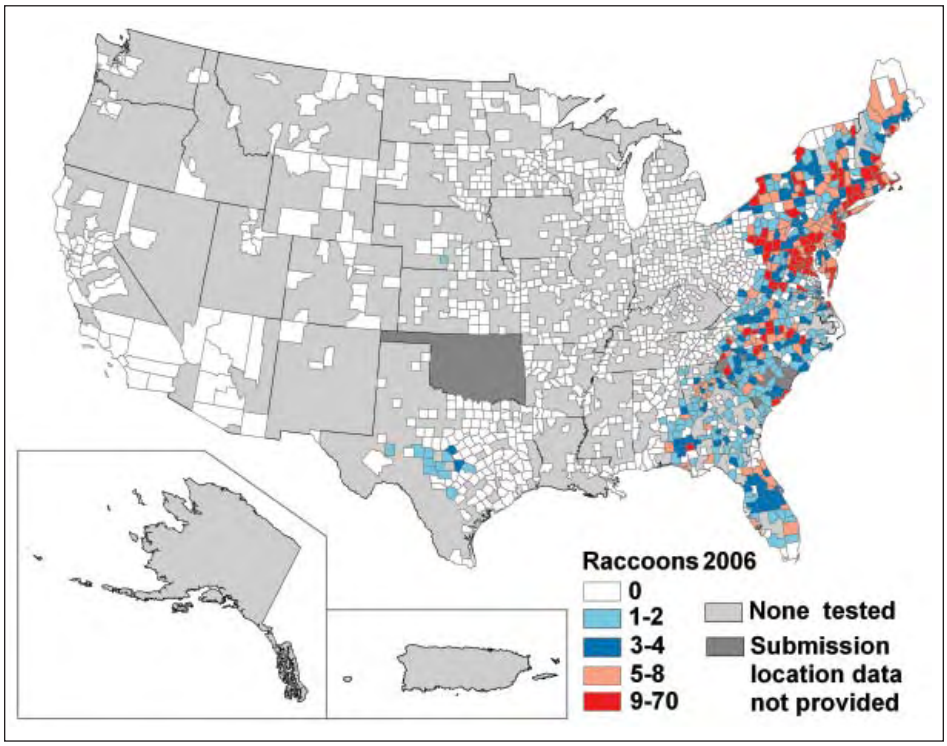

Figure 4—Reported cases of rabies in raccoons, by county, 2006.

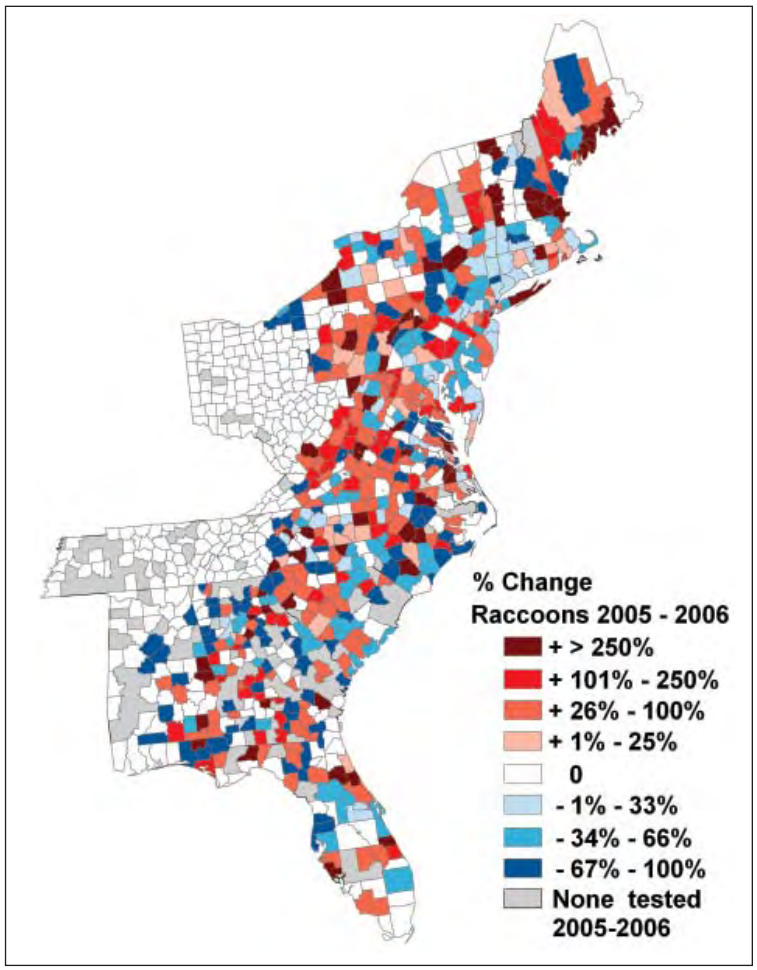

Figure 5—Changes in reported cases of rabies in raccoons in the mid-Atlantic and northeastern states, 2005 to 2006.

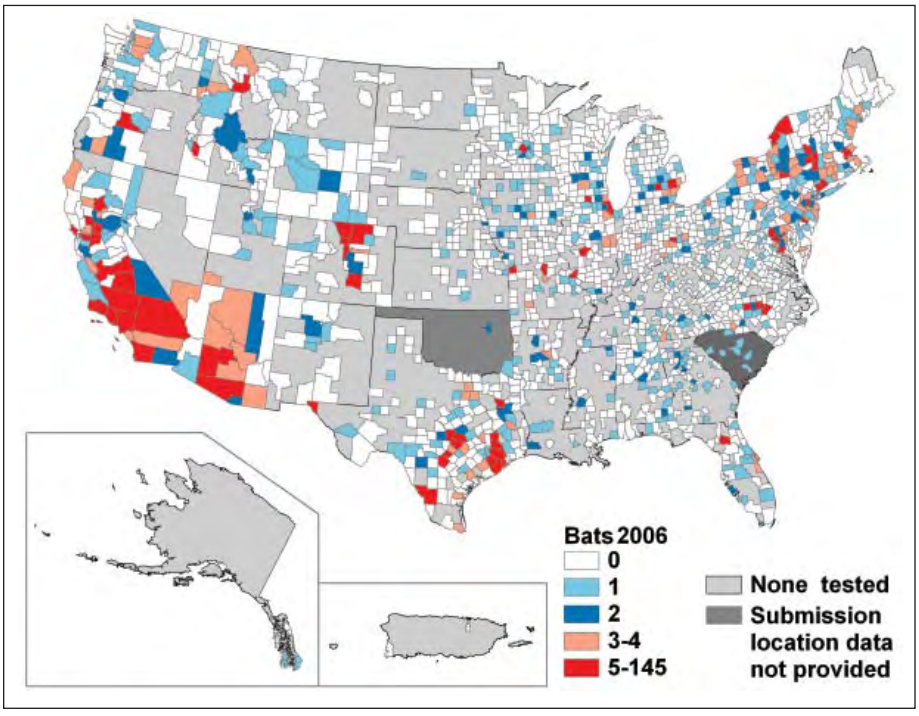

Figure 6—Reported cases of rabies in bats, by county, 2006.

raccoons, bats, skunks, and foxes increased 3.2%, 14.5%, 6.1%, and 13.6%, respectively, from 2005 totals.

Raccoons—The 2,615 cases of rabies in raccoons (*P lotor*) reported in 2006 represented an increase after 3 years of decline. The total percent positive reported increased from 17.1% in 2005 to 18.7% in 2006. Increases in numbers of rabid raccoons during 2006 were reported by 11 of the 20 eastern states in which raccoon rabies is enzootic, including New Hampshire (216.7% increase; 6 cases in 2005 to 19 cases in 2006), West Virginia (114.7%; 34 to 73), Rhode Island (77.8%; 9 to 16), Maine (59.4%; 37 to 59), Alabama (36.6%; 41 to 56), Virginia (25.9%; 247 to 311), Vermont (13.5%; 37 to 42), Pennsylvania (11.4%; 254 to 283), Maryland (11.0%; 245 to 272), North Carolina (7.6%; 276 to 297), and Florida (2.8%; 108 to 111; **Figures 4 and 5**; Table 1).[8] Nine states with well-documented enzootic raccoon rabies reported decreases in the number of rabid raccoons, including Ohio (70.6% decrease; 34 cases in 2005 to 10 cases in 2006), Delaware (42.8%; 28 to 16), Massachusetts (34.8%; 207 to 135), Tennessee (25.0%; 4 to 3), South Carolina (18.6%; 129 to 105), Connecticut (12.5%; 128 to 112), New Jersey (4.8%; 146 to 139), New York (4.2%; 334 to 320), and Georgia (1.3%; 156 to 154). New York City and the District of Columbia reported increases of 56.5% (23 to 36) and 13.0% (23 to 26), respectively, during 2006. The states of the northeast/mid-Atlantic focus of the raccoon rabies epizootic, consisting of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, and West Virginia as well as the District of Columbia and New York City, accounted for 71.5% (1,869 cases; 4.3% increase) of the 2,615 total rabies cases in raccoons in 2006. The southeastern states of Alabama, Florida, Georgia, North Carolina, South Carolina, and Tennessee reported 27.8% (726 cases; 1.7% increase) of the total cases in raccoons.

Ten cases of rabies in raccoons infected with the raccoon rabies virus variant were reported from Ohio. These occurred in 3 of the 6 infected counties in 2006 (Geauga, Lake, and Cuyahoga).[8] After the first rabid raccoon beyond the vaccinated area was identified in 2004, contingency

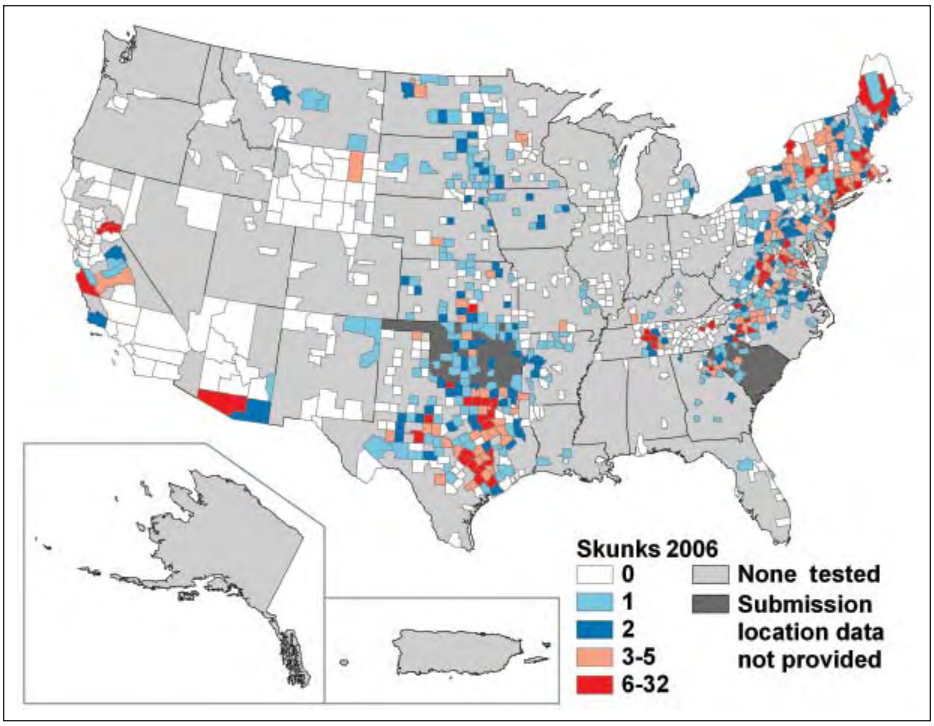

Figure 7—Reported cases of rabies in skunks, by county, 2006.

actions, including enhanced surveillance and extension of the oral vaccination barrier, were initiated. A 2004 breach of the Cape Cod ORV barrier in Barnstable County in Massachusetts resulted in epizootic numbers of raccoon rabies cases throughout the peninsula. At present, rabies cases among raccoons have decreased in Barnstable County by 46.2% (70 cases in 2006, compared with 130 cases in 2005). Nineteen rabid raccoons reported from Texas (4 because of Texas gray fox rabies virus variant, and 15 because of south central skunk rabies virus variant) and 1 in Nebraska (north central skunk rabies virus variant) were the result of spillover infection from local terrestrial reservoirs.

Bats—Rabies in bats accounted for 24.4% of all cases of rabies in animals reported in 2006 (Table 1). The 1,692 cases reported in 2006 represented an increase of 14.5% over those reported in 2005. Total percent positive of tested bats also increased during 2006 from 5.8% in 2005 to 6.3%. Rabies in bats is widely distributed throughout the United States, with cases reported from all 48 contiguous states (**Figure 6**). The first rabid bat since 1993 was reported from Alaska during 2006.[32] Texas reported the largest number of cases in bats (432; 25.5%), followed by California (158; 9.3%) and New York (127; 7.5%). Six states (Colorado, Idaho, Illinois, Mississippi, Nevada, and Washington) reported rabies in bats, but not in terrestrial mammals. Hawaii and Puerto Rico did not report any cases of bat rabies. Of the bats infected with rabies virus, 35.5% (601/1,692) were identified beyond the taxonomic level of order (10 to genus, 591 to species). Among bats identified beyond taxonomic level of order, 64.0% (385/601) were *E fuscus*, the big brown bat; 9.3% (56/601) were *Tadarida brasiliensis*, the Brazilian (Mexican) free-tailed bat; 8.2% (49/601) were *Myotis lucifugus*, the little brown bat; 4.0% (24/601) were *Pipistrellus hesperus*, the western pipistrelle; 3.7% (22/601) were *Lasiurus borealis*, the red bat; 2.7% (16/601) were *Lasiurus cinereus*, the hoary bat; 2.3% (14/601) were *Lasionycteris noctivagans*, the silver-haired bat; 1.3% (8/601) were *Antrozous pallidus*, the pallid bat; 0.9% (5/540) were *Pipistrellus subflavus*, the eastern pipistrelle; 0.5% (3/601) were *Myotis keenii*, the Keen's myotis bat; 0.3% (2/601) were *Lasiurus xanthinus*, the western yellow bat; 0.3% (2/601) were *Myotis septentrionalis*, the northern long-eared myotis; 0.3% (2/601) were *Plecotus townsendii*, Townsend's big-eared bat; 0.2% (1/601) were *Myotis evotis*, the long-eared myotis; 0.2% (1/601) were *Myotis yumanesis*, the Yuma myotis; and 0.2% (1/601) were *Nycticeius humeralis*, the evening bat. Unspeciated bats of the genus *Myotis* (10/601) accounted for the remaining rabid bats and contributed 1.7% to the total of bats identified beyond the taxonomic level of order. Not all public health laboratories had the capacity to speciate bats. Among test-positive bats for which a species was provided, more solitary species (*L borealis, L cinereus, L noctivagans, L xanthinus, P hesperus, P subflavus,* and *P townsendii*) reported a significantly higher proportion of rabid animals than did colonial species (12.98%, compared with 4.95%, respectively; $P < 0.001$).

Skunks—The 1,494 reported cases of rabies in skunks (mainly *M mephitis*) in 2006 represented a 6.1% increase from the number reported in 2005 (**Figure 7**; Table 1). However, total percent positive decreased from 31.6% positive in 2005 to 28.1% positive in 2006. Six of the 24 states where a skunk rabies virus variant is enzootic reported increased numbers of rabid skunks during 2006, including Tennessee (326.1% increase; 23 cases in 2005 to 98 cases in 2006), Montana (150.0%; 2 to 5), Kentucky (50.0%; 6 to 9), California (25.0%; 32 to 40), West Virginia (22.2%; 18 to 22), and Arkansas (20.0%; 15 to 18). Texas reported the greatest number of rabies cases in skunks (351; a 10.4% decrease from 392 cases reported in 2005). Seven states where skunk rabies virus variants are enzootic reported decreases > 50% during 2006, including Illinois (100% decrease; 6 in 2005 to 0 in 2006), Ohio (100%; 2 to 0), Wyoming (80%; 15 to 3), Arizona (75.7%; 66 to 16), Iowa (60.6%; 33 to 13), Nebraska (54.5%; 33 to 15), and Missouri (52.9%; 17 to 8). Illinois and Ohio reported no cases of rabies in skunks in 2006, but reported 6 and 2 cases, respectively, in 2005.

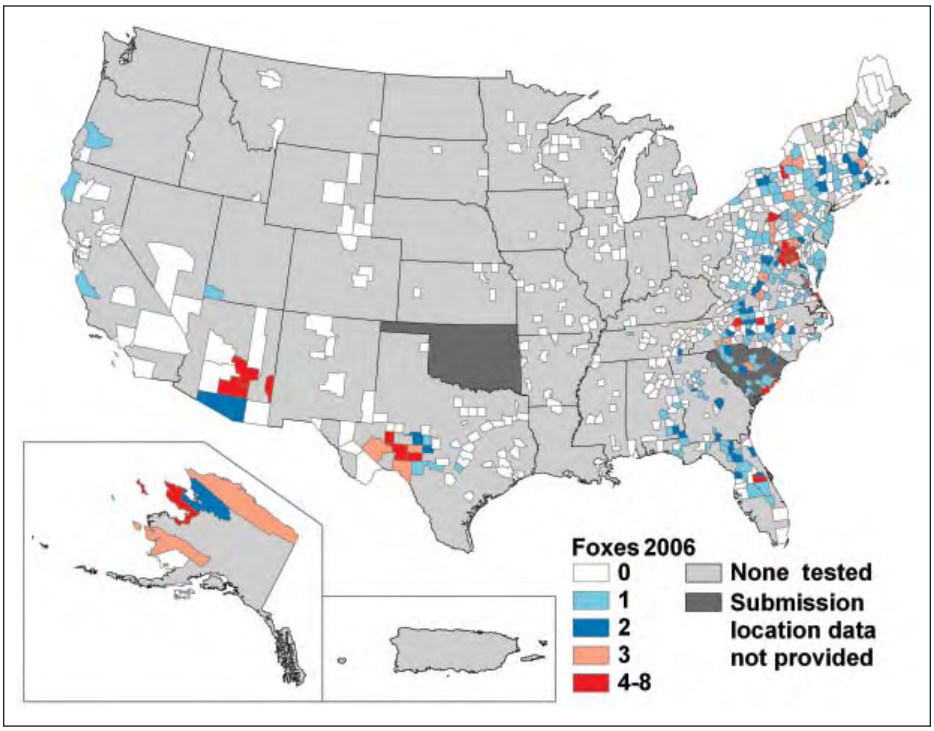

Figure 8—Reported cases of rabies in foxes, by county, 2006.

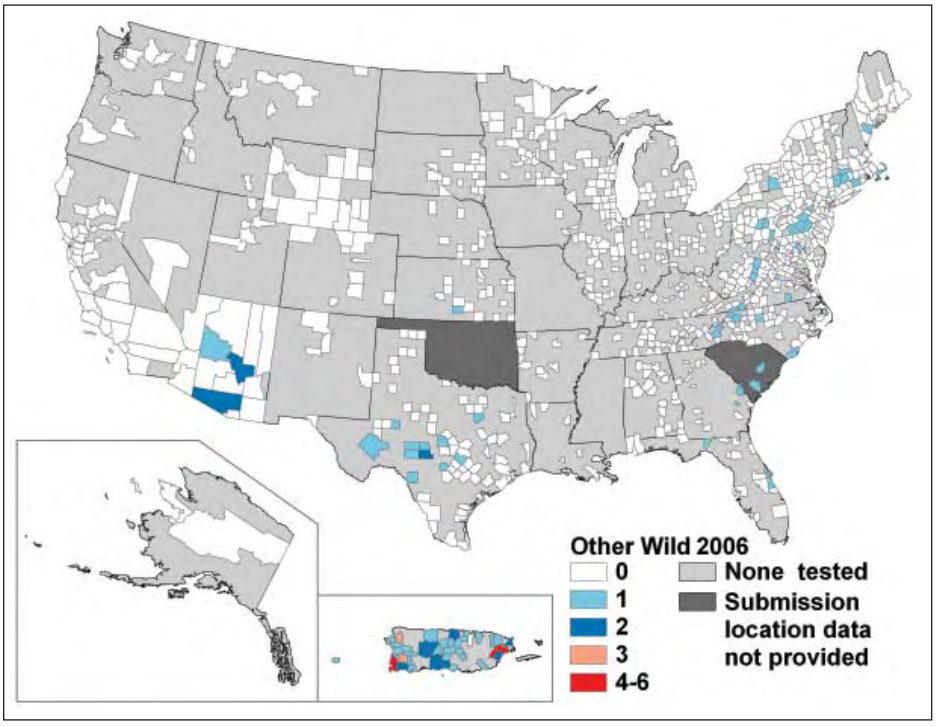

Figure 9—Reported cases of rabies in "Other wild" and "Rodent and lagomorph" categories of Table 1, by county and municipio (Puerto Rico), 2006.

States in which the raccoon rabies virus variant is enzootic (excluding Tennessee, where skunks are the predominant reservoir) reported 49.7% (743/1,494) of the cases of rabies in skunks, most of which were presumably the result of spillover infection of the virus from raccoons. Among the 18 states where the raccoon rabies virus variant is the predominant terrestrial reservoir of rabies, 11 states reported increases in the number of rabid skunks, including New Hampshire (325.0%; 4 cases in 2005 to 17 cases in 2006), Vermont (140.0%; 10 to 24), Maine (104.8%; 21 to 43), North Carolina (51.7%; 60 to 91), New Jersey (45.2%; 31 to 45), Connecticut (47.2%; 36 to 53), Virginia (27.9; 122 to 156), West Virginia (22.2%; 18 to 22), Pennsylvania (12.7%; 55 to 62), New York (11.8%; 85 to 95), and Georgia (5.0%; 40 to 42). Rhode Island reported more rabid raccoons (16) than rabid skunks (7) for the first time in 9 years.

Foxes—Foxes (mainly *V vulpes*, *U cinereoargenteus*, or *A lagopus*) accounted for 6.2% of all cases of rabies in animals reported in 2006 (Table 1). The 427 cases of rabies in foxes represented a 13.6% increase from 2005. The percent positive of foxes submitted for testing during 2006 (24.9%) also increased from that reported in 2005 (23.0%). Most cases of rabies in foxes (356; 83.4%) were reported by states affected by the raccoon rabies virus variant (**Figure 8**). Eleven states reported increases in the number of rabid foxes, compared with 2005: Alaska (500.0% increase; 2 cases in 2005 to 12 cases in 2006), New Hampshire (500.0%; 1 to 6), Arizona (83.3%; 12 to 22), Pennsylvania (68.4%; 19 to 32), Virginia (40.4%; 57 to 80), Texas (34.8%; 23 to 31), New Jersey (33.3%; 6 to 8), Tennessee (33.3%; 3 to 4), West Virginia (33.3%; 6 to 8), New York (29.2%; 24 to 31), and Maryland (5.1%; 39 to 41). The District of Columbia, Maine, Oregon, and Utah reported no cases of rabies in foxes during 2005, but all reported cases during 2006. Colorado, Illinois, Kansas, and Nebraska all reported cases of rabies in foxes in 2005, but no cases in 2006.

Other wild animals—Puerto Rico reported 66 rabid mongooses (*H javanicus*) during 2006, an 8.2% increase from the 61 cases reported in 2005 (**Figure 9**). Other wildlife in which rabies was reported included 30 bobcats (*Lynx rufus*), 43 groundhogs (*Marmota monax*), 10 coyotes (*C latrans*), 6 white-tail deer (*Odocoileus virginianus*), 3 river otters (*Lontra canadensis*), 2 opossums (*Didelphis virginiana*), 1 fisher (*Martes pennanti*), 1 ringtail (*Bassariscus astutus*), 1 rabbit (*Oryctolagus cuniculus*), and 1 wolf hybrid. All cases of rabies in rodents and lagomorphs were reported by states in which rabies is enzootic in raccoons (Table 1).

Of the 10 coyotes found test-positive for rabies, 9 were variant typed (typing results from Massachusetts were unavailable). The 9 coyotes were infected with the predominant terrestrial rabies virus variant for the geographic region where the animal was found (1 Arizona gray fox rabies virus variant, 6 raccoon rabies virus variant, and 2 south central skunk rabies virus variant).

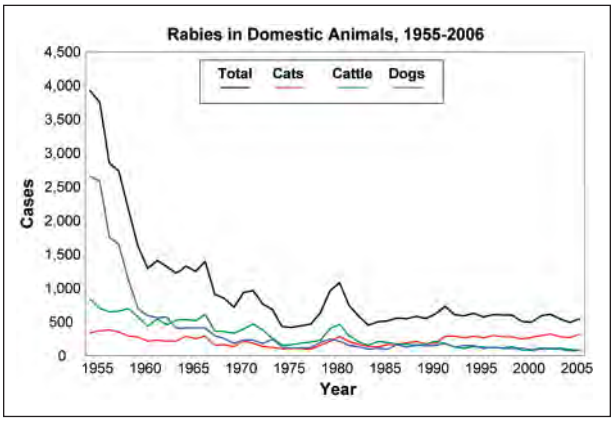

Figure 10—Cases of rabies in domestic animals in the United States, by year, 1955 to 2006.

Rabies in Domestic Animals

Domestic species accounted for 7.9% of all rabid animals reported in the United States in 2006 (Table 1). The number of domestic animals reported rabid in 2006 (547) represented a 10.7% increase from the total reported in 2005 (**Figure 10**). Cases of rabies reported in cats and dogs increased 18.2% and 4.0%, respectively. Pennsylvania reported the largest number of rabid domestic animals (72 cases), followed by Virginia (62), Texas (44), New York (34), and North Carolina (30).

Cats—Most (265) of the 318 cases of rabies in cats were reported from states in which the raccoon rabies virus variant is present (**Figure 11**). Remaining cases were reported principally by Central Plains states, where most cases were presumably the result of spillover from rabid skunks. Nine states reported > 10 cases of rabies in cats (Pennsylvania, 58 cases; Virginia, 40; New York, 25; New Jersey, 20; South Carolina, 20; North Carolina, 19; Georgia, 17; Maryland, 15; and Massachusetts, 12). Twenty-one states and the District of Columbia did not report any rabid cats. Puerto Rico reported 1 case of rabies in a cat, presumably spillover from the mongoose rabies virus variant.

Dogs—Texas (13 cases), Georgia (8), and North Carolina (8) reported the largest numbers of cases of rabies in dogs by individual states. No other states reported > 5 cases of rabies in dogs in 2005. All dogs reported from Texas were sequenced to identify the variant of rabies virus; 5 cases were identified as the

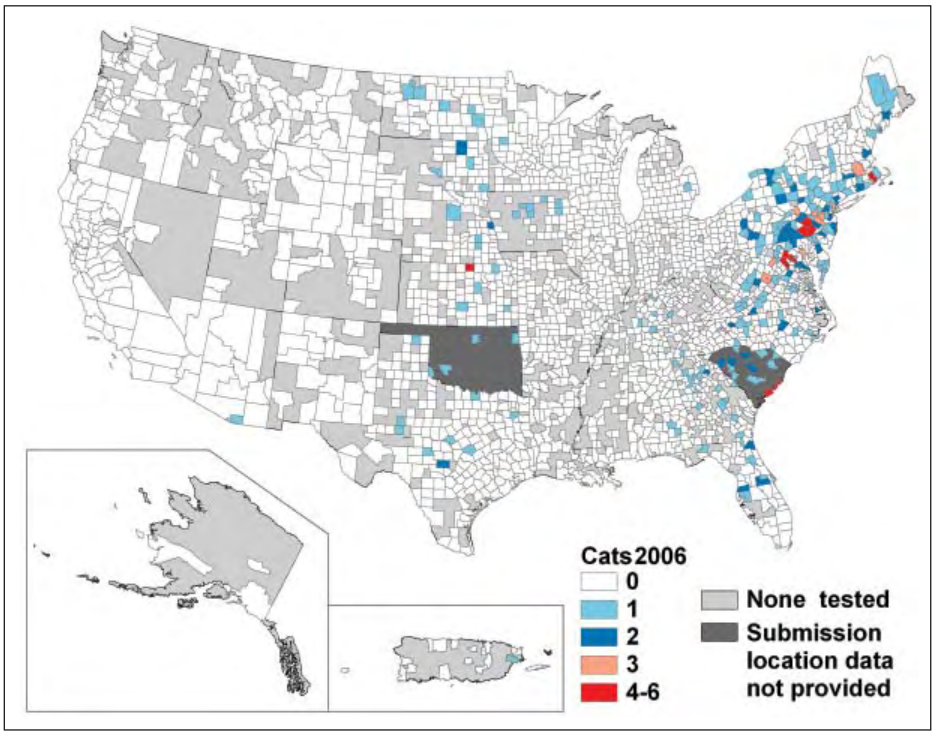

Figure 11—Reported cases of rabies in cats, by county and municipio (Puerto Rico), 2006.

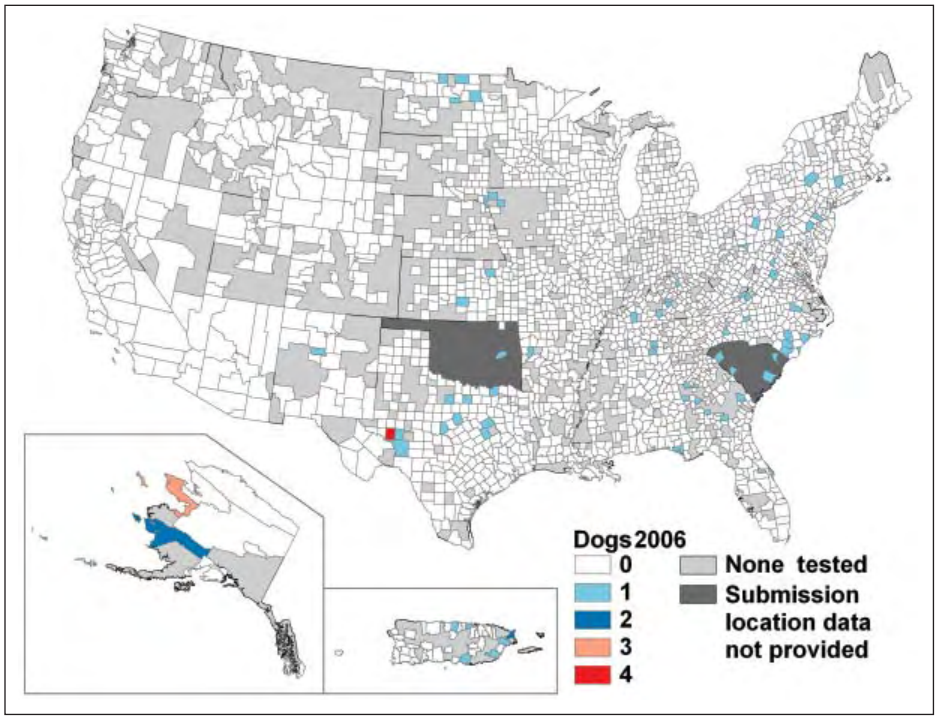

Figure 12—Reported cases of rabies in dogs, by county and municipio (Puerto Rico), 2006.

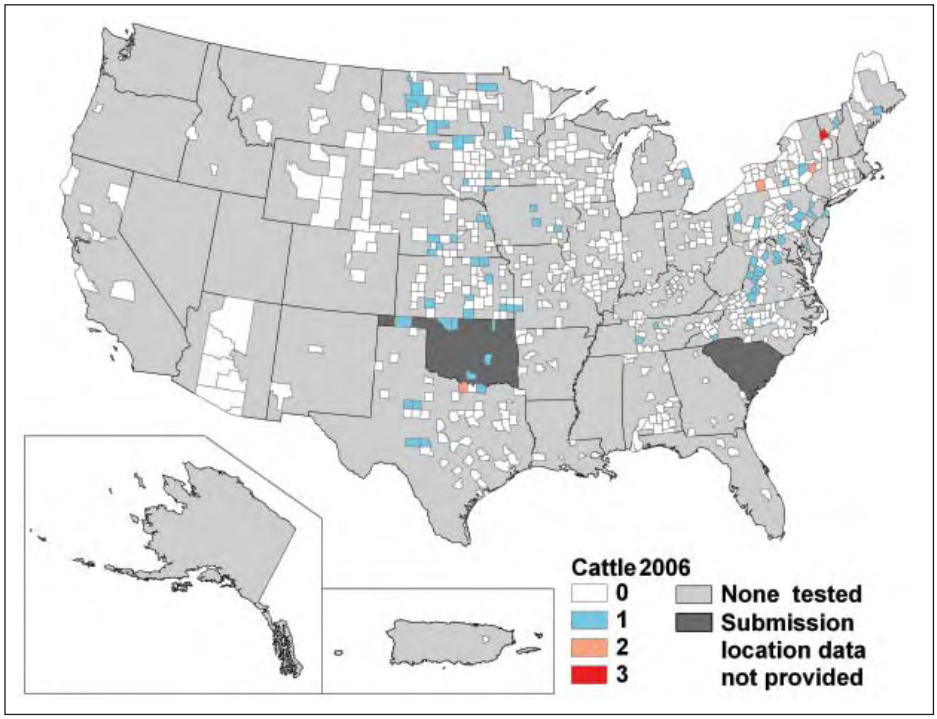

Figure 13—Reported cases of rabies in cattle, by county and municipio (Puerto Rico), 2006.

Texas gray fox rabies virus variant, and the remaining cases were identified as the south central skunk rabies virus variant. No cases were reported involving the dog/coyote rabies virus variant. Thirty states, the District of Columbia, and New York City did not report any rabid dogs. Puerto Rico reported 8 cases of rabies in dogs (**Figure 12**).

Excluding rabid dogs from Puerto Rico (which are presumably attributable to the mongoose rabies virus variant), 71 cases of rabies in dogs were reported from the United States. Of those 71 cases, 86% (n = 61) were reported as typed by monoclonal antibodies or sequenced to determine the rabies virus variant responsible. One dog in Bernalillo County in New Mexico was determined to be infected with a rabies virus variant associated with Mexican free-tailed bats (*T brasiliensis*). The rabies virus variants isolated from all other test-positive dogs typed in 2006 were identified as the terrestrial rabies virus variant associated with the geographic area where the dog was collected (Figure 3). Typing results were not provided from Alaska (1 of 5 test-positive dogs not typed), Connecticut (1/1), Georgia (1/8), Kansas (2/2), North Dakota (2/4), New York (1/1), Pennsylvania (1/4), and Virginia (1/5).

Other domestic animals—The number of cases of rabies in cattle decreased 11.8% from 93 in 2005 to 82 in 2006 (**Figure 13**; Table 1). Distribution of rabid cattle was similar to that of rabid skunks in the central and Midwestern states (Figures 6 and 13) and to rabid raccoons in the mid-Atlantic/northeastern region (Figures 5 and 13). Kansas (9 cases), Virginia (8), Nebraska (7), Texas (7), New York (6), Oklahoma (6), and Pennsylvania (6) reported the largest numbers of rabid cattle. No other state reported > 5 cases of rabies in cattle in 2006. The 53 cases of rabies reported in horses and mules (including donkeys) in 2006 represented a 12.8% increase from the 47 cases reported in 2005. Reported cases of rabies in sheep and goats increased 22.2% from 9 cases in 2005 to 11 cases in 2006. Other reported cases of rabies in domestic animals included 3 ferrets (in North Carolina, New Jersey, and Pennsylvania) and 1 llama (Pennsylvania).

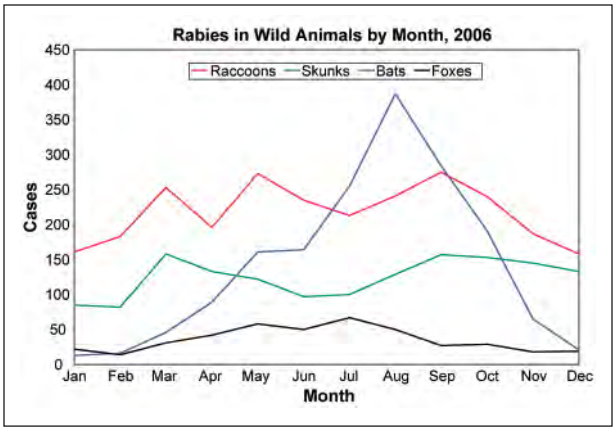

Figure 14—Cases of rabies in wild animals in the United States, by month, 2006.

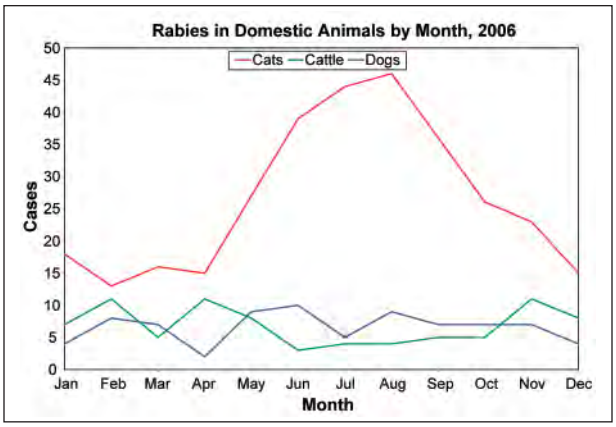

Figure 15—Cases of rabies in domestic animals in the United States, by month, 2006.

Seasonal Trends

The frequency of reported cases of rabies in raccoons had an early peak in March and May, followed by a brief decline until a slightly higher peak was observed in September (**Figure 14**). Reporting for rabid skunks followed a similar seasonal trend, but with no peak in May. Reports of rabid bats increased from January to a peak in August, before a steep decline through December. The frequency of reported rabid foxes had a gradual increase and decline, with a peak in July.

Reported cases in cats fluctuated from January until April, before abruptly increasing to a peak during July and August, followed by a steady decline through fall to a low in December (**Figure 15**). The frequency of reported cases of rabies in cattle and dogs did not appear to have a strong seasonal pattern.

Rabies in Humans

Three cases of rabies in humans were reported in the United States in 2006 (**Table 2**).[33] Cases in Texas and Indiana were indigenously acquired and determined to be associated with bat exposures. An additional case was identified in California in a patient who had recently emigrated from the Philippines and was associated with a dog bite received before coming to the United States.

On May 6, 2006, the CDC was contacted by the Texas Department of State Health Services about a potential rabies case in the Houston area. The patient was a 16-year-old male who reported symptoms of agitation, loss of appetite, and vomiting on May 4. Symptoms progressed to include hydrophobia, aerophobia,

Table 2—Cases of rabies in humans in the United States and Puerto Rico, 2000 through 2006,* by circumstances of exposure and rabies virus variant.

Date of death	State of residence	Exposure history†	Rabies virus variant‡
20 Sep 00	CA	Unknown§	Bat, Tb
9 Oct 00	NY	Bite-Ghana	Dog, Africa
10 Oct 00	GA	Unknown§	Bat, Tb
25 Oct 00	MN	Bite	Bat, Ln/Ps
1 Nov 00	WI	Unknown§	Bat, Ln/Ps
4 Feb 01	CA	Unknown§-Philippines	Dog, Philippines
31 Mar 02	CA	Unknown§	Bat, Tb
31 Aug 02	TN	Unknown§	Bat, Ln/Ps
28 Sep 02	IA	Unknown§	Bat, Ln/Ps
10 Mar 03	VA	Unknown§	Raccoon, eastern United States
5 Jun 03	PR	Bite	Dog/mongoose, Puerto Rico
14 Sep 03	CA	Bite	Bat, Ln/Ps
15 Feb 04	FL	Bite	Dog, Haiti
3 May 04	AR	Bite (organ donor)	Bat, Tb
7 Jun 04	OK	Liver transplant recipient	Bat, Tb
9 Jun 04	TX	Kidney transplant recipient	Bat, Tb
10 Jun 04	TX	Arterial transplant recipient	Bat, Tb
21 Jun 04	TX	Kidney transplant recipient	Bat, Tb
Survived 04	WI	Bite	Bat, unknown
26 Oct 04	CA	Unknown§	Dog, El Salvador
27 Sep 05	MS	Unknown§	Bat, unknown
12 May 06	TX	Unknown§	Bat, Tb
2 Nov 06	IN	Bite	Bat, Ln/Ps
14 Dec 06	CA	Bite	Dog, Philippines

*All laboratory-confirmed cases of rabies in human beings who developed the disease in the United States and Puerto Rico, 2000 through 2006. †Data for exposure history are reported only when the biting animal was available and tested positive for rabies, when plausible information was reported directly by the patient (if lucid or credible), or when a reliable account of an incident consistent with rabies exposure (eg, dog bite) was reported by an independent witness (usually a family member). ‡Variants of the rabies virus associated with terrestrial animals in the United States and Puerto Rico are identified with the names of the reservoir animal (eg, dog or raccoon), followed by the name of the most definitive geographic entity (usually the country) from which the variant has been identified. Variants of the rabies virus associated with bats are identified with the names of the species of bats in which they have been found to be circulating. Because information regarding the location of the exposure and the identity of the exposing animal is almost always retrospective and much information is frequently unavailable, the location of the exposure and the identity of the animal responsible for the infection are often limited to deduction. §In some instances where the exposure history is unknown, there may have been known or inferred interaction that, especially for bats, could have involved an unrecognized bite.

Ln/Ps = *Lasionycteris noctivagans* or *Pipistrellus subflavus*, the silver-haired bat or the eastern pipistrelle. Tb = *Tadarida brasiliensis*, the Brazilian (Mexican) free-tailed bat.

and increased agitation that same day. The patient was hospitalized the next day and then transferred to a tertiary care facility. He developed difficulty breathing and required intubation. Rabies was considered in a differential diagnosis after interviews with family members indicated a possible exposure to a bat. On May 8, samples were sent to the CDC, where rabies was confirmed and the virus sequenced as a rabies virus variant associated with the Mexican free-tailed bat (*T brasiliensis*). The patient's family had reported that, approximately 4 weeks prior to onset, a bat had been discovered in the patient's room and released. The patient reportedly mentioned to acquaintances that he had awakened to find the bat on his face. Staff at the Wisconsin Children's Hospital and the CDC were consulted to start the Wisconsin treatment protocol[34]; however, the patient's status deteriorated before any treatment regimen could be initiated. Life support was withdrawn on May 12, 2007 (8th day of hospitalization).

On September 30, 2006, a 10-year-old girl in Indiana complained to family members of pain in the right arm.[33] By October 3, the symptoms had progressed to include increased arm pain, occasional numbness, and vomiting. Three to five days after initial onset of symptoms, the patient became febrile; developed speech difficulty; had loss of appetite, sore throat, and neck pain; and became irritable and easily agitated. She was hospitalized on October 7 and began having difficulty swallowing secretions. The next day, neurologic deficits became evident, and she was transferred to a tertiary care facility. At the tertiary care facility, the patient was intubated because of difficulty breathing and excess salivation. On the third day of hospitalization, the family indicated that a possible animal exposure might have occurred in June 2006. The patient was able to confirm that she had felt a bat bite or scratch her. Samples were submitted to the CDC, where rabies was confirmed and characterized as a rabies virus variant associated with the silver-haired bat (*L noctivagans*). The patient was started on the Wisconsin rabies treatment protocol approximately 8 days after onset of symptoms. The patient was removed from life support on November 2, 2006 (26th day of hospitalization), because of deteriorating clinical condition and poor prognosis.

On November 15, 2006, an 11-year-old boy in California began complaining of sore throat, fatigue, and fever.[33] That same night, the boy was taken to a local emergency department with chest tightness, dysphagia, and insomnia. The patient had tachycardia and hypertension, but did not have a fever. While at the emergency department, the patient began experiencing irregular lip and mouth movements, hallucinations, agitation, aerophobia, hydrophobia, and profuse salivation. Rabies was considered in a differential diagnosis, and the patient was transferred to a tertiary care pediatric hospital. The patient's family was questioned about possible animal exposures. The family had emigrated from the Philippines on October 2, 2006. Siblings were able to recall that the patient was bitten by a dog approximately 2 years previously when he was living in the Philippines. Samples were submitted to the California Department of Health Services Viral and Rickettsial Disease Laboratory and the CDC. Rabies virus antigen was detected by DFA tests on corneal impressions collected at the laboratory on November 18. The CDC confirmed the diagnosis of rabies, and gene sequences were found similar to those of other canine rabies virus variants from the Philippines. The patient was started on the experimental Wisconsin treatment protocol on November 16. However, the patient experienced multiple complications while hospitalized, and life support was withdrawn on December 13 (27th day of hospitalization).

Rabies should be included in the differential diagnosis of any unexplained acute, rapidly progressive encephalitis, especially in the presence of autonomic instability, dysphagia, hydrophobia, paresis, or parasthesia.[35] Since the survival of a rabies patient after an experimental treatment in 2004, early diagnosis of potential rabies cases has become increasingly important if experimental treatment is to be considered.[36] However, the benefits from any particular experimental rabies treatment regimen have not been determined. No single course of treatment for rabies in humans has been efficacious after clinical signs of rabies develop.

The number of samples being submitted to rule out rabies from encephalitic patients has increased since the Wisconsin protocol became available. From January 2003 to December 2004, samples were received from 64 patients. From 2005 to 2006, samples were received from 116 patients for rabies testing, accounting for an 81.2% increase. Health communications to inform the public of what constitutes a rabies exposure and the application of appropriate and timely human rabies PEP remain the primary methods of preventing clinical disease and death from rabies in humans.

Rabies in Canada and Mexico

Canada reported 229 laboratory-confirmed cases of rabies in domestic and wild animals in 2006. This number represents a 7.7% decrease from the 248 rabies cases reported in 2005 and is the sixth consecutive year in which there has been a decline in cases of rabies. Seventy-seven percent (176) of reported cases were in wild animals, 14.8% (34) in livestock, and 8.3% (19) in domestic companion species. Bat cases decreased by 23.4% (94 cases in 2005, compared with 72 cases in 2006) and accounted for 31.4% of all rabid animals in 2006. Reported cases in skunks and foxes also decreased by 10.6% (94 to 84) and 22.2% (18 to 14), respectively. Reported cases of rabid raccoons increased during 2006 (3 cases in 2005 to 5 cases in 2006). Four cases of raccoons infected with the raccoon rabies virus variant strain were reported from Quebec during 2006, and 1 case of a raccoon infected with Arctic fox variant strain was reported from Ontario. Increases occurred mainly in domestic livestock. Bovine cases increased by 62.5% (16 cases in 2005, compared with 26 cases in 2006), accounting for 11.4% of all rabies. Also, during 2006, equine cases increased more than 3-fold (2 to 7 cases). Cases in dogs and cats increased 8.3% (12 to 13) and 50.0% (4 to 6), respectively, in 2006. One rabid fisher was reported from Manitoba province in 2006. Canada did not report any cases of rabies in humans during 2006.

Mexico reported 283 cases of animal rabies in domestic and wild animals to PAHO during 2006. This represents a 59.4% decrease from the number of cases (698) reported to PAHO during 2005. Twenty-seven percent (77/283) of rabies cases were reported in dogs. Other domestic animals reported include 181 cattle (63.9% of all animals reported), 1 cat (0.4%), and 12 other livestock (4.2%). Among the 12 reported cases in wild species reported test-positive for rabies, 5 were bats. Nine cases of rabies in humans were reported to PAHO during 2006.

Discussion

The number of reported cases of rabies represents only a fraction of the total cases that occur each year. Many rabid animals are never observed and, therefore, go undetected and untested.[37] Cases of rabies included in this report are only those that were confirmed by laboratory diagnosis and reported to the CDC by state and territorial health departments. State health authorities have different requirements for submission of specimens for rabies diagnosis, and thus, levels of surveillance vary. The predominantly passive nature of rabies surveillance and lack of estimates of animal populations dictate that accurate incidence and prevalence data for rabies cannot be determined for most species. To better estimate regional trends, determine surveillance effort, and identify possible bias, states are encouraged to submit denominator data (ie, data for animals tested but with negative results by DFA tests) by species, county, and temporal occurrence.

The public health surveillance system in the United States is neither intended nor sufficient to characterize accurately the distribution of rabies in wildlife. Passive surveillance relies on the interaction of humans with animal reservoirs and the subsequent possible exposure of a person to rabies. Additionally, there is a strong spatiotemporal dynamic to rabies. Moreover, reporting at a political boundary (eg, counties) complicates the ability to detect and analyze detailed relationships between any environmental variables and the spread of rabies. Enhanced surveillance carried out by several state health departments and the USDA WS augments passive public health surveillance in critical geographic areas, such as ahead of epizootic fronts. Combined with a new real-time, coordinate-based surveillance system (RabID)[38] and the use of the direct rapid immunohistochemical test[39] by the USDA in the field, such enhanced surveillance is important in defining accurately the leading edge of the raccoon rabies virus variant reservoir as well as providing input for the various ORV programs along this front.

In the United States, only 2 dogs have been reported infected with the dog/coyote rabies virus variant in Texas since 2001. The last reported case of canine rabies occurred along the Mexico border in Webb County in Texas in March 2004.[26] This case was suspected to have been because of a translocation event across the border. Because no cases of rabies attributable to a canine rabies virus variant have been detected for more than 2 years, the United States is now considered free of any canine rabies virus variants. Thus, the United States is the most recent country globally to eliminate dog-to-dog transmission of rabies. Continued surveillance will be required for early detection and to prevent this rabies virus variant or others from being reintroduced to the United States. Ongoing collaboration with Mexico via the Border Infectious Disease Surveillance project is targeted at monitoring for this variant along the border and continuing vaccination programs into Mexico for the ultimate eradication of this variant.

The number of cases of raccoons reported with rabies in 2006 increased 3.2% from those reported in 2005 after 3 years of decline. Although raccoons continue to account for the highest percentage (37.7%) of rabies cases reported among animals in the United States in 2006, the magnitude of this ratio has declined despite the increased number of reported cases (Figure 2). Enzootic transmission of rabies among raccoons, and from rabid raccoons to other species, continued in 20 states, New York City, and the District of Columbia in 2006. States enzootic for raccoon rabies reported 99.2% (2,595/2,615) of all documented cases of rabies in raccoons and accounted for 69.0% (4,793/6,943) of the national total of rabid animals (80.6%; [4,233/5,251] of total cases in terrestrial animals). The proportion of rabid animals from states affected by enzootic raccoon rabies increased in 2006. Periodic increases in numbers of reported cases of rabies in states where the disease is enzootic occur when populations of raccoons decimated by a previous epizootic again reach densities sufficient to support increased transmission of rabies virus.[24,25] However, the proportion of animal rabies cases geographically associated with the raccoon rabies virus variant indicates the high public health burden of this variant, compared with other terrestrial variants in the United States. Moreover, the human exposure risk to this variant is substantial, as reflected in cross-sectional studies of human PEP.[40,41]

Despite the threat of rabies transmission from wild terrestrial carnivores, the use of population-reduction programs to control rabies among such animals is not desirable. Programs in Europe and southeastern Canada have used modified-live or recombinant virus vaccines for the oral immunization of free-ranging wildlife reservoir species (predominantly foxes) to control the disease. During the past 2 decades, more than 100 million doses of vaccine-laden bait have been distributed over 6 million km^2,[42] with promising results for controlling rabies in red foxes. The use of ORV in Switzerland during the past 30 years resulted in a declaration of rabies-free status for that country in 1998, and similar strategies in France led to rabies-free status being declared in 2000.[43] The elimination of a rabies virus variant associated with red foxes in southern Ontario also supports the hypothesis that rabies virus variants associated with foxes can be eliminated by oral vaccination.[14]

Oral vaccination programs may have restricted the expansion of raccoon rabies. As previously reported, the first field release of the V-RG vaccine in the United States began during 1990, on Parramore Island in Virginia.[44] The vaccine was conditionally licensed in April 1995 and was fully licensed in April 1997. Vaccine distribution in each state remains limited to authorized state or federal rabies control programs. Interventions that use the V-RG vaccine distributed within baits to vaccinate

wild raccoons to prevent or slow the geographic expansion of rabies continue in a number of states and are being expanded to additional states. The effectiveness of these programs remains under assessment in multiple states, including Alabama, Florida (Pinellas County), Georgia, Maine, eastern Massachusetts (Cape Cod),[19] New Hampshire, southern New Jersey (Cape May),[18] New York, North Carolina, Ohio, Pennsylvania, Tennessee, Vermont, Virginia, and West Virginia.

During 2006, multiple state agencies, the USDA WS, and the CDC continued partnerships and cooperation in a massive undertaking to maintain and expand an "immune barrier" beginning on the shores in Ohio, Pennsylvania, and New York and intended to reach the Gulf of Mexico in Alabama, in an attempt to curtail the spread of raccoon rabies. In Ohio, Pennsylvania, Maryland, West Virginia, Virginia, North Carolina, and northeast Tennessee (otherwise known as the Appalachian Ridge ORV zone), approximately 4.8 million doses of V-RG vaccine-laden baits were distributed over a total of 73,584 km^2. In addition, 487,000 doses of oral vaccine were distributed again in the GAT ORV zone over an area of 9,883 km^2.[b] Enhanced surveillance conducted by the USDA WS and routine surveillance by state public health agencies continue to determine the placement of new ORV zones as well as the shape of baiting zones each year.[45] This barrier will be extended farther south and moved eastward over time in an attempt to contain and reduce the area of enzootic rabies in raccoons.[45,46] Concerns regarding vaccine safety, efficacy, ecologic impact, and physical bait variables, which were raised during earlier trials, continue to be assessed.[20,21,45–49] Novel products are also being developed as potential candidates for new vaccines to overcome the limited efficacy of the V-RG vaccine in certain animal species (eg, skunks and mongooses).[50–53] Extended baiting activities continued in 2006 where cases were identified in raccoons west of the Ohio-Pennsylvania border in 2004, and enhanced surveillance and evaluation of the baiting strategy continued in relation to a breach of the ORV barrier on Cape Cod, Mass. Baiting was expanded on Cape Cod during 2006 with the objective of trying to eliminate rabies from the tip of the peninsula. In addition, the GAT ORV zone was expanded again during 2006 to increase the area baited in Tennessee along the Georgia border.

Control efforts consisting of ORV (approx 2.8 million baits delivered over 91,313 km^2)[b] continued in Texas in an attempt to contain and eliminate the gray fox rabies virus variant and prevent the reintroduction of canine rabies virus variants associated with coyotes and dogs from Mexico during 2006.[10–12] Past translocation of animals infected with canid rabies virus variants found in Texas have been documented.[6,7] These events involved infected animals placed in outdoor enclosures used for commercialized hunting venues. Rapid responses to these previous events may have prevented local establishment and spread of these variants.

Rabies in bats is epizootilogically and genetically distinct from terrestrial rabies maintained by mammalian carnivores. Understanding of the circulation of rabies virus variants in bat species remains less developed than that in carnivores. Although some potential exists for the control of terrestrial rabies in the United States through the use of oral vaccines, as has been accomplished in Europe[54] and southeastern Canada,[14] these control actions will have no effect on enzootic rabies in bats and the associated risk of human disease.

Occurrence of rabies in different bat species varies by geographic region. Bat-associated rabies virus variants account for most human infections acquired in the United States during recent years. This trend has been highly publicized and resulted in public health recommendations for potential rabies exposures involving bats.[55,56] Increased publicity and awareness of bats and rabies have increased the rate of submission of bats for diagnostic testing because of a potential exposure. Despite an increase of 14.5% in the number of bats reported from 2005 to 2006, the percent of bats with positive results increased by only 0.5%. Thus, denominator data are critical to understanding trends in the absolute number of cases and placing them in reference to the underlying rate of submission. The proportion positive provides a better index of rabies intensity and for examining long-term trends than reporting of only absolute numbers.

Rabid bats continue to be identified throughout the United States, with the exception of Hawaii. During July 2006, an *M keenii* (Keen's bat) was collected as part of an ecologic study on Prince Wales Island in Alaska. The bat exhibited abnormal behavior and was euthanatized and submitted for rabies testing in August. The Alaska Division of Public Health Laboratory determined the bat was infected, and samples were later antigenically typed as a rabies virus variant associated with *L borealis* (red bat) at the CDC. This represents the second bat confirmed positive in Alaska to date. During June 1993, an *M lucifugus* (little brown bat) was determined to be infected with a rabies virus variant associated with *L noctivagans* (silver-haired bat).[32]

Reports of rabid skunks in 2006 increased 6.1% from the number reported in 2005 (Figure 6; Table 1). Texas reported the greatest number of rabid skunks during 2006 despite reporting 41 fewer cases than in 2005. In the Southwest, Arizona reported a decrease (75.8%) in the number of rabid skunks (16) after a large increase in 2005. During 2001, a new focus of rabies in skunks, in the Flagstaff area of northern Arizona, related to a big brown bat rabies virus variant was recognized as having sustained transmission among skunks. In response to this new variant, Arizona responded with trap, vaccinate, and release programs targeted at skunks as well as a field trial with V-RG to vaccinate skunks orally. No cases of this variant were reported during 2006.[22] More rabid raccoons (16) than rabid skunks (7) were reported from Rhode Island for the first time in 9 years. However, on the basis of antigenic typing of the virus from a subsample of rabid skunks from areas where rabies is enzootic in raccoons, most rabid skunks in these states are presumed to be infected with the raccoon rabies virus variant. To date, studies have been unable to identify evidence of unique adaptation, circulation, or maintenance of the raccoon rabies virus variant in skunks.[57] States where the raccoon rabies virus variant is enzootic continue to report > 40% of the total cases of rabies in skunks. As such, < 60% of all reported

skunks are infected with one of the skunk rabies virus variants.

Cases of rabies in foxes in 2006 increased 13.6% from 2005. Recent epizootics in Alaska and Texas, involving the arctic and gray fox rabies virus variants, respectively, are responsible for some of the increase in 2006. Virginia also experienced an increase of 40.4% from 2005, presumably because of spillover infection from raccoons. The red fox rabies virus variant has not been detected in the northern United States in more than 5 years, most likely because of control measures (eg, ORV) in place in Canada. Cases of rabies in foxes reported by eastern states were most likely related to the rabies virus variant associated with raccoons, as supported by samples further tested by antigenic and molecular methods. Rabies in gray foxes in Arizona and Texas is typically the result of infection with gray fox variants found in each of those states.

Throughout the western hemisphere, small mammals have never been implicated as potential reservoir species. Rabies among rodents and lagomorphs reflect spillover infection from regional terrestrial reservoir species. Among rodents, rabies occurs primarily in groundhogs (43 cases reported in 2006) in areas of the country affected by the raccoon rabies virus variant.[58] Rabies is occasionally reported in other large-bodied members of this group, such as beavers and rabbits (1 case in 2006). Large-bodied wild rodents or captive domestic species in outdoor cages or pens may become infected and survive long enough to pose a risk to other species or humans.[59] Rabies is seldom reported in smaller rodents, presumably because of the higher mortality rate and severe trauma that result from an attack by a rabid carnivore. There has been no documentation of rabies virus transmission from a rodent or lagomorph to a human.

Rabies in domestic animals increased 10.7% in 2006. Reported cases of rabies in cats (318) and dogs (79) increased 18.2% and 4.0%, respectively. Reported cases in cattle decreased 11.8%. The number of cases of rabies reported in cats was more than 4 times the number reported for dogs and nearly 4 times the number reported for cattle. The number of cats reported annually had a marked increase in 1992, and cats have remained the leading domestic species reported each year.[60] Cases of rabies in cats and dogs have been attributed to spillover from local terrestrial reservoirs.[61] Likewise, a study[40] indicates cats are a leading domestic animal source of possible human exposure to rabies requiring PEP.[40] The continued low numbers of reported cases of rabies in dogs attest to the effectiveness of the public health strategy aimed at preventing rabies virus spillover infection to domestic animals from infected wildlife. Further reduction in the number of rabies cases in companion species, especially cats, may require stricter observance and enforcement of vaccination and leash laws. Vaccination remains a crucial element in this effort.

Rabies vaccination of pet mammals and livestock that have regular contact with people is a fundamental barrier to human exposure. A single incident involving a case of rabies in a companion animal species can result in large economic expenditures and public health efforts to ensure that human disease does not occur.[62–64] Although widespread vaccination of livestock is neither economically feasible nor justifiable on public health grounds, vaccination of valuable livestock or livestock that may have regular contact with humans (eg, in a petting zoo) in rabies epizootic areas should be considered.[55] During late August 2006, a horse at a Tennessee Walking Horse exhibit became ill. Rabies was suspected and diagnosed in a postmortem examination. Samples were sent to the CDC, and rabies was sequenced as a variant associated with big brown bats (*E fuscus*). Approximately 150,000 people were in attendance at the venue. During the event, the horse was stabled and ridden in public areas on the exhibit grounds. A health alert was issued by the Tennessee Department of Health on September 8, and an investigation was conducted to identify any person potentially exposed to rabies from the infected horse. In total, the Tennessee Department of Health consulted with 53 individuals about potential rabies exposure, 9 of which were advised to receive rabies boosters or PEP.[c] An additional 15 persons, mostly individuals who had provided direct care to the horse, were advised to receive rabies PEP in Missouri (the horse's state of origin). Balanced health messaging was vital in controlling pubic inquiries from individuals who attended the celebration, but were not exposed. The response by local and state health officials appeared to have limited the unnecessary evaluation and treatment of additional persons.

Including the 3 cases of human rabies reported in 2006, the total number of cases of rabies diagnosed in humans in the United States since 1990 increased to 51 (including 1 case reported from Puerto Rico). Eleven (21.6%) of these 51 individuals were infected outside the continental United States (10 abroad, 1 in Puerto Rico). Most rabies infections in humans that occur in foreign countries where dog rabies is enzootic involve regional canine rabies virus variants. A bite from a dog was reported in 7 of 10 such cases and in the case from Puerto Rico (8/11). Forty (78.4%) of the 51 individuals were infected with rabies virus variants indigenous to the United States. Analysis of monoclonal antibodies and genetic sequencing data indicated that 37 (92.5%) of these 40 persons were infected with bat rabies virus variants. Since 2000, 17 of 19 cases of indigenously acquired rabies in humans were associated with rabies virus variants maintained by bats. Only 5 of these cases involved a report of a definite bat bite (4 received organ transplants or an arterial graft from a rabies virus–infected donor).[6,25] Two cases of bat-associated rabies were reported to have no known exposure to a bat. The remaining 6 cases indicated some prior contact with a bat (eg, awakening to find a bat on the body or picking up a grounded bat). The most likely route of infection with rabies virus (excluding inoculation via infected transplant material) remains transmission by a bite that either was ignored or went unnoticed during an interaction with a bat. Although rabies infection of humans from bats remains a rare occurrence, the prevention of such infections remains an important public health concern.

2007 Rabies Update

Several ORV projects in Texas, Florida, and Alabama have released nearly 4.4 million baits over an area of more than 120,000 km^2 as of June 2007. Baiting will be conducted in the Appalachian Ridge, GAT, and northeast baiting regions in fall 2007. These areas coincide with areas baited previously in 2006. The baiting zone targeting gray foxes in Texas was changed from a ring-shaped containment barrier to baiting of the entire enzootic region. Enhanced surveillance and baiting activities continue in Texas, with the goal of eliminating the Texas gray fox rabies virus variant.

A brief analysis of data from states submitting monthly data to the CDC for the first 4 months of 2007 indicates a continued increase in the number of cases of rabies, compared with the same time period in 2006. The rabies epizootic among foxes in Alaska, which started in 2006, appears to be ongoing. As of April 2007, 27 cases of rabies had been reported from Alaska, 9 more cases than were reported in all of 2006. Similarly, in Texas, the attempt to eliminate the gray fox rabies virus variant has met with recent challenges. Cases of the gray fox rabies virus variant have been identified outside the ORV zone moving northwestward along the Pecos River. Several years of drought in this section of Texas may have led to movement of gray fox populations along the river for increased access to water. This might have induced a channeling effect of gray fox populations and the associated rabies virus variant away from the drought-stricken ORV zone.

No cases of human rabies in the United States during the first 6 months of 2007 were reported to the CDC.

In direct contrast to the recent reattainment of canine rabies–free status in the United States, uncontrolled rabies in dogs still occurs in Asia, Africa, and some parts of Latin America, with unnecessary death in animals and humans. As determined decades ago, comprehensive and coordinated rabies vaccination of dog populations is capable of eliminating canine rabies virus variants, especially if coupled with population management and novel ORV for hard-to-reach animals. Collaborative initiatives toward the control of this classic zoonotic disease, if imaginatively packaged as part of comprehensive human and animal health delivery, have the capacity to develop and augment public health and veterinary infrastructure in areas of greatest need. Recently, a group of rabies scientists, through the formation of the Alliance for Rabies Control, has attempted to reach out to relevant partners, including international health organizations; national, state, and local public health partners; professional organizations; and commercial pharmaceutical companies, to raise global awareness of rabies. This effort has culminated in the declaration of the first annual World Rabies Day on September 8, 2007. Events are planned throughout the world to increase awareness of rabies and to raise support and funding toward its control and prevention (www.worldrabiesday.org).

a. ArcMap, version 8.3, Redlands, Calif.
b. Hicks B. USDA, APHIS, Wildlife Services, Austin, Tex: Personal communication, 2007.
c. Dunn J. Tennessee Department of Health, Nashville, Tenn: Personal communication, 2007.

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