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Rabies surveillance in the United States during 2008

Jesse D. Blanton, MPH; Kis Robertson, DVM, MPH; Dustyn Palmer, BA; Charles E. Rupprecht, VMD, PhD

Summary—During 2008, 49 states and Puerto Rico reported 6,841 cases of rabies in animals and 2 cases in humans to the CDC, representing a 3.1% decrease from the 7,060 cases in animals and 1 case in a human reported in 2007. Approximately 93% of the cases were in wildlife, and 7% were in domestic animals. Relative contributions by the major animal groups were as follows: 2,389 (34.9%) raccoons, 1,806 (26.4%) bats, 1,589 (23.2%) skunks, 454 (6.6%) foxes, 294 (4.3%) cats, 75 (1.1%) dogs, and 59 (0.9%) cattle. Compared with numbers of cases reported in 2007, numbers of cases reported in 2008 increased among cats, cattle, and skunks and decreased among dogs, raccoons, bats, and foxes. Numbers of rabid raccoons reported during 2008 decreased in 11 of the 20 eastern states where raccoon rabies was enzootic; overall number of rabid raccoons reported decreased by 8.6% during 2008, compared with 2007.

On a national level, the number of rabies cases involving skunks increased by 7.7% during 2008, compared with the number reported in 2007; this was the first increase in the number of reported rabid skunks since 2006. The total number of cases of rabies reported nationally in foxes decreased 1.7% in 2008, compared with 2007. The 1,806 cases of rabies reported in bats represented a 6.7% decrease, compared with the number reported in 2007. One case of rabies in a dog imported from Iraq was reported at a quarantine station in New Jersey during 2008. Follow-up of potentially exposed animals in the same shipment did not reveal any secondary transmission. The United States remained free from dog-to-dog transmission of canine rabies virus variants. Total number of rabid dogs reported decreased 19.4% in 2008, compared with 2007.

Two human rabies cases were reported from California and Missouri during 2008. The California case involved a recent immigrant from Mexico and was attributed to a newly identified rabies virus variant most likely associated with Mexican free-tailed bats. The case in Missouri was attributed to a rabies virus variant associated with eastern pipistrelle and silver-haired bats.

The present report provides an update on rabies epidemiology and events in the United States during 2008. Summaries of 2008 surveillance data for Canada and Mexico are also provided because of their common borders with the United States and the frequent travel between the United States and these countries. A brief preliminary update on cases of rabies and other related activities reported to the CDC during 2009 is also included.

As is the case in many developed countries, wild animals accounted for the majority (93%) of all rabies cases in the United States reported to the CDC during 2008. The most frequently reported rabid wildlife were raccoons, bats, skunks, and foxes; however, their relative proportions have continued to fluctuate over the years owing to epizootics of rabies among animals infected with various distinct rabies virus variants.[1]

Rabies virus infections involving 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.

The spatial boundaries of enzootic rabies in reservoir species are temporally dynamic (**Figure 1**), and affected areas may expand and contract as a result of virus transmission and animal population interactions.[2,3] Population increases and emigration result in expansion of enzootic areas, whereas natural barriers, such as mountain ranges and bodies of water, may sustain lower population densities or restrict animal move-

From the Poxvirus and Rabies Branch, Division of Viral and Rickettsial Diseases, National Center for Zoonotic, Vector-borne, and Enteric Diseases, Coordinating Center for Infectious Disease (Blanton, Palmer, Rupprecht), and the Epidemic Intelligence Service, Office of Workforce and Career Development (Robertson), Centers for Disease Control and Prevention, 1600 Clifton Rd NE, Atlanta, GA 30333.

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Address correspondence to Mr. Blanton.

ments, slowing the spread of rabies. Unusual animal dispersal patterns and human-mediated translocation of infected animals have resulted in more rapid or unexpected introduction of rabies into new areas.[1–6]

The canine rabies virus variant, which is responsible for dog-to-dog rabies transmission, was reintroduced in coyotes in the United States in the late 1980s, but, following > 10 years of oral vaccination, has again been eliminated.[7–10] An ongoing analysis of the phylogenetics of circulating terrestrial rabies virus variants has suggested that canine rabies virus variants were the probable origins of several circulating wildlife rabies virus variants of foxes (Texas and Arizona) and skunks (California and north central United States). This is likely representative of a long process that began with the introduction of canine rabies during colonization of the Americas followed by spillover and adaptation of Old World canine rabies virus variants to New World wildlife species, which have maintained an independent sylvatic circulation of canine origin rabies virus variants.[11]

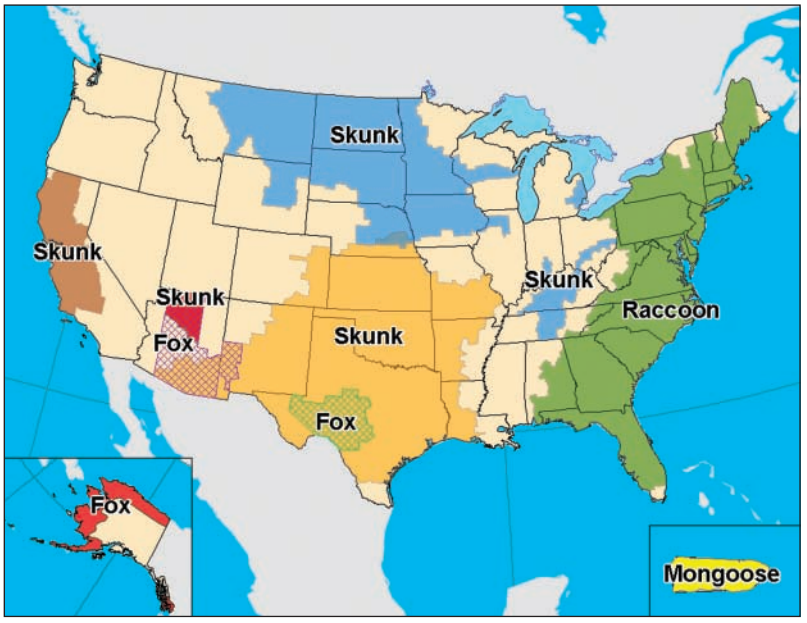

Figure 1—Distribution of major rabies virus variants among wild terrestrial animal reservoirs in the United States and Puerto Rico, 2008.

Following translocation of rabid raccoons (*Procyon lotor*) from an enzootic area in the southeastern United States to the mid-Atlantic region, raccoon rabies spread rapidly and has become enzootic in all of the eastern coastal states as well as in Alabama, Ohio, Pennsylvania, Tennessee, Vermont, and West Virginia. Three different 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 arctic and red foxes (*Alopex lagopus* and *Vulpes vulpes*, respectively). Two different rabies virus variants are present in geographically limited populations of gray foxes (*Urocyon cinereoargenteus*) in Arizona and Texas. On the island of Puerto Rico, another wildlife rabies reservoir exists in mongooses (*Herpestes javanicus*).[12,13]

Distribution of an oral vaccinia–rabies glycoprotein recombinant vaccine targeting raccoons in the eastern United States[14–16] and gray foxes and coyotes (*Canis latrans*) in Texas[10] has shown promise as an important adjunct to traditional rabies control methods (ie, parenteral vaccination of domestic animals). Biologics used in oral vaccination programs contain live replicating virus, and the unintentional exposure of nontarget species, including humans, must be minimized and monitored.[17–19]

There are multiple, independent reservoirs of rabies virus in several species of insectivorous bats, with distribution patterns overlaying the distribution of rabies virus variants maintained in 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.

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.[20] As a result, most cases of rabies in humans have resulted from infection with rabies virus variants associated with bats.[21,22] Rabies control in bats by conventional methods is difficult, and preventing infection with bat-associated rabies virus variants in humans is further complicated by the frequent absence of documented exposure histories involving a bat bite.

Reporting and Analysis

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.[23] The predominantly passive nature of public health and veterinary rabies surveillance programs and the lack of accurate estimates of animal populations mean that incidence and prevalence of rabies cannot be accurately determined for most species. 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.[24,25] Furthermore, laboratory-based reporting of rabies cases to the CDC is complicated by the presence of multiple laboratories that perform rabies diagnostic testing in some states (eg, public health, agricultural, and veterinary pathology laboratories).

During 2008, 8 states (Georgia, Massachusetts, Maryland, Michigan, North Dakota, Virginia, Vermont, and West

Virginia) transmitted testing data electronically through the use of the updated Public Health Laboratory Isolate Surveillance system, which leverages the Public Health Informatics Network–Messaging System to securely transmit text files in a defined messaging format to a CDC database. With the creation of this electronic, laboratory-based reporting system, the CDC database for rabies surveillance data has been restructured to allow collection of data for individual animals, so that additional data elements can be submitted on each animal, as opposed to the historical reporting of aggregate counts by species and county. The updated Public Health Laboratory Isolate Surveillance system provides a stopgap solution for electronic reporting of animal rabies testing data while standards-based messaging guides for animal rabies reporting are being developed at the federal and state levels. The system's relative ease of use and independence from specific laboratory information systems (most database systems can export data to text files) make its implementation in non–public health laboratories feasible. Additional information provided voluntarily by some state health departments during 2008 included sex, age, and vaccination status of rabid animals; human and animal exposures to rabid animals; coordinate or street address of collection; and variant typing information.

To facilitate consistent reporting from states that do not use the Public Health Laboratory Isolate Surveillance system, all states and territories are requested to submit finalized data directly to the Poxvirus and Rabies Branch of the CDC. In animals suspected of having rabies, a diagnosis was made by detecting rabies viral antigen in brain material submitted to state laboratories by means of a direct immunofluorescent antibody test, as described.[26] Virus isolation in neuroblastoma cell cultures or in mice, nucleic acid detection via a reverse transcriptase PCR assay, and sequencing and genetic analysis were used to confirm the diagnosis in some cases. This year, CDC also requested direct reporting of testing activity by USDA Wildlife Services field biologists who were using a direct rapid immunohistochemistry test[27] for enhanced rabies surveillance, and information was provided for 7,088 samples, representing 5.8% of all samples reportedly tested during 2008. All samples for which the direct rapid immunohistochemistry test provided positive or indeterminate results and 10% of samples for which the test provided negative results were submitted to the CDC for confirmation by means of the direct fluorescent antibody test.

Between January 1 and December 31, 2008, all 50 states, New York City, the District of Columbia, and Puerto Rico reported numbers of cases of animal rabies to the CDC. All states also provided data on total rabies diagnostic testing activity during 2008. However, county of origin was not reported for animals from the state of Oklahoma for which test results were negative. A total of 121,728 animals were reportedly tested in the United States during 2008, accounting for a 0.7% increase in the number of animals tested, compared with 2007.

For rabies cases involving most terrestrial mammals, state public health laboratories generally report the common name of affected animals, with affected animals typically identified to the level of genus and often to the level of species. However, for cases involving bats, affected animals are frequently identified only to the level of taxonomic order (ie, Chiroptera) because not all public health laboratories have the capacity to speciate bats, even though they are encouraged to do so.

All year-end totals included in the present report were confirmed through e-mail or telephone conversations with state or territorial health department officials. Data from Canada were obtained from the Terrestrial Animal Health Division, Canadian Food Inspection Agency, and data from Mexico were obtained from the Pan American Health Organization Epidemiological Information System.[a]

State health authorities have different requirements for submission of specimens for rabies testing; therefore, intensity of surveillance varies. To better estimate regional trends, determine the rigor of surveillance efforts, and identify possible biases, states are encouraged to submit denominator data (ie, data for animals tested, but for which results of direct fluorescent antibody testing were negative) by species, county, and temporal occurrence. Calculations of percentages of positive test results 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 signs of illness, percentages of tested animals with positive results in the present report are not representative of the incidence of rabies in the general population. Further, because of differences in protocols and submission rates among species and states, comparison of percentages of animals with positive results between species or states is inappropriate. For comparison of historical rates, data from states lacking total submission data were excluded from calculations.

Geographic areas for various rabies virus reservoirs in the United States were produced by aggregating data from 2004 through 2008. County boundaries where cases were reported in the reservoir species over this period were dissolved with a geographic information system[b] to produce a single polygon representing the distribution of a specific 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. Owing to the

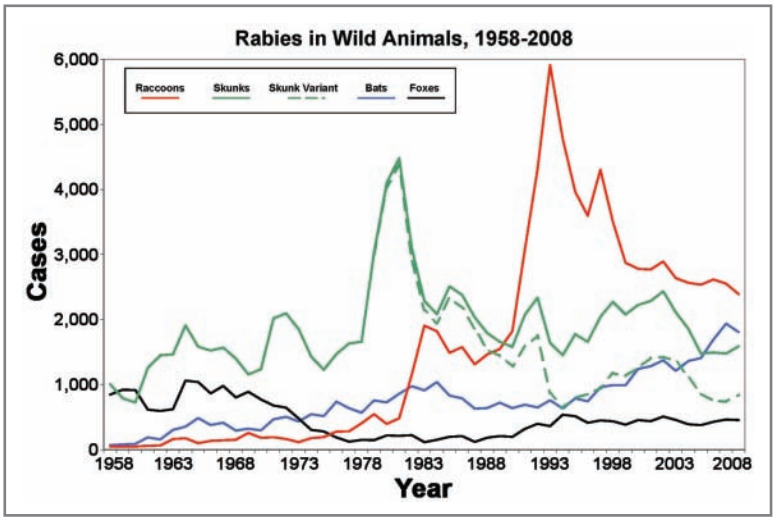

Figure 2—Cases of rabies in wild animals in the United States, by year and species, 1958 to 2008.

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. Because of the positive skew of the data, a geometric classification scheme was used for choropleth maps used to display number of animals tested; pro-

Table 1—Cases of rabies in the United States, by state and category, during 2008.

				Domestic animals						Wild animals									
State (city)	Total cases	Domestic	Wild	Cats	Cattle	Dogs	Horses/ mules	Sheep/ goats	Other domestic*	Raccoons	Bats	Skunks	Foxes	Other wild†	Rodents and lagomorphs‡	Humans	% Positive 2008	2007 cases	Change (%)
AK	15	0	15	0	0	0	0	0	0	0	0	0	15	0	0	0	31.2	45	–66.67
AL	84	2	82	0	0	1	1	0	0	51	17	0	11	3[b]	0	0	3.8	80	5.00
AR	49	5	44	0	0	4	0	1	0	0	5	39	0	0	0	0	5.1	33	48.48
AZ	182	2	180	0	0	1	1	0	0	0	89	57	21	13[c]	0	0	6.6	159	14.47
CA	179	1	177	1	0	0	0	0	0	0	137	31	9	0	0	1	2.5	188	–4.79
CO	65	1	64	1	0	0	0	0	0	1	44	19	0	0	0	0	6.9	56	16.07
CT	202	11	191	11	0	0	0	0	0	109	40	32	6	3[d]	1[t]	0	7.7	219	–7.76
DC	49	6	43	6	0	0	0	0	0	28	12	0	3	0	0	0	10.9	43	13.95
DE§	21	7	13	6	0	0	1	0	0	7	4	0	1	0	1[u]	0	8.4	11	90.91
FL	151	11	140	9	0	0	2	0	0	95	20	2	20	3[e]	0	0	3.9	128	17.97
GA	389	24	365	15	1	6	1	0	1[a]	235	25	62	36	7[f]	0	0	14.8	301	29.24
HI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	0.00
IA	27	10	17	8	1	1	0	0	0	0	11	6	0	0	0	0	1.7	31	–12.90
ID	10	0	10	0	0	0	0	0	0	0	10	0	0	0	0	0	2.0	12	–16.67
IL	103	0	103	0	0	0	0	0	0	0	103	0	0	0	0	0	1.7	113	–8.85
IN	13	0	13	0	0	0	0	0	0	0	13	0	0	0	0	0	0.8	13	0.00
KS	67	13	54	11	0	0	2	0	0	0	6	48	0	0	0	0	5.5	110	–39.09
KY	46	9	37	1	0	6	2	0	0	0	14	23	0	0	0	0	3.5	20	130.00
LA	6	0	6	0	0	0	0	0	0	0	3	3	0	0	0	0	0.9	6	0.00
MA	154	18	136	15	0	1	1	1	0	62	19	44	8	1[g]	2[v]	0	5.3	152	1.32
MD	420	27	393	21	2	1	2	1	0	271	33	41	37	0	11[w]	0	9.2	431	–2.55
ME	65	0	65	0	0	0	0	0	0	33	8	21	3	0	0	0	9.2	86	–24.42
MI	79	1	78	1	0	0	0	0	0	0	70	6	2	0	0	0	2.1	210	–62.38
MN	70	9	61	2	4	3	0	0	0	0	33	28	0	0	0	0	2.4	40	75.00
MO	66	1	64	0	0	0	1	0	0	0	58	6	0	0	0	1	2.1	38	73.68
MS	7	0	7	0	0	0	0	0	0	0	7	0	0	0	0	0	2.1	3	133.33
MT	14	1	13	0	0	1	0	0	0	0	11	2	0	0	0	0	3.3	23	–39.13
NC	474	25	449	18	3	3	0	1	0	270	18	93	60	7[h]	1[x]	0	12.5	474	0.00
ND	34	14	20	5	4	4	1	0	0	1	1	18	0	0	0	0	7.6	30	13.33
NE	43	7	36	1	4	0	2	0	0	0	10	25	1	0	0	0	4.0	31	38.71
NH	59	3	56	1	0	0	0	2	0	28	3	19	6	0	0	0	9.7	54	9.26
NJ	285	17	268	15	0	2	0	0	0	155	57	44	6	1[i]	5[y]	0	8.5	283	0.71
NM	25	2	23	1	0	1	0	0	0	0	0	6	17	0	0	0	5.8	17	47.06
NV	16	0	16	0	0	0	0	0	0	0	16	0	0	0	0	0	4.0	9	77.78
NY	496	31	465	23	6	1	1	0	0	262	112	63	20	3[j]	5[z]	0	5.6	512	–3.13
NYC	19	1	18	1	0	0	0	0	0	9	2	7	0	0	0	0	2.5	47	–59.57
OH	64	0	64	0	0	0	0	0	0	5	55	3	0	1[k]	0	0	1.5	86	–25.58
OK	43	11	32	2	6	2	1	0	0	0	2	29	0	1[l]	0	0	3.8	78	–44.87
OR	13	0	13	0	0	0	0	0	0	0	13	0	0	0	0	0	5.1	12	8.33
PA	431	60	371	53	3	3	0	1	0	228	43	71	25	2[m]	2[aa]	0	4.6	439	–1.82
PR	58	16	42	3	1	11	1	0	0	0	0	0	0	42[n]	0	0	29.3	47	23.40
RI	34	2	32	1	0	0	1	0	0	9	7	12	4	0	0	0	7.4	45	–24.44
SC	166	6	160	3	2	1	0	0	0	81	10	34	34	1[o]	0	0	7.2	162	2.47
SD	24	4	20	0	2	0	2	0	0	0	4	16	0	0	0	0	3.5	27	–11.11
TN	128	6	122	2	0	3	1	0	0	28	18	69	7	0	0	0	4.9	132	–3.03
TX	1,022	45	977	15	9	15	4	2	0	16	548	393	14	6[p]	0	0	7.1	969	5.47
UT	14	0	14	0	0	0	0	0	0	0	14	0	0	0	0	0	2.5	16	–12.50
VA	622	48	574	34	6	4	2	2	0	310	22	158	78	1[q]	5[bb]	0	14.4	730	–14.79
VT	75	1	74	0	1	0	0	0	0	41	3	25	3	1[r]	1[cc]	0	13.3	165	–54.55
WA	17	0	17	0	0	0	0	0	0	0	17	0	0	0	0	0	3.1	22	–22.73
WI	24	0	24	0	0	0	0	0	0	0	24	0	0	0	0	0	1.1	26	–7.69
WV	96	13	83	8	4	0	0	1	0	54	3	18	7	1[s]	0	0	5.1	77	24.68
WY	28	0	28	0	0	0	0	0	0	0	12	16	0	0	0	0	4.0	19	47.37
Total	**6,843**	**471**	**6,369**	**294**	**59**	**75**	**30**	**12**	**1**	**2,389**	**1,806**	**1,589**	**454**	**97**	**34**	**2**	**5.62**	**7,060**	**–3.07**
% 2008	100.00	6.90	93.07	4.30	0.86	1.10	0.44	0.18	0.01	34.91	26.39	23.22	6.63	1.42	0.50	0.03			
% Pos 2008	5.62	0.78	10.47	0.95	4.97	0.28	3.02	2.60	0.30	14.48	5.96	26.55	24.89	3.49	0.99	—			
Total 2007	7,060	469	6,590	262	57	93	41	13	3	2,549	1,935	1,476	462	118	50	1			
% Change	–3.07	0.43	–3.35	12.21	3.51	–19.35	–26.83	–7.69	–66.67	–6.28	–6.67	7.66	–1.73	–17.80	–32.00	100.00			

*Other domestic includes: [a]1 llama. †Other wild includes: [b]1 bobcat, 2 coyotes; [c]7 bobcats, 1 coati, 1 cougar, 4 coyotes; [d]1 coyote, 2 deer; [e]3 bobcats; [f]5 bobcats, 2 coyotes; [g]1 bobcat; [h]3 bobcats, 3 coyotes, 1 opossum; [i]1 opossum; [j]1 coyote, 2 deer; [k]1 coyote; [l]1 bobcat; [m]1 bobcat, 1 deer; [n]42 mongooses; [o]1 opossum; [p]6 coyotes; [q]1 opossum; [r]1 otter; [s]1 deer. ‡Rodents and lagomorphs include: [t]1 groundhog; [u]1 rabbit; [v]2 groundhogs; [w]11 groundhogs; [x]1 beaver; [y]5 groundhogs; [z]4 groundhogs, 1 rabbit; [aa]2 groundhogs; [bb]5 groundhogs; [cc]1 groundhog. §One rabid animal reported from Delaware without species information.

% Pos = (Total number positive/total number tested) X 100. — = Not calculated.

portional symbols were used to display reported cases by county. All maps were constructed with the Albers equal-area conic projection to minimize areal distortion over the United States.

Rabies in Wild Animals

Wild animals accounted for 6,369 (93.1%) of the 6,841 reported cases of rabies in 2008 (**Figure 2**). This number represented a 3.4% decrease from the 6,590 cases reported in 2007 (**Table 1**). Raccoons continued to be the most frequently reported rabid wildlife species (34.9% of all animal cases during 2008), followed by bats (26.4%), skunks (23.2%), foxes (6.6%), and other wild animals, including rodents and lagomorphs (1.9%). Numbers of reported cases in raccoons, bats, and foxes decreased 6.3%, 6.7%, and 1.7%, respectively, compared with 2007 totals. Reported cases in skunks increased 7.7%, compared with 2007. Seasonal trends for wildlife species were similar to previous years, with peaks in reported cases of raccoons, skunks, and foxes in March and May, with a second higher peak among raccoons and skunks in August and September. Reports of rabid bats had a single peak in August.

Raccoons—The 2,389 cases of rabies in raccoons reported in 2008 represented a continued declining trend since the last increase reported in 2006 (Table 1). Overall, the percentage of raccoons with positive test results has also decreased, from 17.7% in 2007 to 14.5% in 2008. Decreases of ≥ 50% in the numbers of rabid raccoons during 2008 were reported by 3 of the 20 eastern states where raccoon rabies is enzootic (ie, Vermont, 60.2% decrease from 2007 [103 cases] to 2008 [41 cases]; Rhode Island, 57.1% decrease from 2007 [21 cases] to 2008 [9 cases]; and Ohio, 54.5% decrease from 2007 [11 cases] to 2008 [5 cases]) and by New York City (77.5% decrease from 2007 [40 cases] to 2008 [9 cases]; **Figure 3**). Delaware (75.0% increase from 2007 [4 cases] to 2008 [7 cases]) was the only state to report a ≥ 50% increase in the number of rabid raccoons. States in the northeastern and mid-Atlantic focus of the raccoon rabies epizootic accounted for 67.4% (1,611 cases; 13.7% decrease) of the 2,389 total rabies cases in raccoons during 2008. The southeastern states of Alabama, Florida, Georgia, North Carolina, South Carolina, and Tennessee reported 31.8% (760 cases; 1.6% decrease) of the total cases in raccoons. Excluding Tennessee and Ohio, where skunk rabies is also present, states where raccoon rabies was the only terrestrial rabies virus variant reported 97.9% (2,338/2,389) of all documented cases of rabies in raccoons and accounted for 62.7% (4,292/6,841) of the national total of rabid animals (76.1% [3,834/5,035] of total cases in terrestrial animals).

Rabid raccoons reported by Texas (n = 16), North Dakota (1), and Colorado (1) were presumably the result of spillover infection from local terrestrial reservoirs. Fourteen of the cases in Texas were attributed to the south central skunk rabies virus variant (2 cases were untyped). The case in Colorado was attributed to the south central skunk rabies virus variant. The virus variant in the case in North Dakota was untyped.

Bats—The 1,806 cases of rabies reported in bats during 2008 represented a decrease of 6.7%, compared with the number reported in 2007. Total percentage of tested bats with positive results also decreased from 6.4% in

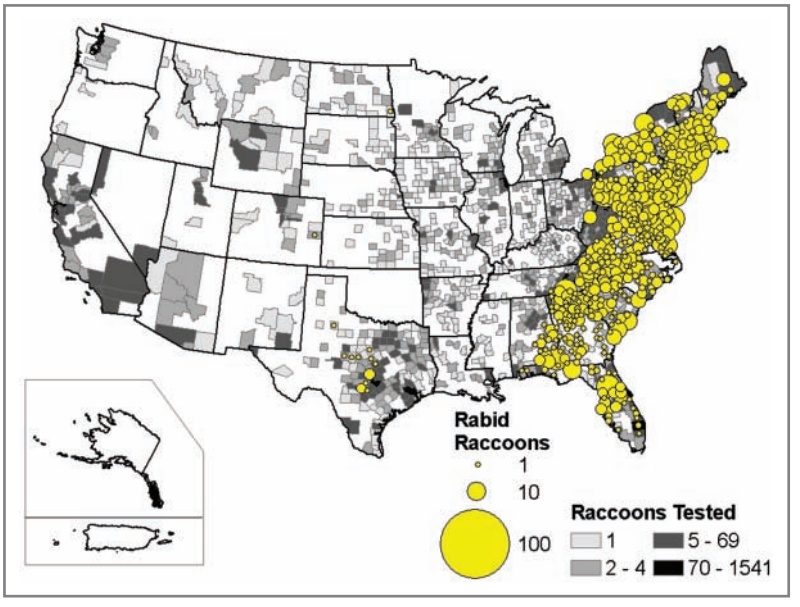

Figure 3—Reported cases of rabies in raccoons, by county, 2008.

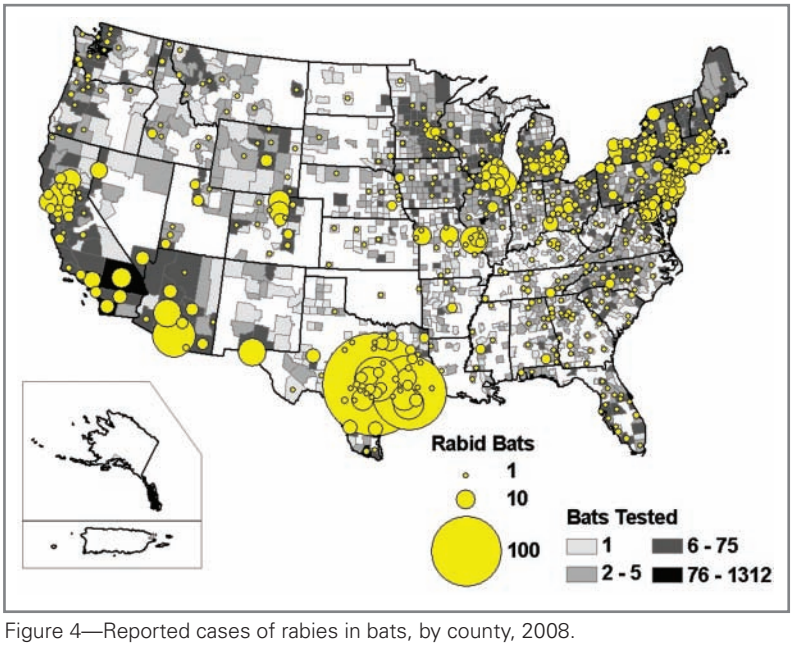

Figure 4—Reported cases of rabies in bats, by county, 2008.

2007 to 6.0% in 2008. Rabies in bats was widely distributed throughout the United States, with cases reported from 47 of the 48 contiguous states (**Figure 4**). Alaska, Hawaii, New Mexico, and Puerto Rico did not report any cases of bat rabies during 2008. Four states reported > 100 cases of rabies in bats, and these 4 states accounted for nearly half of the reported cases of rabies in bats during 2008 (Texas, 548 cases [30.3%]; California, 137 cases [7.6%]; New York, 112 cases [6.2%]; and Illinois, 103 cases [5.7%]). Nine states (Idaho, Illinois, Indiana, Mississippi, Nevada, Oregon, Utah, Washington, and Wisconsin) reported rabies in bats but not in terrestrial mammals. Of the bats infected with rabies virus, 26.3% (475/1,806) were identified beyond the taxonomic level of order (18 to the level of genus and 457 to the level of species). Among bats identified beyond the taxonomic level of order, 63.8% (303) were the big brown bat (*Eptesicus fuscus*), 10.1% (48) were the Brazilian (Mexican) free-tailed bat (*Tadarida brasiliensis*), 4.4% (21) were the hoary bat (*Lasiurus cinereus*), 4.2% (20) were the red bat (*Lasiurus borealis*), 4.0% (19) were the western pipistrelle (*Pipistrellus hesperus*), 3.4% (16) were the little brown bat (*Myotis lucifugus*), 1.9% (9) were the silver-haired bat (*Lasionycteris noctivagans*), 1.3% (6) were the pallid bat (*Antrozous pallidus*), 0.6% (3) were the long-legged myotis (*Myotis volans*), 0.4% (2) were the California myotis (*Myotis californicus*), 0.4% (2) were the northern long-eared myotis (*Myotis septentrionalis*), 0.4% (2) were the Yuma myotis (*Myotis yumanesis*), 0.4% (2) were the western yellow bat (*Lasiurus xanthinus*), 0.4% (2) were the big free-tailed bat (*Nyctinomops macrotis*), 0.2% (1) was the evening bat (*Nycticeius humeralis*), and 0.2% (1) was the Seminole bat (*Lasiurus seminolus*). Unspeciated bats of the genus *Myotis* (18/475) accounted for the remaining rabid bats and contributed 3.8% to the total number of bats identified beyond the taxonomic level of order.

Skunks—The 1,589 reported cases of rabies in skunks (mainly *M mephitis*) in 2008 represented a 7.7% increase from the number reported in 2007 (**Figure 5**; Table 1). However, the total percentage of tested skunks with positive results was the same during 2008 (26.6%) as during 2007. Eleven of the 24 states where a skunk rabies virus variant was enzootic reported a ≥ 50% increase in the number of rabid skunks during 2008 (ie, Kentucky, 475% increase from 2007 [4 cases] to 2008 [23 cases]; Colorado, 375% increase from 2007 [4 cases] to 2008 [19 cases]; Arizona, 338% increase from 2007 [13 cases] to 2008 [57 cases]; Wyoming, 300% increase from 2007 [4 cases] to 2008 [16 cases]; New Mexico, 200% increase from 2007 [2 cases] to 2008 [6 cases]; Louisiana, 200% increase from 2007 [1 case] to 2008 [3 cases]; Nebraska, 92% increase from 2007 [13 cases] to 2008 [25 cases]; Arkansas, 70% increase from 2007 [23 cases] to 2008 [39 cases]; North Dakota, 64% increase from 2007 [11 cases] to 2008 [18 cases]; Minnesota, 56% increase from 2007 [18 cases] to 2008 [28 cases]; and Missouri, 50% increase from 2007 [4 cases] to 2008 [6 cases]). Illinois, Indiana, and Wisconsin reported no rabies in skunks during 2008. Indiana reported a single case of rabies in a skunk in 2007, Illinois has not reported a case of rabies in a skunk since 2005, and Wisconsin has not reported a case of rabies in a skunk since 2006. Montana reported a 67% decrease in the number of rabid skunks from 2007 (6 cases) to 2008 (2 cases).

States in which the raccoon rabies virus variant is enzootic (excluding Tennessee, where skunks are the predominant reservoir) reported 47.1% (749/1,589) of the cases of rabies in skunks, most of which were presumably the result of spillover infection from raccoons. This was a slight

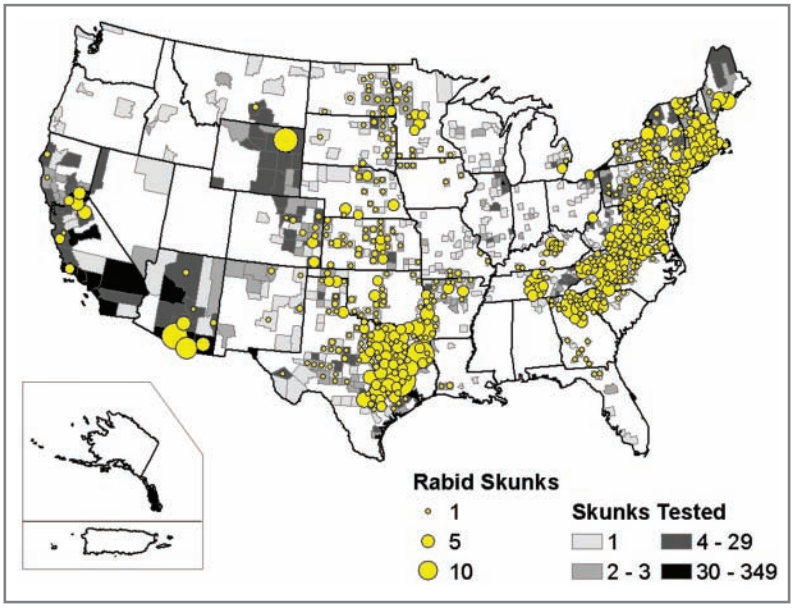

Figure 5—Reported cases of rabies in skunks, by county, 2008.

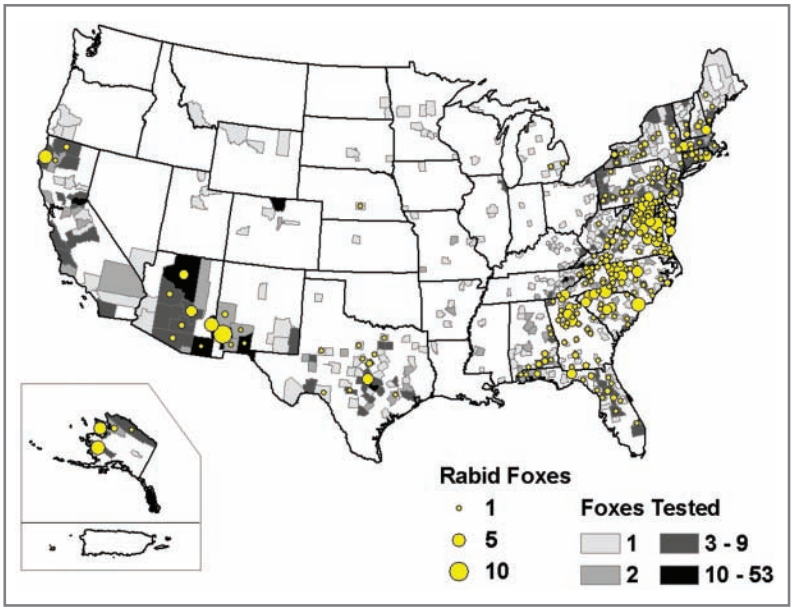

Figure 6—Reported cases of rabies in foxes, by county, 2008.

decrease from the proportion of rabid skunks presumably infected with the raccoon rabies virus variant in previous years. Among the 19 states where the raccoon rabies virus variant is the predominant terrestrial reservoir of rabies, 4 states (South Carolina, 143% increase from 2007 [14 cases] to 2008 [34 cases]; Georgia, 77% increase from 2007 [35 cases] to 2008 [62 cases]; New Jersey, 57% increase from 2007 [28 cases] to 2008 [44 cases]; and West Virginia, 50% increase from 2007 [12 cases] to 2008 [18 cases]) and New York City (133% increase from 2007 [3 cases] to 2008 [7 cases]) reported ≥ 50% increases in the number of rabid skunks. Rhode Island reported more rabid skunks than raccoons for the first time since 2005.

Foxes—Foxes (mainly *A lagopus*, *U cinereoargenteus*, or *V vulpes*) accounted for 6.6% of all cases of rabies in animals reported in 2008 (Table 1). The 454 cases of rabies in foxes represented a 1.7% increase from 2007. The percentage of tested foxes with positive results decreased from 28.4% in 2007 to 24.9% in 2008. Most cases of rabies in foxes (368 [81.0%]) were reported by states affected predominantly by the raccoon rabies virus variant (**Figure 6**). Ten states (Connecticut, 500% increase from 2007 [1 case] to 2008 [6 cases]; West Virginia, 250% increase from 2007 [2 cases] to 2008 [7 cases]; New Hampshire, 200% increase from 2007 [2 cases] to 2008 [6 cases]; Massachusetts, 167% increase from 2007 [3 cases] to 2008 [8 cases]; Georgia, 100% increase from 2007 [18 cases] to 2008 [36 cases]; Rhode Island, 100% increase from 2007 [2 cases] to 2008 [4 cases]; New Mexico, 78% increase from 2007 [9 cases] to 2008 [16 cases]; and California, 50% increase from 2007 [6 cases] to 2008 [9 cases]) and the District of Columbia (200% increase from 2007 [1 case] to 2008 [3 cases]) reported a ≥ 50% increase in the number of rabid foxes, compared with 2007. Nebraska and Tennessee reported no cases of rabies in foxes during 2007 but reported 1 and 7 cases, respectively, during 2008.

Other wild animals—Puerto Rico reported 42 rabid mongooses (*H javanicus*) during 2008, a 31% increase from the 32 cases reported in 2007 (Table 1). Other wildlife in which rabies was reported included 31 groundhogs (*Marmota monax*), 22 bobcats (*Lynx rufus*), 20 coyotes (*C latrans*), 6 white-tail deer (*Odocoileus virginianus*), 4 opossums (*Didelphis virginiana*), 2 rabbits (species not identified), 1 beaver (*Castor canadensis*), 1 coati (*Nasua narica*), 1 cougar (*Puma concolor*), and 1 river otter (*Lontra canadensis*). All cases of rabies in rodents and lagomorphs were reported by states in which rabies is enzootic in raccoons.

For 17 of the 20 coyotes positive for rabies, the variant was typed. Variant information was not reported for cases in Connecticut (n = 1) and Georgia (2). All rabid coyotes for which variant typing results were available were infected with the predominant terrestrial rabies virus variant for the geographic region where the animal was found (4 infected with the Texas gray fox rabies virus variant, 7 infected with the raccoon rabies virus variant, 2 infected with the south central skunk rabies virus variant, and 4 infected with the Arizona gray fox virus variant).

Rabies in Domestic Animals

Domestic species accounted for 6.9% of all rabid animals reported in the United States in 2008 (Table 1). The number of rabid domestic animals reported in 2008 (471) represented a 0.5% increase from the total reported in 2007 (**Figure 7**). Cases of rabies reported in dogs, horses, and sheep and goats decreased by 19.4%, 26.8%, and 7.7%, respectively, while cases of rabies reported in cats and cattle increased 12.2% and 3.5%, respectively. Pennsylvania reported the largest number of rabid domestic animals (60 cases), followed by Virginia (48), Texas (45), New York (31), Maryland (27), and North

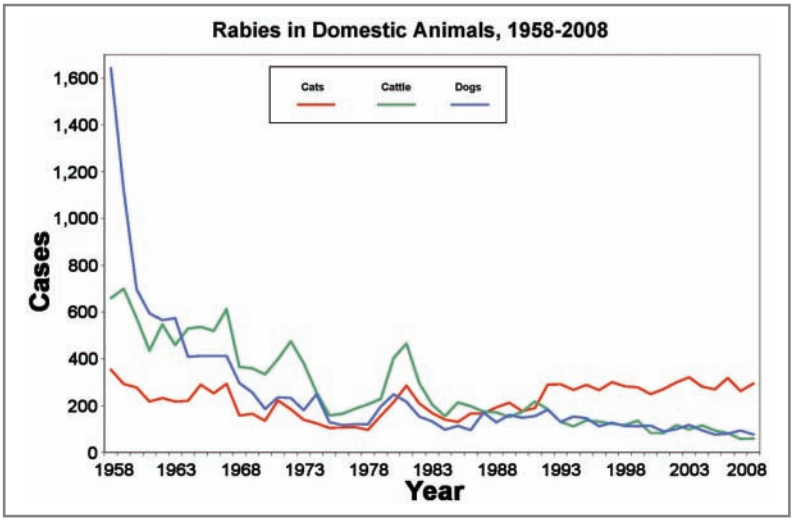

Figure 7—Cases of rabies in domestic animals in the United States, by year, 1958 to 2008.

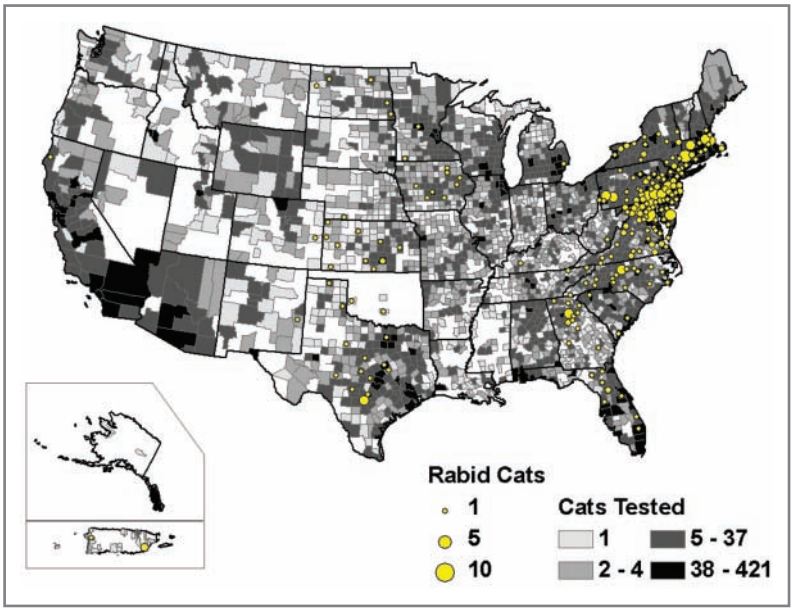

Figure 8—Reported cases of rabies in cats, by county and municipio (Puerto Rico), 2008.

Carolina (25). Seasonal distribution for reporting of rabies in domestic animals was similar to that for previous years. Reported cases of rabies in cats had a slight peak during June and July. Reported cases of rabies in cattle and dogs do not show any strong seasonal patterns.

Cats—The number of cases of rabies reported in cats was nearly 4 times the number reported for dogs and 5 times the number reported for cattle. Most (82.3%) of the 294 cases of rabies in cats were reported from states in which the raccoon rabies virus variant was present (**Figure 8**). Remaining cases were reported principally by Central Plains states, where most cases were presumably the result of spillover from rabid skunks. Eleven states reported > 10 cases of rabies in cats (Pennsylvania, 53 cases; Virginia, 34; New York, 23; Maryland, 21; North Carolina, 18; Texas, 15; Georgia, 15; Massachusetts, 15; New Jersey, 15; Kansas, 11; and Connecticut, 11). Twenty-one states did not report any rabid cats.

Dogs—Texas (15 cases), Puerto Rico (11), Georgia (6), and Kentucky (6) reported the largest numbers of cases of rabies in dogs (**Figure 9**). No other state reported > 5 cases of rabies in dogs in 2008. No cases were reported involving the dog/coyote rabies virus variant last identified in Texas in 2004. Twenty-eight states, the District of Columbia, and New York City did not report any rabid dogs.

Excluding rabid dogs from Puerto Rico, which are presumably infected with the mongoose rabies virus variant, 64 cases of rabies in dogs were reported from the United States. For 43 of these 64 (67%) cases, the variant was reportedly typed through the use of monoclonal antibodies or sequenced to determine the rabies virus variant. By comparison, the virus variant was typed in 58% of cases involving rabid dogs reported from the continental United States during 2007. One dog imported from Iraq to New Jersey was found to be infected with a canine rabies virus variant. Rabies virus variants isolated from all other rabid dogs that were typed in 2008 were reported as the terrestrial rabies virus variant associated with the geographic area where the dog was collected (Figure 1). Typing results were not reported from Arkansas (variant not typed for 3 of 4 rabid dogs), Georgia (2 of 6), Iowa (1 of 1), Kentucky (6 of 6), Massachusetts (1 of 1), North Dakota (4 of 4), New Jersey (1 of 2), and Pennsylvania (3 of 3).

Other domestic animals—The number of cases of rabies in cattle increased 3.5% from 57 in 2007 to 59 in 2008 (**Figure 10**; Table 1). Texas (9 cases), New York (6), Oklahoma (6), and Virginia (6) reported the largest numbers of rabid cattle. No other state reported > 5 cases of rabies in cattle in 2008. The 30 cases of rabies reported in horses and mules (including donkeys) in 2008 represented a 26.8% decrease from the 41 cases reported in 2007. Reported cases of rabies in sheep and goats decreased 7.7% from 13 cases in 2007 to 12 cases in 2008. A rabid llama was reported from Georgia.

Rabies in Humans

Two cases of rabies in humans were reported in the United States in 2008 (**Table 2**). In March 2008, a newly arrived immigrant from Mexico presented to a hospital in Santa Barbara, Calif, with encephalitic symptoms and died shortly thereafter. Rabies was suspected on the basis of the individual's clinical signs and reports of domestic and wild animal exposures acquired in Oaxaca,

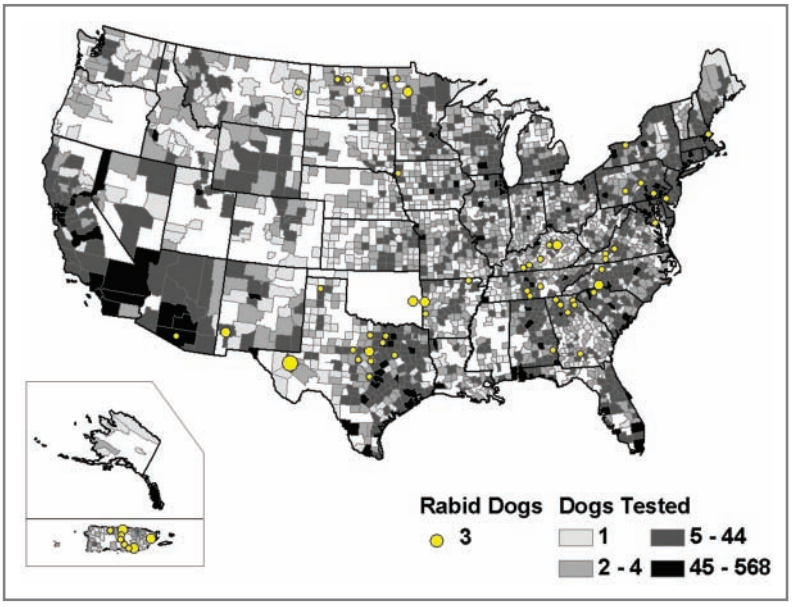

Figure 9—Reported cases of rabies in dogs, by county and municipio (Puerto Rico), 2008.

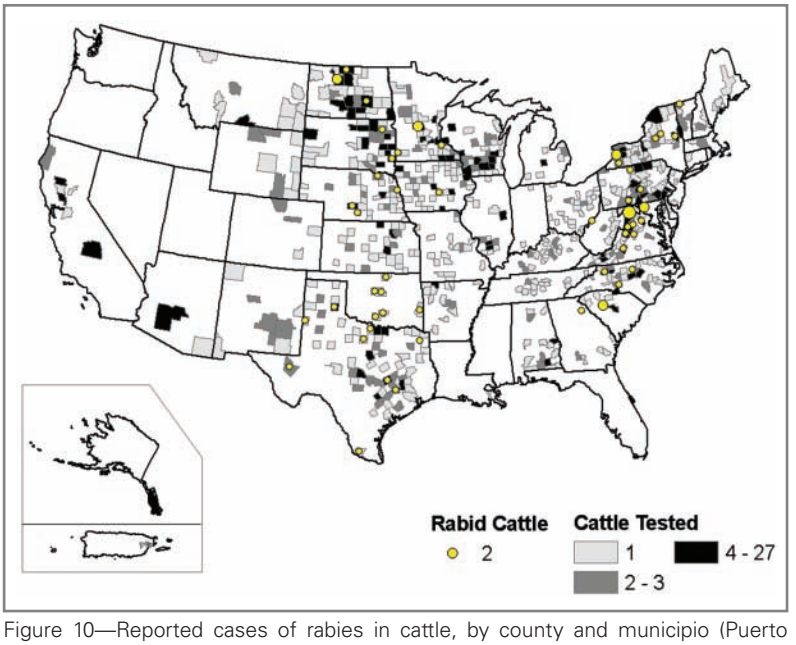

Figure 10—Reported cases of rabies in cattle, by county and municipio (Puerto Rico), 2008.

Table 2—Cases of rabies in humans in the United States and Puerto Rico, 2000 through 2008, 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
20 Oct 07	MN	Bite	Bat, unknown
18 Mar 08	CA	Bite-Mexico	Bat, Tb related
30 Nov 08	MO	Bite	Bat, Ln/Ps

*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 in which 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.

Mexico. At autopsy, samples were submitted for rabies diagnosis, and results of a direct fluorescent antibody test performed by the California Department of Health Services were positive. Further testing by the CDC identified a novel rabies virus variant that phylogenetic analysis indicated was most closely related to rabies virus variants associated with free-tailed bats.[28]

On November 24, 2008, the CDC was contacted by the Missouri Department of Health and Senior Services regarding a potential case of human rabies. The patient was a 55-year-old male who had first presented to a hospital in southeastern Missouri on November 18 with chest and back pain. Clinical signs progressed to left arm paresthesia, dysphagia, erratic behavior, and hydrophobia. Rabies was suspected after the patient and family members related that approximately 4 to 6 weeks before the onset of clinical signs, the patient had been bitten on the ear by a bat. The patient had not sought rabies prophylaxis because the bat did not appear sick. On November 25, samples were submitted to the CDC and a diagnosis of rabies was confirmed. The virus was characterized as a rabies virus variant associated with silver-haired (*L noctivagans*) and eastern pipistrelle (*Pipistrellus subflavus*) bats. The patient died November 30 after 12 days of hospitalization.

During 2008, samples from 45 human patients in the United States were submitted to the CDC for rabies testing, representing a 24% decrease from the 59 samples tested during 2007. Primarily, prevention of human rabies consists of health communications to inform the public about proper behavior to decrease the likelihood of exposure, animal vaccination, and application of appropriate and timely postexposure prophylaxis in exposed humans.

Rabies in Canada and Mexico

Canada reported 235 laboratory-confirmed cases of rabies in domestic and wild animals in 2008. This was a decrease of 13.9% from the 273 cases reported in 2007 and was the seventh time in the past 8 years that there had been a decrease in the number of reported rabies cases. Eighty-seven percent (n = 204) of reported cases involved wild animals, 6.8% (16) involved livestock, and 6.4% (15) involved domestic companion animal species. There was also a decrease of 369 in the total number of diagnostic specimens tested in 2008, compared with 2007. The total number of diagnostic specimens tested has remained relatively stable over the 8-year period from 2001 through 2008 (mean, 7,962 samples tested/y). The number of rabid raccoons decreased by 54% (59 to 27), and rabid raccoons accounted for 11.5% of all rabid animals in 2008. Reported cases in bats and cattle decreased by 34% (93 to 61) and 20% (15 to 12), respectively. Increases occurred mainly in skunks, dogs, and foxes. Skunk cases increased by 27% (78 to 99), accounting for 42.1% of all rabies cases. Reported cases in dogs and foxes increased by 71% (7 to 12) and 15% (13 to 15), respectively. Some regional distribution of rabid wild species (eg, bats in British Columbia; skunks in Manitoba; foxes, skunks, and raccoons in Ontario; and raccoons in Quebec) was evident in Canada. No human cases of rabies were reported in Canada in 2008.

Mexico reported 232 cases of animal rabies in domestic and wild animals during 2008. This represented a 19.4% decrease from the number of cases (288) reported during 2007. Thirteen percent (31/232) of rabies cases involved dogs. Other domestic animals reported included cattle (183 [78.9% of all animals reported]) and other livestock (16 [6.9%]). Two cases of rabies were reported in wildlife species. Three cases of rabies in humans were reported during 2008; all were attributed to exposure to a vampire bat.

Discussion

Passive surveillance for rabies relies largely on interactions between humans and animal reservoirs and subsequent possible exposure of people to the rabies virus. Importantly, reporting of cases at an aggregate political boundary (ie, counties) complicates the ability to detect and analyze detailed relationships between environmental variables and the spread of zoonotic diseases such as rabies. Enhanced surveillance carried out by several state health departments and the USDA Wildlife Services augments passive public health surveillance in critical geographic areas, such as those areas ahead of epizootic fronts.

Although raccoons continued to account for the highest percentage (34.9%) of rabies cases reported among animals in the United States in 2008, the magnitude of this ratio has decreased consistently since 2004. 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 2008. The proportion of animal rabies cases geographically associated with the raccoon rabies virus variant reflected 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 postexposure prophylaxis.[29,30]

Rabid bats were reported from 47 of the 48 contiguous states during 2008. The epizootiology and phylogenetics of rabies in bats is distinct from the epizootiology and phylogenetics of terrestrial rabies maintained by mammalian carnivores. Knowledge regarding the circulation of rabies virus variants in bat species remains less developed than knowledge of variants found in carnivores. Bat-associated rabies virus variants account for most human infections in the United States in recent years. This trend has been highly publicized and resulted in public health recommendations for potential rabies exposures involving bats.[31,32] Increased publicity and awareness of bats and rabies have increased the rate of submission of bats for diagnostic testing following potential exposure. Since 1996, when the public health recommendations began to include more conservative guidelines regarding rabies exposure involving bats, the number of bats submitted for rabies testing has increased from approximately 10,000 to > 30,000 in 2008. Bats are submitted for testing at a rate that is comparable to that for cats and dogs, exceeding the submission rate of any other wildlife species.

Reports of rabid skunks increased in 2008. Given the results of antigenic typing of the virus from a subsample of rabid skunks from areas where raccoon rabies is enzootic, most rabid skunks in these states are presumed to be infected with the raccoon rabies virus variant. To date, studies have been unable to demonstrate evidence of unique adaptation, circulation, or maintenance of the raccoon rabies virus variant in skunks.[33] Approximately half of all reported skunks are infected with one of the skunk rabies virus variants. When skunks presumably infected with the raccoon rabies virus variant on the basis of geographic location were excluded, a dramatic decrease in the number of reported cases of rabies in skunks attributable to a skunk variant was observed.

In the southwest, Arizona reported an increase in the number of rabid skunks (n = 57). During 2001, a new focus of rabies in skunks related to a big brown bat rabies virus variant in the Flagstaff area of northern Arizona was recognized as having sustained transmission among skunks.[34,35] In response to this new variant, Arizona responded with trap, vaccinate, and release programs targeted at skunks as well as a field trial with a vaccinia–rabies glycoprotein recombinant vaccine to orally vaccinate skunks. Following 2 years of no reported cases involving this variant, a resurgence occurred during 2008. Responses similar to prior years are ongoing to try to control the spread of this novel variant.

The red fox rabies virus variant has not been detected in the northern United States in an excess of 5 years, most likely because of control measures (eg, oral vaccination programs) in place in Canada and the northern United States. Rabies in gray foxes in Arizona and Texas is typically the result of infection with gray fox variants found in each of those states. Oral vaccination of gray foxes in west and central Texas has been responsible for reducing the distribution of the Texas gray fox rabies vi-

rus variant. However, this oral vaccination program was challenged during 2008 as increased spillover into coyotes was observed, and cases were identified northwestward along the Pecos River outside the existing baiting zone. Additional baiting in these areas was initiated to provide extended coverage.

Throughout the western hemisphere, small mammals have never been implicated as potential reservoir species. Rabies among rodents and lagomorphs reflects spillover infection from regional terrestrial reservoir species. Among rodents, rabies occurs primarily in groundhogs (31 cases reported in 2008) in areas of the country affected by the raccoon rabies virus variant.[36] Rabies is occasionally reported in other large-bodied members of this order, such as beavers (1 case in 2008). Large-bodied wild rodents and captive rabbits in outdoor cages or pens may become infected and survive long enough to pose a risk to other species, such as humans.[37] Rabies is seldom reported in smaller rodents, presumably because of the high likelihood of death or severe trauma in small rodents attacked by rabid carnivores. There has been no documentation of rabies virus transmission from a rodent or lagomorph to a human.

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. Use of an oral vaccination program in Switzerland during the past 30 years resulted in a declaration of rabies-free status for that country in 1998, and similar strategies led to rabies-free status being declared in France in 2000 and in Germany in 2008.[38,39] 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 through oral vaccination programs.[40]

In the United States, oral rabies vaccination programs may have restricted the expansion of raccoon rabies. Programs involving distribution of the vaccinia–rabies glycoprotein recombinant vaccine in baits to prevent or slow the geographic expansion of rabies in wild raccoons continue in a number of states and are being expanded. During 2008, multiple state agencies, USDA Wildlife Services, and the CDC continued to cooperate in a massive undertaking to maintain and expand an "immune barrier" beginning 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 northeastern Tennessee (otherwise known as the Appalachian Ridge oral rabies vaccination zone), approximately 5 million doses of vaccinia–rabies glycoprotein recombinant vaccine–laden baits were distributed. In addition, approximately 1 million doses of oral vaccine were distributed in Georgia, Alabama, and Tennessee (the GAT oral rabies vaccination zone).[41] Approximately 3 million baits were distributed 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 2008.[8–10] Enhanced surveillance conducted by USDA Wildlife Services and routine surveillance by state public health agencies continue to determine the placement of new oral rabies vaccination zones as well as the shape of baiting zones each year. Translocation of infected animals, as has occurred in the past, continues to pose a substantial threat to the goals of national oral rabies vaccination programs.[5,42] Concerns regarding vaccine safety and efficacy, ecologic impact, and physical bait variables, which were raised during earlier trials, continue to be assessed.[17,18,42–46] Development of novel biologics is ongoing to overcome the limited efficacy of the vaccinia–rabies glycoprotein recombinant vaccine in certain animal species (eg, skunks and mongooses).[47–50]

Despite little change in the total number of overall reported rabies cases in domestic animals, a 19.4% decrease in the reported cases of rabies in dogs occurred from 2007 to 2008. Cases of rabies in cats and dogs are primarily attributable to spillover from local terrestrial reservoirs,[51] and the United States has been free from dog-to-dog transmission of rabies since 2004.[52,53] However, continued surveillance will be required for early detection and to prevent this rabies virus variant or others from being reintroduced into the United States. The potential for reintroduction has been demonstrated in recent years. Following the importation of a rabid puppy from India in 2007, a rabid dog was imported from Iraq into New Jersey during 2008.[54] Since 2004, at least 4 cases of rabies in recently imported dogs have been reported. The risk of importation of rabies and other exotic zoonotic diseases may be increasing as more animals are brought into the United States each year.[55]

Since 1992, cats have remained the leading domestic animal species with rabies reported each year.[56] Several studies[29,30] have indicated that cats are a leading domestic animal source of possible human exposure to rabies requiring postexposure prophylaxis. Further reduction in the number of rabies cases in companion species, especially cats, may require stricter observance and enforcement of vaccination and supervision. Vaccination remains a crucial element in this effort. However, not all states currently have laws requiring vaccination of cats against rabies.

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.[57–59] 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 human beings (eg, animals in petting zoos) in rabies epizootic areas should be considered.[60,61]

Twenty-eight cases of human rabies have been reported in the United States since 1998, including the 2 cases reported in 2008. Seven of these 28 (25%) individuals were infected outside the continental United States (6 abroad and 1 in Puerto Rico). Most human rabies infections that occur in foreign countries where dog rabies is enzootic involve regional canine rabies virus variants, with the exception of the 2008 case from Mexico, which was associated with wildlife species. Twenty-one of the 28 (75%) individuals were infected with rabies virus variants indigenous to the United States. Analysis of monoclonal antibodies and

genetic sequencing data indicated that 17 of these 21 (81%) persons were infected with bat rabies virus variants. Epidemiologic investigations in 3 additional cases implicated a bat as the most likely source of exposure. In 1 case, the virus was typed as a rabies virus variant associated with raccoons. In 13 of the 20 (65%) human rabies cases associated with bats since 1998, there has been a report of a bite or direct contact with a bat (eg, awaking to find a bat on the body or picking up a grounded bat). Four (20%) cases were associated with organ transplants or an arterial graft from a rabies-infected donor.[4,22] Three patients with bat-associated rabies were reported to have no known exposure to a bat. In these instances, the most likely route of infection with rabies virus was a bite that was ignored or went unnoticed during an interaction with a bat. Although rabies infection of humans following exposure to bats remains a rare occurrence, the prevention of such infections remains an important public health concern.

Rabies should be included in the differential diagnosis for any patient with unexplained, acute, rapidly progressive encephalitis, especially in the presence of autonomic instability, dysphagia, hydrophobia, paresis, or parasthesia.[62] Given the report[63] of survival of a rabies patient after experimental treatment in 2004, early diagnosis of potential rabies cases has become increasingly important, particularly if experimental treatment is to be considered. However, the benefits of any particular experimental rabies treatment regimen have not been determined. No single course of treatment for rabies in humans has been documented to be efficacious after clinical signs of rabies are present.

New Advisory Committee on Immunization Practices recommendations on human rabies prevention were issued in May 2008, in addition to an update of the national rabies compendium.[31,60] The committee's recommendations were updated to provide an evidence-based approach to current recommendations for rabies preexposure vaccination and postexposure prophylaxis, providing a review of current knowledge on human rabies vaccines, rabies immune globulin, prophylaxis series, and adverse events. Overall recommendations regarding postexposure prophylaxis did not change from the 1999 recommendations.

During 2008, ongoing rabies vaccine supply issues reinforced the need to emphasize basic human rabies prevention and prophylaxis recommendations as well as animal rabies control. Circumstances initiated in late 2007 led to limitations in the available supply of both of the commercially licensed human vaccines in the United States. A national working group of subject matter experts, consisting of state and federal health officials, experts from academia, and representatives from relevant professional organizations, was convened to provide guidance and recommendations in response to the limited rabies vaccine supply and in the event of a true shortage (defined as the point at which vaccine would not be projected to be available for persons with rabies exposure). Throughout most of 2008, rabies vaccine was restricted to use for postexposure prophylaxis only, except for use in critical first responders (eg, rabies diagnosticians) by approval of state and federal public health officials. To prevent a shortage, close consultation with local and state health departments was recommended before initiation of postexposure prophylaxis after a potential exposure. This extensive public health response prevented a true shortage of rabies vaccine throughout the summer during peak rabies season, and supplies improved toward the end of 2008 and into 2009. The national working group continues to evaluate recommendations for rabies postexposure prophylaxis in the event of a shortage, improvements to human rabies postexposure prophylaxis surveillance, and national stockpile options.

2009 Rabies Update

A preliminary analysis of data from states submitting monthly data to the CDC for the first 4 months of 2009 showed a decrease in the number of cases of rabies, compared with the same time period during 2008. One case of human rabies was reported from Texas during the first 5 months of 2009. In March 2009, a 17-year-old female presented to a hospital in Houston with a history of headaches, photophobia, and left-sided weakness. The condition worsened over the next several days, and the patient was hospitalized with acute neurologic abnormalities and aggressiveness. Results of all routine tests for suspected conditions were negative. The patient had no history of foreign travel. During follow-up, the patient reported a visit to a Texas cave where she had had direct contact with bats but no reported bite. Samples were submitted to the CDC to rule out rabies. Antibodies to rabies virus were detected in the patient's CSF, but no viral amplicons were detected in saliva or in a nuchal biopsy specimen. The patient's condition improved gradually, and she was discharged without incident.

Rabies vaccine supplies showed improvement over the limitation observed in 2008. One vaccine, RabAvert, remained available for both pre- and postexposure prophylaxis, whereas the vaccine Imovax was available only for postexposure prophylaxis following consultation with a state health department. Published evidence regarding the necessity of the fifth dose of vaccine in patients undergoing rabies postexposure prophylaxis was prepared for review by the Advisory Committee on Immunization Practices. At its June 24, 2009, meeting, the committee's rabies working group presented evidence in support of a recommendation to reduce the number of vaccine doses in the human rabies postexposure prophylaxis series from 5 to 4 doses. After much discussion, the committee voted in favor of accepting the recommendation. This will effectively change the 2008 Advisory Committee on Immunization Practices' recommendations for human rabies prevention as follows: the postexposure prophylaxis protocol will consist of administration of human rabies immune globulin (20 U/kg) on day 0 and administration of 4 doses of vaccine (1 mL, IM) on days 0, 3, 7, and 14. Formal publication of the recommendations will be forthcoming.

a. SIEPI Epidemiological Information System [database online]. Washington, DC: Pan American Health Organization, Pan American Center for Foot-and-Mouth Disease, 2008. Available at: siepi.panaftosa.org.br/Export.aspx. Accessed Jul 15, 2009.

b. ArcMap, version 8.3, ESRI, Redlands, Calif.

References

1. Smith JS, Orciari L, Yager P. Molecular epidemiology of rabies in the United States. *Semin Virol* 1995;6:387–400.
2. Childs JE, Curns AT, Dey ME, et al. Predicting the local dynamics of epizootic rabies among raccoons in the United States. *Proc Natl Acad Sci U S A* 2000;97:13666–13671.
3. Childs JE, Curns AT, Dey ME, et al. Rabies epizootics among raccoons vary along a North-South gradient in the Eastern United States. *Vector Borne Zoonotic Dis* 2001;1:253–267.
4. Krebs JW, Mandel EJ, Swerdlow DL, et al. Rabies surveillance in the United States during 2003. *J Am Vet Med Assoc* 2004;225:1837–1849.
5. CDC. Translocation of coyote rabies—Florida, 1994. *MMWR Morb Mortal Wkly Rep* 1995;44:580–581, 587.
6. Rupprecht CE, Smith JS. Raccoon rabies: the re-emergence of an epizootic in a densely populated area. *Semin Virol* 1994;5:155–264.
7. Smith JS, Orciari LA, Yager PA, et al. Epidemiologic and historical relationships among 87 rabies virus isolates as determined by limited sequence analysis. *J Infect Dis* 1992;166:296–307.
8. Clark KA, Neill SU, Smith JS, et al. Epizootic canine rabies transmitted by coyotes in south Texas. *J Am Vet Med Assoc* 1994; 204:536–540.
9. Meehan SK. Rabies epizootic in coyotes combated with oral vaccination program. *J Am Vet Med Assoc* 1995;206:1097–1099.
10. Sidwa TJ, Wilson PJ, Moore GM, et al. Evaluation of oral rabies vaccination programs for control of rabies epizootics in coyotes and gray foxes: 1995–2003. *J Am Vet Med Assoc* 2005;227:785–792.
11. Velasco-Villa A, Reeder SA, Orciari LA, et al. Enzootic rabies elimination from dogs and reemergence in wild terrestrial carnivores, United States. *Emerg Infect Dis* 2008;14:1849–1854.
12. Everard CO, Everard JD. Mongoose rabies in the Caribbean. *Ann N Y Acad Sci* 1992;653:356–366.
13. Velasco-Villa A, Orciari LA, Souza V, et al. Molecular epizootiology of rabies associated with terrestrial carnivores in Mexico. *Virus Res* 2005;111:13–27.
14. Hanlon CA, Rupprecht CE. The reemergence of rabies. In: Scheld WM, Armstrong D, Hughes JM, eds. *Emerging infections 1*. Washington, DC: ASM Press, 1998;59–80.
15. Roscoe DE, Holste WC, Sorhage FE, et al. Efficacy of an oral vaccinia-rabies glycoprotein recombinant vaccine in controlling epidemic raccoon rabies in New Jersey. *J Wildl Dis* 1998;34:752–763.
16. Robbins AH, Borden MD, Windmiller BS, et al. Prevention of the spread of rabies to wildlife by oral vaccination of raccoons in Massachusetts. *J Am Vet Med Assoc* 1998;213:1407–1412.
17. McGuill MW, Kreindel SM, DeMaria A Jr, et al. Human contact with bait containing vaccine for control of rabies in wildlife. *J Am Vet Med Assoc* 1998;213:1413–1417.
18. Rupprecht CE, Blass L, Smith K, et al. Human infection due to recombinant vaccinia-rabies glycoprotein virus. *N Engl J Med* 2001;345:582–586.
19. Fehlner-Gardiner C, Nadin-Davis S, Armstrong J, et al. Era vaccine-derived cases of rabies in wildlife and domestic animals in Ontario, Canada, 1989–2004. *J Wildl Dis* 2008;44:71–85.
20. Meltzer MI. Assessing the costs and benefits of an oral vaccine for raccoon rabies: a possible model. *Emerg Infect Dis* 1996;2:343–349.
21. Noah DL, Drenzek CL, Smith JS, et al. Epidemiology of human rabies in the United States, 1980 to 1996. *Ann Intern Med* 1998;128:922–930.
22. Messenger SL, Smith JS, Rupprecht CE. Emerging epidemiology of bat-associated cryptic cases of rabies in humans in the United States. *Clin Infect Dis* 2002;35:738–747.
23. Greenwood RJ, Newton WE, Pearson GL, et al. Population and movement characteristics of radio-collared striped skunks in North Dakota during an epizootic of rabies. *J Wildl Dis* 1997;33:226–241.
24. Chomel BB, Belotto A, Meslin FX. Wildlife, exotic pets, and emerging zoonoses. *Emerg Infect Dis* 2007;13:6–11.
25. Kuiken T, Leighton FA, Fouchier RA, et al. Public health. Pathogen surveillance in animals. *Science* 2005;309:1680–1681.
26. CDC. Protocol for postmortem diagnosis of rabies in animals by direct fluorescent antibody testing. Available at: www.cdc.gov/rabies/docs/RabiesDFASPv2.pdf. Accessed Aug 19, 2009.
27. Lembo T, Niezgoda M, Velasco-Villa A, et al. Evaluation of a direct, rapid immunohistochemical test for rabies diagnosis. *Emerg Infect Dis* 2006;12:310–313.
28. Velasco-Villa A, Messenger SL, Orciari LA, et al. New rabies virus variant in Mexican immigrant. *Emerg Infect Dis* 2008;14:1906–1908.
29. Blanton JD, Bowden NY, Eidson M, et al. Rabies postexposure prophylaxis, New York, 1995–2000. *Emerg Infect Dis* 2005;11:1921–1927.
30. Haskell M. The epidemiology of rabies post-exposure prophylaxis in humans, Virginia, 2002–2003. *Va Epidemiol Bull* 2006;106:1–6.
31. Manning SE, Rupprecht CE, Fishbein D, et al. Human rabies prevention—United States, 2008: recommendations of the Advisory Committee on Immunization Practices. *MMWR Recomm Rep* 2008;57(RR-3):1–28.
32. CDC. Human rabies prevention—United States, 1999. Recommendations of the Advisory Committee on Immunization Practices (ACIP) (Errata published in *MMWR Morb Mortal Wkly Rep* 1999;48:16 and *MMWR Morb Mortal Wkly Rep* 2000;49:737). *MMWR Recomm Rep* 1999;48(RR-1):1–21.
33. 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.
34. Leslie MJ, Messenger SL, Rohde RE, et al. Bat-associated rabies virus in skunks. *Emerg Infect Dis* 2006;12:1274–1277.
35. Blanton JD, Krebs JW, Hanlon CA, et al. Rabies surveillance in the United States during 2005. *J Am Vet Med Assoc* 2006;229:1897–1911.
36. Childs JE, Colby L, Krebs JW, et al. Surveillance and spatiotemporal associations of rabies in rodents and lagomorphs in the United States, 1985–1994. *J Wildl Dis* 1997;33:20–27.
37. Eidson M, Matthews SD, Willsey AL, et al. Rabies virus infection in a pet guinea pig and seven pet rabbits. *J Am Vet Med Assoc* 2005;227:932–935, 918.
38. World Health Organization. Rabies in individual countries. *Rabies Bull Eur* 2000;24:3–13.
39. Editorial team of the WHO *Rabies Bulletin Europe*. Austria and Germany declared "free from terrestrial rabies." *Rabies Bull Eur* 2009;32:7.
40. MacInnes CD, Smith SM, Tinline RR, et al. Elimination of rabies from red foxes in eastern Ontario. *J Wildl Dis* 2001;37:119–132.
41. USDA, APHIS, Wildlife Services. National ORV information by state, 2008. Available at: www.aphis.usda.gov/wildlife_damage/oral_rabies/rabies_info_by_state.shtml. Accessed Jul 15, 2009.
42. Slate D, Rupprecht CE, Rooney JA, et al. Status of oral rabies vaccination in wild carnivores in the United States. *Virus Res* 2005;111:68–76.
43. USDA, APHIS, Wildlife Services. National rabies management program. Available at: www.aphis.usda.gov/wildlife_damage/oral_rabies/. Accessed Jul 15, 2009.
44. Rupprecht CE, Hanlon CA, Hamir AN, et al. Oral wildlife rabies vaccination: development of a recombinant rabies vaccine. *Trans N Am Wildl Natl Res Conf* 1992;57:439–452.
45. Rupprecht CE, Hanlon CA, Niezgoda M, et al. Recombinant rabies vaccines: efficacy assessment in free-ranging animals. *Onderstepoort J Vet Res* 1993;60:463–468.
46. Hanlon CA, Niezgoda M, Shankar V, et al. A recombinant vaccinia-rabies virus in the immunocompromised host: oral innocuity, progressive parenteral infection, and therapeutics. *Vaccine* 1997;15:140–148.
47. Dietzschold B, Schnell MJ. New approaches to the development of live attenuated rabies vaccines. *Hybrid Hybridomics* 2002;21:129–134.
48. Dietzschold ML, Faber M, Mattis JA, et al. In vitro growth and stability of recombinant rabies viruses designed for vaccination of wildlife. *Vaccine* 2004;23:518–524.
49. Blanton JD, Meadows A, Murphy SM, et al. Vaccination of small Asian mongoose (*Herpestes javanicus*) against rabies. *J Wildl Dis* 2006;42:663–666.
50. Hanlon CA, Niezgoda M, Morrill P, et al. Oral efficacy of an attenuated rabies virus vaccine in skunks and raccoons. *J Wildl Dis* 2002;38:420–427.
51. McQuiston JH, Yager PA, Smith JS, et al. Epidemiologic charac-

teristics of rabies virus variants in dogs and cats in the United States, 1999. *J Am Vet Med Assoc* 2001;218:1939–1942.
52. Krebs JW, Mandel EJ, Swerdlow DL, et al. Rabies surveillance in the United States during 2004. *J Am Vet Med Assoc* 2005;227:1912–1925.
53. Blanton JD, Hanlon CA, Rupprecht CE. Rabies Surveillance in the United States during 2006. *J Am Vet Med Assoc* 2007;231:540–556.
54. CDC. Rabies in a dog imported from Iraq—New Jersey, June 2008 (Erratum published in *MMWR Morb Mortal Wkly Rep* 2008;57:1106). *MMWR Morb Mortal Wkly Rep* 2008;57:1076–1078.
55. McQuiston JH, Wilson T, Harris S, et al. Importation of dogs into the United States: risks from rabies and other zoonotic diseases. *Zoonoses Public Health* 2008;55:421–426.
56. Rupprecht CE, Childs JE. Feline rabies. *Feline Pract* 1996;24(5):15–19.
57. CDC. Mass treatment of humans exposed to rabies—New Hampshire, 1994. *MMWR Morb Mortal Wkly Rep* 1995;44:484–486.
58. Rotz LD, Hensley JA, Rupprecht CE, et al. Large-scale human exposures to rabid or presumed rabid animals in the United States: 22 cases (1990–1996). *J Am Vet Med Assoc* 1998;212:1198–1200.
59. Krebs JW, Long-Marin SC, Childs JE. Causes, costs, and estimates of rabies postexposure prophylaxis treatments in the United States. *J Public Health Manag Pract* 1998;4:56–62.
60. National Association of State Public Health Veterinarians Inc, CDC. Compendium of animal rabies prevention and control, 2008: National Association of State Public Health Veterinarians, Inc. (NASPHV). *MMWR Recomm Rep* 2008;57(RR-2):1–9.
61. National Association of State Public Health Veterinarians Inc, CDC, Council of State and Territorial Epidemiologists, AVMA. Compendium of measures to prevent disease associated with animals in public settings, 2009: National Association of State Public Health Veterinarians, Inc. (NASPHV). *MMWR Recomm Rep* 2009;58(RR-5):1–21.
62. Rupprecht CE, Hanlon CA, Hemachudha T. Rabies re-examined. *Lancet Infect Dis* 2002;2:327–343.
63. Willoughby RE Jr, Tieves KS, Hoffman GM, et al. Survival after treatment of rabies with induction of coma. *N Engl J Med* 2005;352:2508–2514.