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Rabies surveillance in the United States during 2010

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Summary

During 2010, 48 states and Puerto Rico reported 6,154 rabid animals and 2 human rabies cases to the CDC, representing an 8% decrease from the 6,690 rabid animals and 4 human cases reported in 2009. Hawaii and Mississippi did not report any laboratory-confirmed rabid animals during 2010. Approximately 92% of reported rabid animals were wildlife. Relative contributions by the major animal groups were as follows: 2,246 raccoons (36.5%), 1,448 skunks (23.5%), 1,430 bats (23.2%), 429 foxes (6.9%), 303 cats (4.9%), 71 cattle (1.1%), and 69 dogs (1.1%). Compared with 2009, number of reported rabid animals decreased across all animal types with the exception of a 1% increase in the number of reported rabid cats.

Two cases of rabies involving humans were reported from Louisiana and Wisconsin in 2010. Louisiana reported an imported human rabies case involving a 19-year-old male migrant farm worker who had a history of a vampire bat (*Desmodus rotundus*) bite received while in Mexico. This represents the first human rabies case reported in the United States confirmed to have been caused by a vampire bat rabies virus variant. Wisconsin reported a human rabies case involving a 70-year-old male that was confirmed to have been caused by a rabies virus variant associated with tri-colored bats (*Perimyotis subflavus*).

The present report provides an update on rabies epidemiology and events in the United States during 2010.

Rabies is a zoonotic disease caused by viruses of the *Lyssavirus* genus. Rabies has the highest case fatality ratio of any infectious disease if prompt PEP is not initiated. Postexposure prophylaxis consists of wound washing, passive immunization with rabies immune globulin, and a series of 4 doses of rabies vaccine.[1,2]

Rabies was most likely present in the New World before European colonization. Reports of Spanish conquistadors dying after being bitten by vampire bats exist as early as 1514.[3] However, canine rabies was most likely introduced after colonization. Rabies epizootics associated with dogs were not reported until the early 18th century, but dogs remained the

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primary source of rabies in the United States until the mid-20th century. Animal rabies was added as a nationally notifiable disease in 1938, and the first successful example of a mass canine vaccination campaign occurred in Memphis in 1948.[4] However, as canine rabies was controlled and ultimately eliminated, the epidemiology of rabies in the United States shifted to primary circulation and maintenance in wildlife species.

Wildlife have accounted for > 80% of reported rabid animals in the United States since 1975. The primary reservoir species responsible for maintaining rabies are raccoons, bats, skunks, foxes, and mongooses (in Puerto Rico). Infections involving distinct rabies virus variants associated with mesocarnivores occur in geographically definable regions where transmission is primarily between members of the same species (Figure 1). The spatial boundaries of those areas in which rabies is enzootic in reservoir species are temporally dynamic, and affected areas may expand and contract as a result of virus transmission and animal population interactions.[5] Natural and anthropomorphic factors directly impact population dynamics and can act as barriers or corridors for the spread of rabies.[6,7] However, unusual animal dispersal patterns and human-mediated translocation of infected animals have resulted in unexpected introductions of rabies virus variants into new areas and remain a threat to control programs.[8–11]

Spillover infection of nonmaintenance species with distinct variants occurs, but does not typically result in sustained transmission.[12] However, host switching of rabies virus variants does occur, and once established, these variants can perpetuate regionally and become enzootic in new reservoir species.[13–15] Phylogenetic analysis of circulating variants has suggested that canine rabies virus variants were the probable origins of several circulating wildlife variants of foxes (Texas and Arizona), skunks (California and north central United States), and mongooses (Puerto Rico). The remaining extant rabies virus variants in the US (ie, raccoon, south central skunk, and Flagstaff rabies virus variants) have been phylogenetically associated with switching from bat-associated rabies virus variants.[13]

Circulating independently of rabies virus variants associated with mesocarnivores are multiple variants associated with several species of bats. More than 30 species of bats have been reported with rabies in the United States, and more than 8 rabies virus lineages have been identified and associated with these bat species.[16] However, in contrast to the circulation of rabies in mesocarnivores, the greater mobility and population interactions of bats preclude definitive determination of the distribution of bat rabies virus variants other than the geographic ranges of the implicated host bat species. Recent studies[17] have suggested lower frequencies of cross-species transmission and host shift with increasing phylogenetic distance between bat species. Similarities in biological barriers and social structures of closely related bat species could account for higher rates of cross-species transmission of rabies virus and may be a factor in the evolution of current bat rabies virus variants.

Ongoing public health activities, including vaccination of wildlife and companion animals, education of the public and health professionals, and application of rabies PEP, have dramatically reduced the burden of rabies in humans in the United States. However, over the past 2 decades, human rabies has become primarily associated with bat exposures.

Investigations of human rabies cases in the United States over the past 2 decades have often found a history of known proximity to or contact with a bat in which a report of a bite was not acknowledged. These investigations are frequently limited by recall bias (exposures typically occurred several months before the patient becomes ill) and may rely on hearsay reports from friends and family after the patient is nonresponsive. While a bite from a rabid bat remains the most parsimonious explanation for these human rabies cases in the absence of known contact, these findings are the foundation of current Advisory Committee on Immunization Practices recommendations to evaluate persons with direct contact with a bat or persons who may have had unacknowledged contact with a bat (eg, a deeply sleeping person or an unattended child, a mentally disabled person, or an intoxicated person finding a bat in a room). If a person can be reasonably certain a bite, scratch, or mucous membrane contact did not occur or the bat is available for testing and is negative for the presence of rabies virus, PEP is not necessary.[1] Rabies control in bats by conventional methods is not currently feasible, and prevention of human rabies infection with bat rabies virus variants will continue to rely on health education to avoid exposure, careful exposure assessment in the event of potential contact, and judicious administration of PEP.

Reporting and Analysis

Human and animal rabies are nationally notifiable conditions in the United States.[18,19] Animal rabies surveillance is laboratory based, comprising 126 state health, agriculture, and university pathology laboratories performing the standard direct fluorescent antibody test to establish a rabies diagnosis.[20] In addition, targeted enhanced surveillance is carried out by more than 25 wildlife biologists engaged by the USDA Wildlife Services to work with oral rabies vaccination programs; the direct rapid immunohistochemical test is used in these programs.[21]

During 2010, 9 states (Arkansas, Georgia, Idaho, Massachusetts, Michigan, North Dakota, South Dakota, Vermont, and West Virginia) transmitted laboratory data for rabies diagnostic activity primarily by use of the Public Health Information Network Messaging System.[22] Other states submitted animal rabies data on a monthly or annual basis directly to the CDC Poxvirus and Rabies Branch. In addition, diagnostic activity conducted as part of enhanced surveillance activities carried out by USDA Wildlife Services was reported directly to the CDC. During 2010, a total of 106,472 samples were submitted to a laboratory for rabies testing, and of these, 104,647 were considered adequate for testing. This represents a 12.5% decrease in the number of animals tested for rabies, compared with the number tested in 2009. A total of 7,463 animals were submitted by USDA Wildlife Services personnel for testing with the direct rapid immunohistochemical test, accounting for 7.1% of all animals tested in 2010.

The CDC program requests enhanced data on animals submitted for rabies testing, as described previously.[22] All states provided data on species, county, and date of testing or collection for all animals submitted for rabies testing, with the exception of Oklahoma, which provided only aggregate numbers by species for nonrabid animals. All states are encouraged to identify bats that are submitted for rabies testing. Twenty-nine states provided some level of bat speciation during 2010. States are also strongly encouraged to type the

rabies virus variant isolated from rabid animals by means of either antigenic typing with monoclonal antibodies or phylogenetic typing with sequencing.[23,24] During 2010, 28% of the reported rabid animals included information on the rabies virus variant. Fifteen states provided information on rabies vaccination status of domestic animals submitted for testing, and 25 states and the District of Columbia provided information on human exposures to submitted animals. Nearly 49% of reported animals submitted for rabies testing included a collection location below county level.

For the present report, calculations of the percentage of rabid animals are based on the total number of animals submitted for rabies testing. Because most animals submitted for testing are selected on the basis of abnormal behavior or signs of illness, percentages presented in this report are not representative of the incidence of rabies in the general population. In addition, because of difference in protocols and submission rates among species and states, comparisons of the percentages of rabid animals between species or states are inappropriate. Geographic areas for displayed reservoirs in the United States were produced by aggregating data from 2006 through 2010, and all maps were produced as described.[25]

Calculations of submission rates were based on 2010 population data available from the US Census Bureau. Animal rabies data for Canada during 2010 were provided by the Centre of Expertise for Rabies—Ottawa Laboratory Fallowfield and the Terrestrial Animal Health Division, Canadian Food Inspection Agency. Data for Mexico were obtained from the Pan American Health Organization Epidemiological Information System.[a]

Rabies in Wild Animals

Wild animals accounted for 5,666 (92.1%) of the reported rabid animals in 2010, representing an 8.4% decrease in the number of rabid wild animals reported overall, compared with 2009 (Figure 2). Raccoons continued to be the most frequently reported rabid wildlife species (36.5% of all rabid animals during 2010), followed by skunks (23.5%), bats (23.2%), foxes (7.0%), and other wild animals including rodents and lagomorphs (1.8%). Seasonal trends for wildlife species were similar to trends for previous years, with peaks in number of rabid raccoons and skunks reported in March to May with a second peak in September to October. Number of rabid foxes reported showed a moderate peak around June to July, and number of rabid bats peaked sharply in August.

Raccoons

The 2,246 rabid raccoons reported in 2010 represented a 3.5% decrease, compared with the number reported during 2009, continuing a declining trend since 2006 (Table 1). The percentage of raccoons submitted for rabies testing that were rabid increased from 11.7% in 2009 to 15.6% in 2010. Fewer rabid raccoons were reported by 14 of the 20 eastern states and the District of Columbia, where raccoon rabies is enzootic, with decreases of ≥ 50% reported by 2 of these states (New Hampshire and Tennessee). New York City had a 392.8%

[a]SIEPI Epidemiological Information System [database online]. Washington, DC: Pan American Health Organization, Pan American Center for Foot-and-Mouth disease, 2009. Available at: www.paho.org/common/Display.asp?Lang=E&RecID=9260. Accessed Jul 1, 2011.

increase in the number of rabid raccoons, but no state reported an increase > 100%. States in the northeast and mid-Atlantic in which raccoon rabies was enzootic accounted for 72.1% (1,620 cases; 3.1% increase) of the 2,246 rabid raccoons reported in 2010 (Figure 3). The southeastern states in which raccoon rabies was enzootic—Alabama, Florida, Georgia, North Carolina, South Carolina, and Tennessee—reported 27.0% (606 cases; 17.4% decrease) of all rabid raccoons. Rabid raccoons reported by Texas (18; south central skunk rabies virus variant), Kentucky (1; north central skunk rabies virus variant), and New Mexico (1; Arizona gray fox rabies virus variant) accounted for the remaining cases reported in 2010.

Excluding Tennessee and Ohio, for which rabid raccoons represented a small proportion of all rabid animals reported, states in which raccoon rabies was enzootic reported 65.2% (4,015/6,154) of the national total of rabid animals and 77.6% (3,665/4,724) of all rabid animals other than bats. Overall, these states submitted 41.0 animals/100,000 persons for rabies testing during 2010, down from 47.2 animals/100,000 persons during 2009.

Bats

The 1,430 rabid bats reported during 2010 represented a 12.0% decrease, compared with the number reported during 2009. The percentage of bats submitted for rabies testing that were rabid remained stable at 5.9%. Rabid bats were reported from all 48 contiguous states with the exceptions of Delaware, Mississippi, and Vermont (Figure 4). Six states (Idaho, Illinois, Indiana, Nevada, Utah, and Washington) reported rabies in bats only. A ≥ 50% increase in the number of rabid bats was reported by 3 states (Kentucky, North Dakota, and Wyoming) and New York City. Over 45% (10,956/24,298) of the bats submitted for rabies testing were identified beyond the taxonomic level of order (Table 2). Overall, states where bats were the only recognized reservoir for rabies submitted 11.0 animals/100,000 persons for testing during 2010, down from 12.9 animals/100,000 persons during 2009.

Skunks

The 1,448 rabid skunks reported during 2010 represented a 9.7% decrease, compared with the number reported during 2009. The percentage of skunks submitted for testing that were rabid increased from 23.9% in 2009 to 27.4% in 2010. Two of the 23 states where skunk rabies virus variants are enzootic (Colorado and Oklahoma) reported a ≥ 50% increase in the number of rabid skunks during 2010. One rabid skunk (north central skunk rabies virus variant) was reported from Wisconsin, the first since 2006. No rabid skunks have been reported from Illinois since 2006 or from Indiana since 2007.

During 2010, 42.6% of the rabid skunks were reported from states where the south central skunk rabies virus variant is enzootic (8.8% decrease, compared with 2009), 11.3% were reported from states where the north central skunk rabies virus variant is enzootic (27.1% decrease), 1.6% were reported from California (47.7% decrease), and 44.4% were reported from states where the raccoon rabies virus variant is enzootic (1.8% decrease; Figure 5). For the second consecutive year, Ohio reported more rabid skunks in the counties where raccoon rabies is enzootic than rabid raccoons. Overall, states where skunks are the primary reservoir for rabies submitted 32.2 animals/100,000 persons for rabies testing during 2010, down from

35.8 animals/100,000 persons in 2009. When data were stratified by the various skunk rabies virus variants, similar decreases in submission rates were observed for the south central, north central, and California skunk rabies virus variants (38.3, 36.3, and 16.0 animals/100,000 persons respectively).

Foxes

The 429 rabid foxes reported during 2010 represented a 14.9% decrease, compared with the number reported during 2009. The percentage of foxes submitted for testing that were rabid decreased from 26.1% in 2009 to 25.1%. Most of the rabid foxes (378; 88.1%) were reported from states where raccoon rabies is enzootic (Figure 6). Besides those foxes in which rabies was attributable to spillover from rabid raccoons, 26 (6.1%) foxes had rabies attributable to spillover from rabid skunks, 12 (2.8%) had rabies associated with the arctic fox rabies virus variant, 7 (1.6%) had rabies associated with various bat rabies virus variants, and 6 (1.4%) had rabies associated with the Arizona gray fox rabies virus variant. Oregon reported 6 rabid foxes during 2010 because of an epizootic focused in 1 county in the southern part of the state. For 4 of the reported rabid foxes from Oregon, the infective virus variant was identified as a rabies virus variant associated with bats of the genus *Myotis*, and for 2, it was identified as a rabies virus variant associated with big brown bats (*E fuscus*). No foxes with rabies caused by the Flagstaff or Texas gray fox rabies virus variants were reported during 2010.

Other wild animals

Puerto Rico reported 25 rabid mongooses during 2010, a 26.5% decrease from the 34 cases reported during 2009. Other reported rabid wildlife included 29 groundhogs (*Marmota monax*), 22 bobcats (*Lynx rufus*), 10 coyotes (*Canis latrans*), 10 deer (presumably *Odocoileus virginianus*), 4 otters (presumably *Lontra canadensis*), 3 opossums (*Didelphis virginiana*), 2 fishers (*Martes pennanti*), 2 javelinas (*Pecari tajacu*), 1 badger (*Taxidea taxus*), 1 coati (*Nasua nasua*), 1 marmot (*Marmota* sp; not otherwise specified), 1 muskrat (*Ondatra zibethicus*), 1 rabbit (species not identified), and 1 squirrel (presumably *Sciurus carolinensis*). With the exception of the rabid muskrat and squirrel, all rodents and lagomorphs were reported from states where raccoon rabies is enzootic. The rabid squirrel in Louisiana was determined to be infected with a south central skunk rabies virus variant. There was insufficient tissue for confirmation and typing of the infective virus variant for the rabid muskrat reported from Colorado.

For 2 of the 10 rabid coyotes, the infective virus variant was typed. Variant information was not reported for rabid coyotes in Alabama (1 rabid coyote), California (1), Colorado (1), Georgia (1), New Jersey (1), New York (2), and New York City (1). Both rabid coyotes for which variant typing was reported were infected with the predominant carnivore reservoir for the geographic region where the animal was found (1 rabid coyote in Alabama and 1 in North Carolina).

Rabies in Domestic Animals

Domestic animals accounted for 7.9% of all rabid animals reported during 2010, a decrease of 3.6% compared with the number reported during 2009. The number of reported cases of rabies decreased for all domestic species with the exception of cats. Six states reported more than half of all rabid domestic animals reported during 2010: Pennsylvania (72), New York (51), Texas (49), Virginia (44), Georgia (26), and North Carolina (25).

Cats and dogs

Rabid cats continue to represent the majority (62.2%) of reported rabid domestic animals. Most (82.2%) of the 303 rabid cats were reported from states where raccoon rabies was enzootic, with 2 states (Pennsylvania and New York) accounting for nearly a third of rabid cats reported during 2010 (Figure 7). New York reported a 55.6% increase in the number of rabid cats reported, the most on record since 1993.

During 2010, 69 rabid dogs were reported, a 14.8% decrease compared with the number reported during 2009. Texas (15 rabid dogs), Puerto Rico (9), and Virginia (5) reported the largest numbers of rabid dogs. No other states reported > 4 rabid dogs during 2010. None of the rabid dogs were reported to be infected with a canine rabies virus variant. Twenty-seven states, the District of Columbia, and New York City did not report any rabid dogs during 2010.

Excluding dogs from Puerto Rico, which were presumably infected with a canine/mongoose rabies virus variant, 47 of the 60 reports of rabid dogs included the rabies virus variant responsible for infection. Variant information was not reported from Alabama (1 rabid dog), California (1), Georgia (4), Iowa (1), North Dakota (1), Oklahoma (2), Pennsylvania (2), and Virginia (1). Among variants that were reported, 21 were south central skunk, 10 were north central skunk, 14 were raccoon, 1 was California skunk, and 1 was Arctic fox rabies virus variants.

Other domestic animals

The number of rabid cattle decreased 4.0% from 74 in 2009 to 71 in 2010. Virginia (11 rabid cattle), Pennsylvania (7), South Dakota (6), Texas (5), Kansas (5), North Carolina (5), and New York (5) reported the largest numbers of rabid cattle. No other states reported > 4 rabid cattle during 2010. Texas reported 1 rabid cow infected with a vampire bat rabies virus variant. This cow had recently been imported into the US and most likely had been exposed while in Mexico. The 37 rabid horses and mules reported during 2010 represented a 9.8% decrease, compared with the number reported during 2009. The number of rabid goats and sheep that were reported decreased 25.0%. A single rabid pig was reported from Tennessee.

Rabies in Humans

During 2010, samples from 40 human patients in the United States were submitted to the CDC for rabies testing, representing a 16.7% decrease from the number of samples submitted during 2009. Two cases of human rabies were reported. Since 2001, a total of 29 human rabies cases have been reported in the United States (Table 3). Of the 21 human

patients with domestically acquired rabies, 15 (71.4%) were male; median age of the infected human patients was 26.5 years.

On August 2, 2010, a 19-year-old male in Louisiana began experiencing left arm and shoulder pain and left facial paresthesia.[26] He had entered the United States on July 25 as a migrant farm worker. His illness progressed rapidly to generalized weakness, and he was intubated. On August 12, local clinicians contacted the Louisiana Office of Public Health for information regarding rabies testing. Samples were submitted to the CDC, where rabies was confirmed on the basis of detection of rabies virus–specific antibody in serum and CSF. No rabies virus antigens or nucleic acid were detected in antemortem samples. However, testing of brain tissue collected at autopsy with a reverse transcriptase PCR assay and subsequent sequencing of amplicons identified a rabies virus variant associated with vampire bats (*Desmodus rotundus*). The patient died on August 21, 2010. Investigations in the United States and Mexico identified a history of a vampire bat bite to the patient around July 15 in the patient's home state of Michoacán, Mexico, for which the patient had not received medical attention. Mexican health services identified 5 close contacts of the patient in Michoacán and conducted risk assessments of other persons in the community for exposure to vampire bats. This case represents the first reported human rabies case in the United States associated with a vampire bat rabies virus variant.

In Wisconsin, around December 24, 2010, a 70-year-old man began experiencing right shoulder pain. Approximately 2 days later, he became tremulous and started experiencing difficulty swallowing. Four days after the onset of clinical signs, he presented to an emergency department complaining of weakness, right shoulder pain, and difficulty swallowing. The patient's condition worsened, and he was admitted to the intensive care unit. On the third day of hospitalization, the patient became unresponsive and required intubation. Antemortem samples were submitted for rabies testing to the CDC, where rabies virus antigens were detected in a nuchal skin biopsy specimen. Sequencing of amplicons obtained from a saliva sample by means of a reverse transcriptase PCR assay identified a rabies virus variant associated with tri-colored bats (*Perimyotis subflavus*). By the time rabies was diagnosed, the patient was nonresponsive. No one interviewed reported any history of the patient having contact with bats. Of > 178 potential health-care and community contacts evaluated, 7 persons (5 health-care workers and 2 family contacts) were recommended to receive PEP because of potential contact with the patient's saliva.

Rabies in Canada and Mexico

Canada reported 123 laboratory-confirmed cases of rabies involving animals during 2010, a 15.2% decrease from the number reported during 2009. A decrease in total number of rabid animals has been reported in 9 of the past 10 years. Ninety-three percent (n = 114) of the cases involved rabid wildlife, 1.6% (2) involved rabid livestock, and 5.7% (7) involved rabid cats and dogs. The overall number of animals submitted for diagnostic testing to the Canadian Food Inspection Agency rabies laboratories decreased 11.2% from 5,515 in 2009 to 4,898 in 2010. In addition to Canadian Food Inspection Agency submissions, several provincial ministries undertook active wildlife rabies surveillance testing during 2010, with 1 rabid skunk identified in Ontario by means of the direct rapid immunohistochemical test.

No rabid raccoons have been reported in Canada since 2008. No rabid wolves were reported in Canada in 2010, compared with 5 in 2009. The numbers of rabid foxes, bats, dogs, and cattle that were reported decreased by 53.8% (13 to 6), 12.7% (55 to 48), 66.7% (9 to 3), and 87.5% (8 to 1), respectively, compared with numbers reported during 2009. Increases were reported in the numbers of rabid skunks (22.4%; 49 to 60), cats (33.3%; 3 to 4), and equids (0 to 1). No human cases of rabies were reported in Canada during 2010.

Mexico reported 357 rabid animals during 2010, a 108.8% increase compared with the number reported during 2009. Nearly 83% (296/357) of reported rabid animals were cattle. A total of 32 rabid livestock (15 horse, 5 sheep, 3 goats, and 9 not specified) excluding cattle were reported. A total of 20 rabid dogs (66.7% increase) were reported, in addition to 9 rabid wild animals. Four human rabies cases were reported from Mexico during 2010.

Discussion

State and local jurisdictions provide enhanced rabies surveillance data to the CDC, including total diagnostic activity and detailed laboratory and epidemiologic information on animals submitted in excess of aggregate case counts. This information is critical for zoonotic disease surveillance where animal population demographics are unavailable. Since 2006, US laboratories have tested an average of 115,445 animals (95% confidence interval, 109,448 to 121,442 animals) for rabies each year. The total number of animals submitted for rabies testing during 2010 represented a substantial decline in testing activity. The national surveillance network for rabies consists of more than 125 state and local health and agriculture laboratories and university-based veterinary pathology laboratories that provide primary testing of animals suspected to have rabies. Supporting this national laboratory network is a diverse set of participants consisting of local health departments, animal control services, law enforcement departments, private veterinarians, and the general public who collect, process, and submit animals for rabies testing. Overall, this system is relatively robust given the critical role of rabies testing on individual exposure assessments and decisions to initiate PEP. However, surveillance systems are frequently susceptible to impacts from budget restrictions and changes in the financial climate.[27]

The current global financial crisis has likely had an impact on both the national surveillance system for submitting and processing of animals as well as the budgets of rabies diagnostic laboratories. Given the limited financial resources of many agencies responsible for assisting with animal submission, as well as diagnostic laboratories, it is likely that some jurisdictions may increase triage of submitted animals on the basis of human exposure risk. Although the total number of animals submitted for rabies testing decreased in 2010, most animal groups remained within previous ranges for the percentage in which rabies was diagnosed. Cats were the only species with a substantially higher percentage in which rabies was diagnosed (1.3%), compared with the mean percentage of 0.98% (95% confidence interval, 0.89 to 1.08) for the previous 4 years.

Despite the resurgence of the Flagstaff rabies virus variant in gray foxes in northern Arizona during 2009, no animals in which rabies was attributed to this variant were reported during 2010. A combination of wildlife vaccination (trap-vaccinate-release of skunks and oral

rabies vaccination targeted at foxes), harsh winter weather, and regional forest fires may have limited this most recent epizootic. Continued active surveillance will be necessary to determine whether the Flagstaff variant will reemerge in local wildlife populations as in previous years.[14] Similarly, the 6 rabid foxes with bat rabies virus variants reported from Josephine County in Oregon during 2010 raise concerns because of epidemiologic characteristics similar to those seen in relation to the emergence of rabies in Flagstaff, Ariz. Since 2000, 12 rabid foxes with bat rabies virus variants have been reported from the southern region of Oregon. These cases may represent a unique environmental condition allowing increased viral transmission from bats to foxes or could be suggestive of a potential host shift with fox-to-fox transmission. Additional active surveillance, applied ecological studies, and phylogenetic analysis of rabies viruses from this area are necessary to further evaluate transmission patterns.

Since 2000, vampire bat rabies has become the leading cause of human rabies in Latin America.[28] The recent cases of imported human rabies in the United States are a further indication of the changing epidemiology of rabies in Mexico. In addition to the imported human rabies case associated with a vampire bat variant during 2010, a rabid cow was reported that was infected with a confirmed vampire bat variant. This cow was imported into the United States in 2010 from Mexico and spent time on pasture before being transferred to a feedlot in northern Texas on January 13, 2010. The cow began showing signs of aggression and ambulatory instability on May 1 and rabies was diagnosed shortly afterwards.[b] Further investigations of the origin of the cow in Mexico were unsuccessful because of a lack of available documentation, although limited phylogenetic analysis of the isolate clustered with a lineage of vampire bat rabies viruses associated with the state of Tamaulipas in Mexico. Few cases of vampire bat rabies in imported cattle have been reported in the past; the most recent involved a Texas cow identified in 2008.

New research[c] suggests that, although currently restricted to Latin America, vampire bat ranges are expanding northward and that this northward expansion may be facilitated by climate change. The introduction of vampire bats in the southern United States would likely result in an increase in the number of human exposures and have an important impact on regional rabies virus transmission to cattle. Monitoring of rabies virus variants in bats and other species along the US-Mexico border as well as any rabid animals with a history of international movement will be critical to identifying any expansion of this important rabies reservoir. As this reservoir approaches the United States, traceability of livestock movement will be important to determine when domestic infections have occurred in cattle.[29]

Twenty-nine cases of human rabies have been reported in the United States since 2001, including the 2 cases reported in 2010 and 1 case reported during the first half of 2011. Eight of these 29 (27.6%) individuals were infected outside the continental United States (7 abroad and 1 in Puerto Rico). In the United States, most imported rabies virus infections that occurred in foreign countries where dog rabies is enzootic involved regional canine rabies

[b]Sidwa T, Texas Department of State Health Services, Zoonosis Control Branch, Austin, Tex: Personal communication, 2011.
[c]Mistry S, Moreno A. Modeling changes in vampire bat distributions in response to climate change: implications for rabies in North America (abstr), in *Proceedings*. 19th Int Conf Rabies Am 2008;38–39.

virus variants, with the exceptions of the 2008 and 2010 human cases from Mexico, which were associated with bat rabies virus variants. The remaining 21 (72.4%) persons were infected with rabies virus variants indigenous to the United States. Phylogenetic analysis indicated that 15 of these 21 (71.4%) persons were infected with bat rabies virus variants. Epidemiologic investigations implicated a bat as the most likely source of exposure in 4 additional cases. Only 2 human rabies cases that have occurred in the United States since 2001 have not been associated with exposure to bats. In a 2003 Virginia case, the infective virus variant was typed as a raccoon rabies virus variant, and in a case reported during 2011, the source of the rabies virus was not identified. Excluding 4 human rabies cases associated with organ transplants and an arterial graft from a donor infected with bat rabies virus, there have been a total of 15 bat-associated human rabies cases since 2001. In 11 of the 15 (73.3%) cases, there was a report of a bite or direct contact with a bat (eg, waking to find a bat on the body or handling a bat with bare hands). Only 4 patients (27%) with bat-associated rabies reported no known exposure to a bat. In the absence of direct contact or a known bite, the most likely route of infection with rabies virus remains 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.[30] If experimental treatment is to be considered, early diagnosis of rabies is critical. However, to date, no single course of treatment of rabies in humans has been documented to be efficacious after clinical signs of rabies are present. The documentation of a human case of abortive rabies virus infection continues to challenge preconceived notions of rabies as an invariably fatal disease as well as traditional guidelines for submitting samples for rabies testing. Clinicians treating possible cases of human rabies, indicated by acute, progressive infectious encephalitis, a compatible exposure history, and serologic evidence of a specific lyssavirus response, even in the absence of fulminant neurologic decline, should contact their state health department as soon as possible for consultation with the CDC.

2011 Rabies Update

On May 6, 2011, the CDC was contacted by officials from the California Department of Public Health regarding a possible case of human rabies. The patient, an 8-year-old female, had been admitted to a local hospital on April 30 with suspected viral encephalitis following several days of malaise, sore throat, and abdominal pain. The next day, her condition deteriorated rapidly and she was intubated and transferred to a tertiary care center. Diagnostic testing performed by the California Viral and Rickettsial Disease Laboratory identified rabies virus–specific IgG and IgM in her serum. These results were confirmed by the CDC where rabies virus–specific IgG and IgM were also identified in CSF. The patient did not have a history of prior rabies vaccination. No rabies virus antigens or RNA were identified in a nuchal skin biopsy specimen or saliva samples collected over several days. The patient was treated by induction of a therapeutic coma and administration of antiviral medications according to the Milwaukee protocol.[31] The patient began showing signs of

improvement around May 15 and has been discharged from the hospital. The patient's family reported several potential exposure sources. She had fed a horse that died on the farm in November 2010. This horse was exhumed, but no rabies virus antigens were identified in CNS tissue. She had also had multiple cat bites from at least 2 cats in a feral cat population residing near her school. While the presence of bats was noted around the farm, no infestation was noted in the household, and no contact with a bat was reported. The lack of any isolated rabies virus in this case makes further analysis of exposure route speculative. Contact investigations identified 10 community members and 14 health-care workers who were recommended to receive PEP on the basis of potential exposure to the patient's saliva.

The lack of development of rabies virus neutralizing antibodies in this patient and her clinical signs raise questions about the relative role of treatment versus presumptive abortive infection.[32] Rabies remains preventable when proper PEP is administered after an exposure; however, the recent cases of recovery after treatment and abortive rabies virus infection suggest the disease may possibly not be universally fatal. Public education should continue to emphasize avoiding exposure to bats and other potentially rabid wildlife and seeking prompt medical attention after exposure to such animals.

In New Jersey, a 73-year-old female patient reported to an emergency department with onset of headaches starting around June 29, 2011. On July 2, she developed confusion, lethargy, abnormal speech, and intermittent seizures. Samples were submitted to the CDC for rabies testing; rabies virus–specific antigen was identified in a nuchal skin biopsy specimen and rabies virus–specific RNA was identified in a saliva sample. The patient died on July 20, 2011. She had moved to New Jersey from Haiti approximately 6 weeks prior to the onset of clinical signs. Exposure investigation of family and contacts in Haiti found a history of a dog bite received in late April from a young dog.

Acknowledgments

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Abbreviation

PEP Postexposure prophylaxis

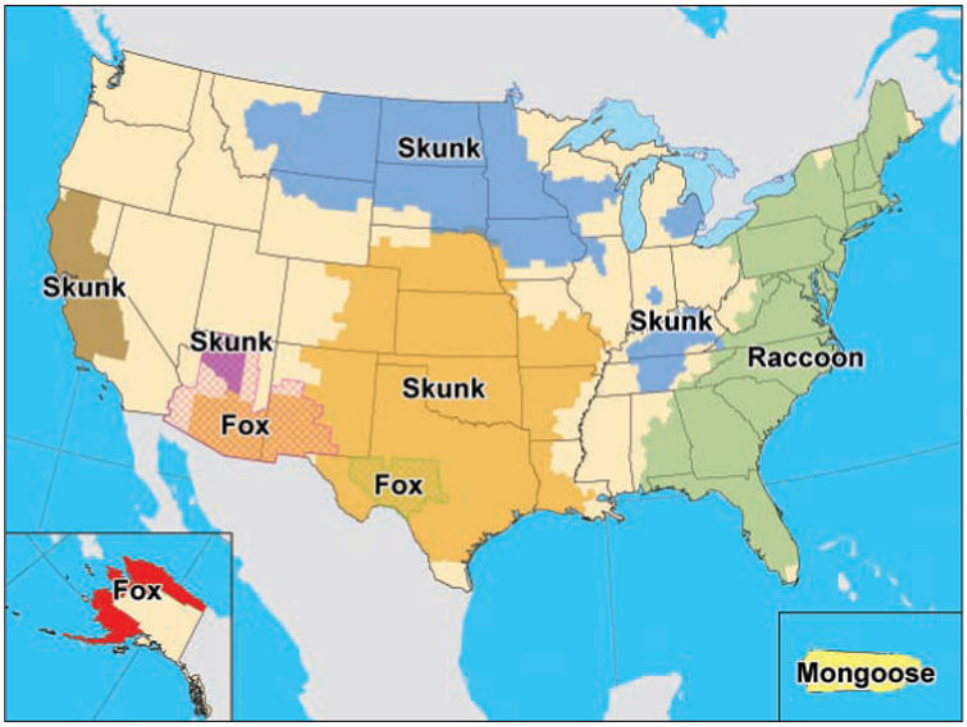

Figure 1.
Distribution of major rabies virus variants among mesocarnivore reservoirs in the United States and Puerto Rico, 2010.

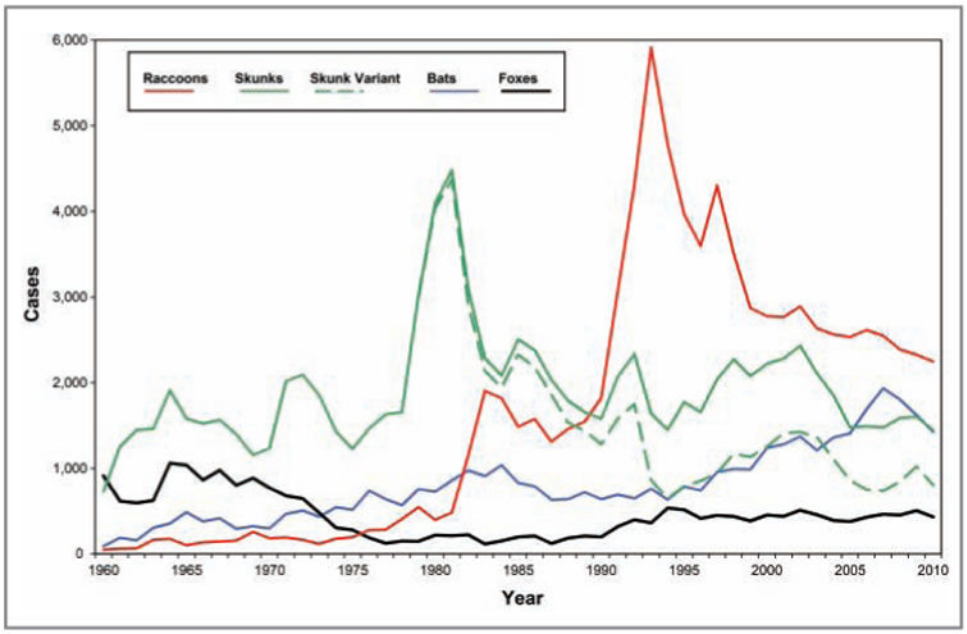

Figure 2.
Cases of rabies among wildlife in the United States, by year and species, 1960 to 2010.

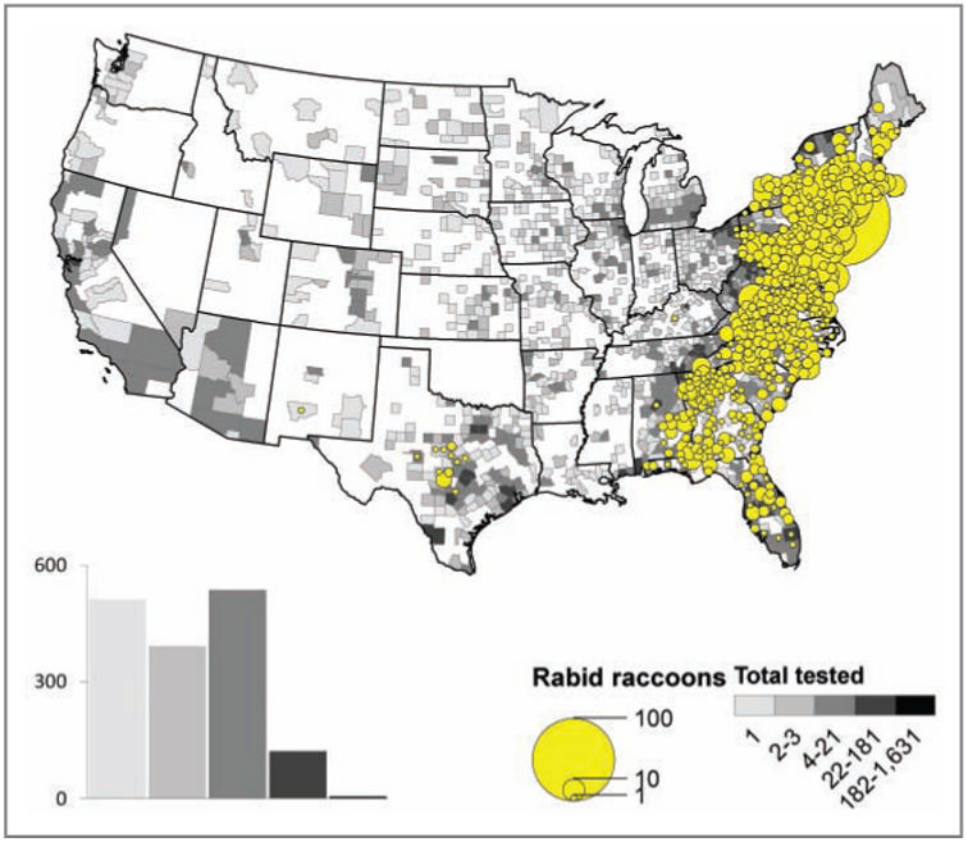

Figure 3.
Reported cases of rabies involving raccoons, by county, 2010. Histogram represents numbers of counties in each category for total number of raccoons submitted for testing.

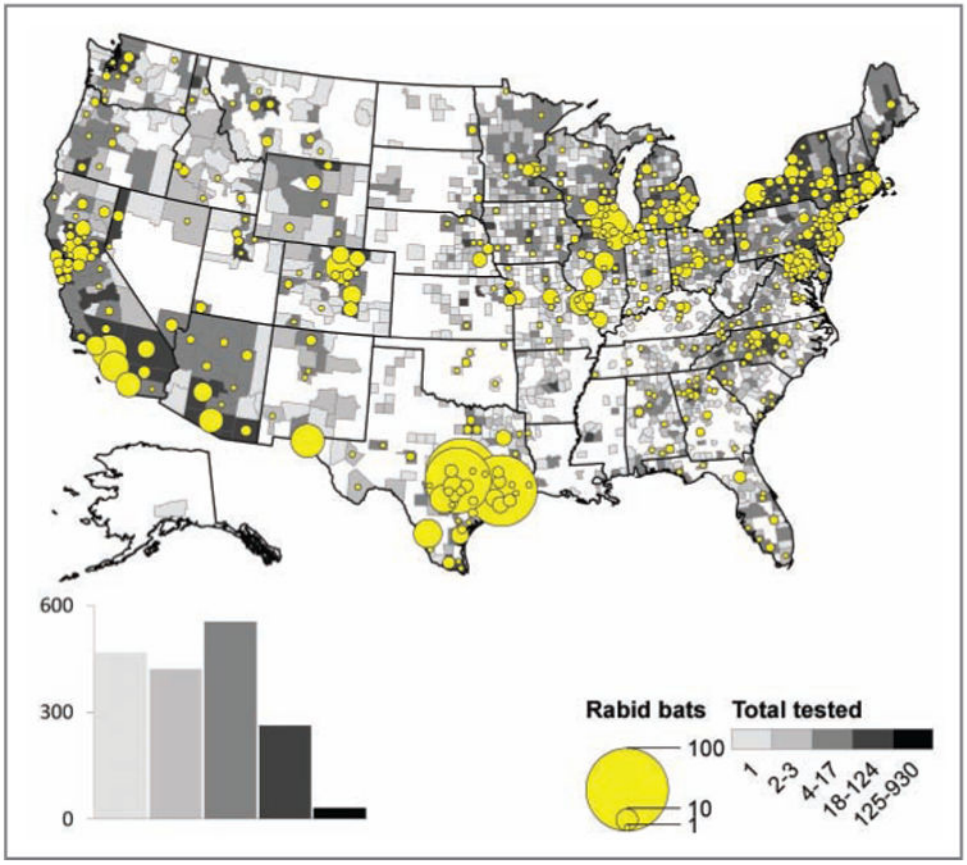

Figure 4.

Reported cases of rabies involving bats, by county, 2010. Histogram represents numbers of counties in each category for total number of bats submitted for testing.

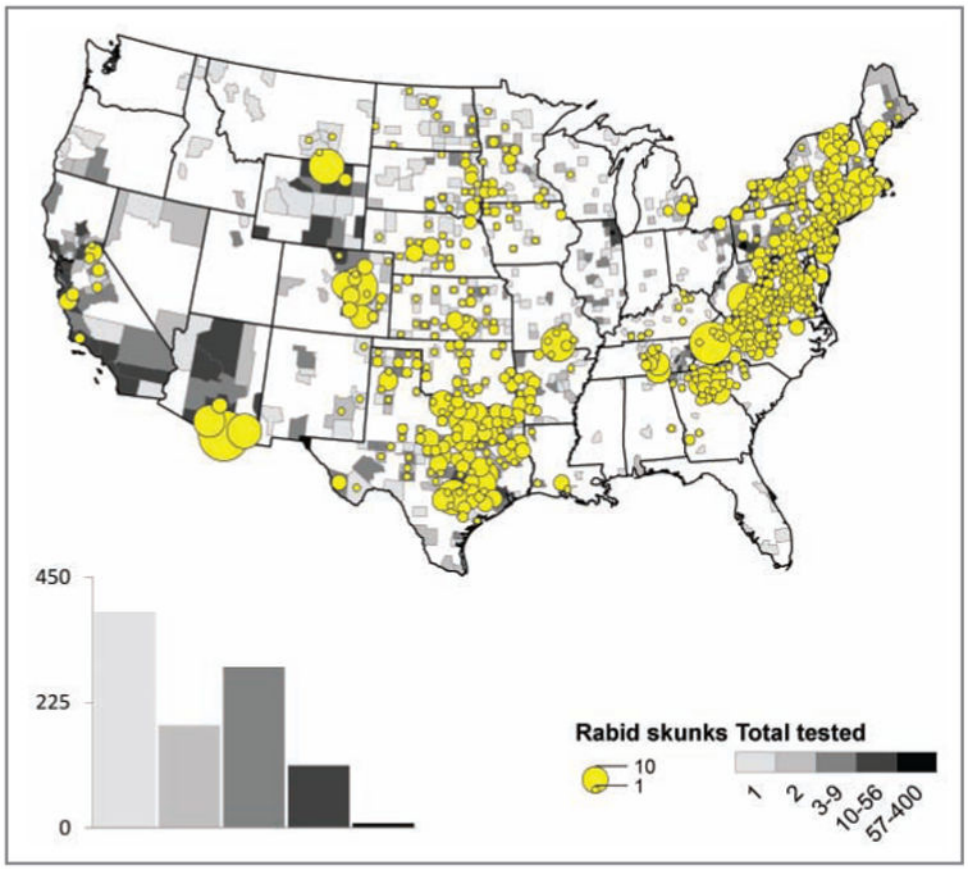

Figure 5.

Reported cases of rabies involving skunks, by county, 2010. Histogram represents numbers of counties in each category for total number of skunks submitted for testing.

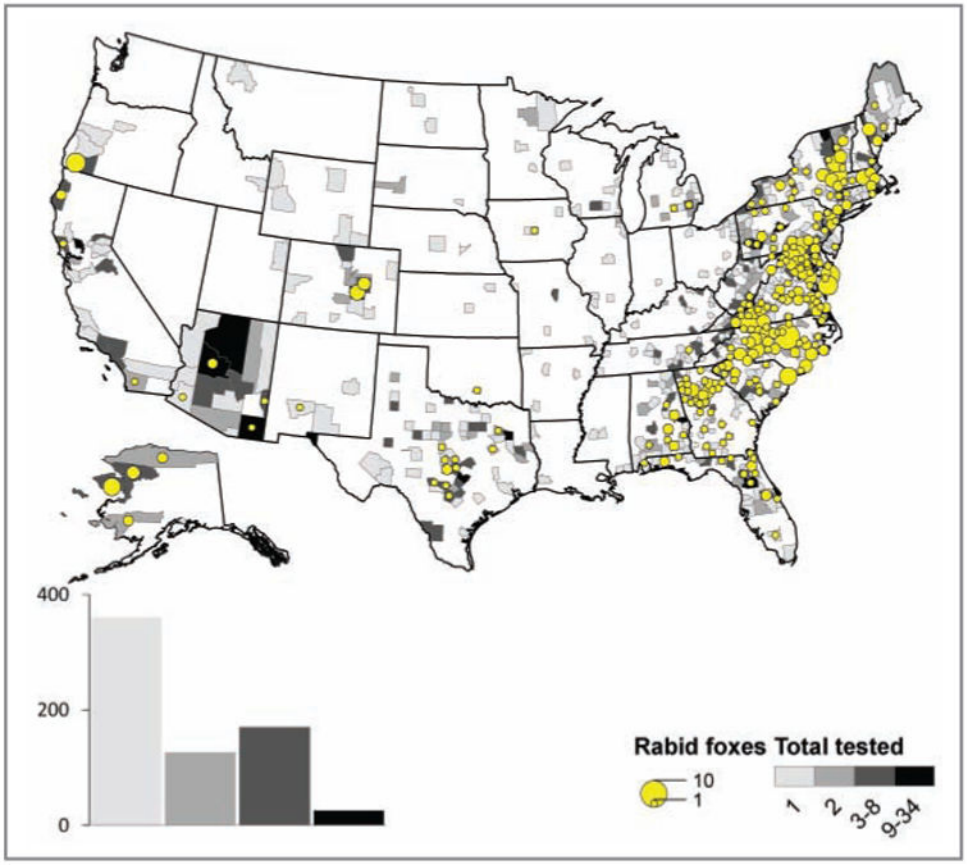

Figure 6.

Reported cases of rabies involving foxes, by county, 2010. Histogram represents numbers of counties in each category for total number of foxes submitted for testing.

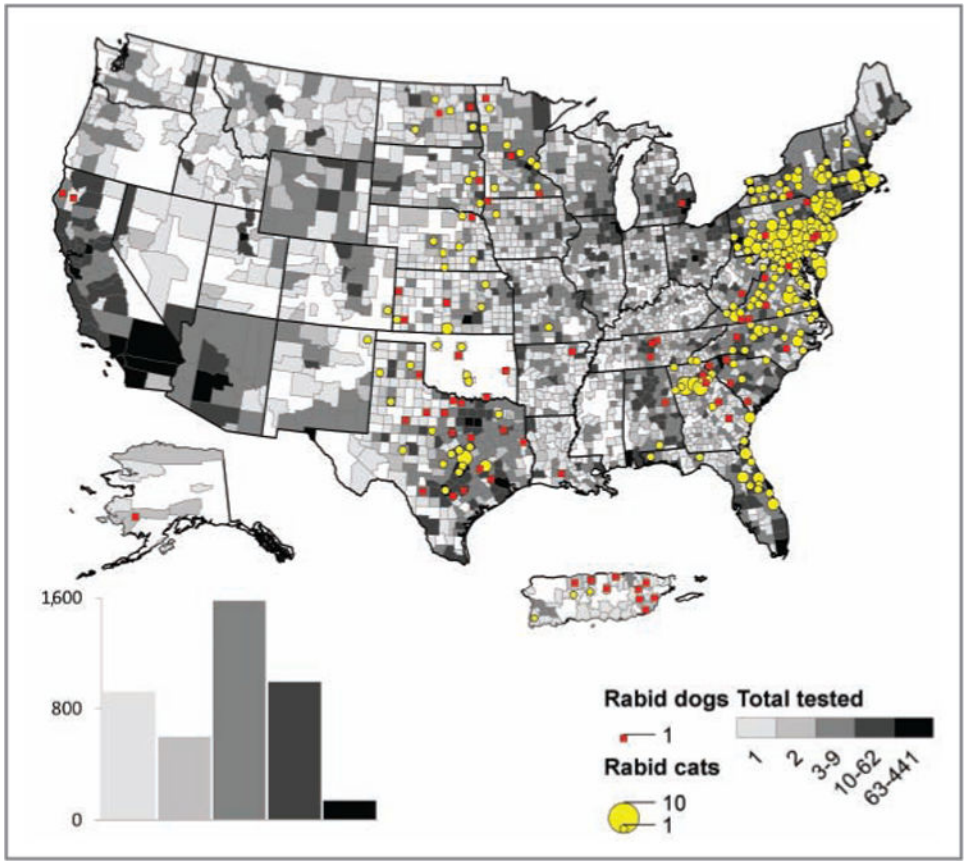

Figure 7.

Reported cases of rabies involving cats and dogs, by county and municipio (Puerto Rico), 2010. Histogram represents numbers of counties in each category for total number of cats and dogs submitted for testing.

Table 1

tes, by location, during 2010.

	Domestic animals						Wild animals									
Wild	**Cats**	**Cattle**	**Dogs**	**Horses/mules**	**Goats/sheep**	**Other domestic***	**Raccoons**	**Bats**	**Skunks**	**Foxes**	**Other wild†**	**Rodents and lagomorphs‡**	**Humans**	**% Pos 2010**	**2009 cases**	**Change (%)**
12	0	0	1	0	0	0	0	0	0	12	0	0	0	46.4	14	–7.14
69	1	0	1	0	0	0	44	11	1	11	2[b]	0	0	3.0	81	–12.35
33	0	0	1	0	0	0	0	1	32	0	0	0	0	4.1	47	–27.66
111	0	0	0	0	0	0	0	34	65	5	7[c]	0	0	7.8	273	–59.34
172	0	1	2	0	0	0	0	144	23	4	1[d]	0	0	2.9	227	–22.91
134	1	0	0	1	0	0	0	61	63	7	2[e]	1[w]	0	10.8	104	30.77
140	1	3	0	1	0	0	80	14	41	3	1[f]	1[x]	0	12.9	153	–5.23
34	4	0	0	0	0	0	27	6	0	1	0	0	0	12.1	57	–33.33
6	5	0	0	0	0	0	4	0	0	1	0	1[y]	0	6.8	15	–26.67
116	15	0	0	1	0	0	78	15	0	16	7[g]	0	0	4.6	162	–18.52
349	21	1	4	0	0	0	208	20	76	40	5[h]	0	0	14.6	404	–7.18
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	0.00
24	1	1	1	0	0	0	0	10	13	1	0	0	0	1.9	35	–22.86
11	0	0	0	0	0	0	0	11	0	0	0	0	0	2.6	8	37.50
118	0	0	0	0	0	0	0	118	0	0	0	0	0	2.3	83	42.17
26	0	0	0	0	0	0	0	26	0	0	0	0	0	2.7	40	–35.00
45	5	5	3	0	0	0	0	6	39	0	0	0	0	4.6	78	–25.64
21	0	0	0	0	0	0	1	12	8	0	0	0	0	2.1	46	–54.35
9	0	0	1	0	0	0	0	1	7	0	0	1[z]	1	1.5	5	120.00
133	9	0	0	2	0	0	73	14	29	10	2[i]	5[aa]	0	6.0	130	10.77
341	17	4	0	0	0	0	223	44	27	41	0	6[bb]	0	8.4	384	–5.73
61	1	0	0	0	0	0	28	5	20	7	0	1[cc]	0	11.6	62	0.00
70	1	0	1	1	0	0	0	60	8	2	0	0	0	2.2	69	5.80
44	8	4	3	0	0	0	0	20	24	0	0	0	0	2.4	69	–14.49
63	1	0	0	0	0	0	0	41	22	0	0	0	0	2.5	66	–3.03

	Domestic animals						Wild animals									
Wild	Cats	Cattle	Dogs	Horses/mules	Goats/sheep	Other domestic*	Raccoons	Bats	Skunks	Foxes	Other wild†	Rodents and lagomorphs‡	Humans	% Pos 2010	2009 cases	Change (%)
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	4	–100.00
16	0	0	0	1	0	0	0	13	3	0	0	0	0	4.1	24	–29.17
386	17	5	2	1	0	0	217	31	59	76	3[j]	0	0	10.9	492	–16.46
14	4	2	2	0	0	0	0	2	11	0	1[k]	0	0	4.9	16	37.50
39	6	4	1	1	1	0	0	12	27	0	0	0	0	4.7	90	–42.22
15	2	0	0	0	0	0	5	2	5	1	1[l]	1[dd]	0	3.9	34	–50.00
270	12	0	0	0	0	0	184	40	35	7	3[m]	1[ee]	0	8.7	288	–2.08
12	1	0	0	1	0	0	1	6	3	1	1[n]	0	0	4.0	26	–46.15
9	0	0	0	0	0	0	0	9	0	0	0	0	0	2.5	12	–25.00
445	42	5	1	2	1	0	249	68	85	34	4[o]	5[ff]	0	7.9	439	12.98
144	1	0	0	0	0	0	138	3	1	0	2[p]	0	0	25.6	29	400.00
46	0	1	0	0	0	0	2	41	3	0	0	0	0	1.3	47	0.00
45	4	3	3	6	1	0	0	6	38	1	0	0	0	5.3	50	24.00
16	0	0	0	0	1	0	0	10	0	6	0	0	0	6.2	12	41.67
322	56	7	4	5	0	0	202	28	56	25	6[q]	5[gg]	0	4.7	453	–13.02
25	4	0	9	3	0	0	0	0	0	0	25[r]	0	0	34.5	43	–4.65
27	2	0	0	0	0	0	13	7	4	3	0	0	0	6.9	45	–35.56
99	3	0	4	0	0	0	53	9	14	22	1[s]	0	0	5.5	153	–30.72
25	3	6	1	0	0	0	0	3	22	0	0	0	0	3.8	53	–33.96
73	1	0	3	1	0	1[a]	6	9	57	1	0	0	0	3.2	88	–10.23
725	20	5	15	8	1	0	18	373	322	11	1[t]	0	0	6.1	830	–6.75
10	0	0	0	0	0	0	0	10	0	0	0	0	0	2.0	13	–23.08
547	27	11	5	1	0	0	324	20	130	65	4[u]	4[hh]	0	15.0	572	3.32
54	0	0	0	0	0	0	17	0	28	7	1[v]	1[ii]	0	14.8	67	−19.40
14	0	0	0	0	0	0	0	14	0	0	0	0	0	3.7	14	0.00
28	0	0	0	0	0	0	0	27	1	0	0	0	1	1.4	25	16.00
86	7	1	1	1	1	0	51	1	26	8	0	0	0	4.9	123	–21.14

	Domestic animals						Wild animals									
Wild	**Cats**	**Cattle**	**Dogs**	**Horses/mules**	**Goats/sheep**	**Other domestic***	**Raccoons**	**Bats**	**Skunks**	**Foxes**	**Other wild†**	**Rodents and lagomorphs‡**	**Humans**	**% Pos 2010**	**2009 cases**	**Change (%)**
32	0	2	0	0	0	0	0	12	20	0	0	0	0	5.6	40	−15.00
5,666	**303**	**71**	**69**	**37**	**6**	**1**	**2,246**	**1,430**	**1,448**	**429**	**80**	**33**	**2**	**—**	**6,694**	**−8.05**
92.06	4.92	1.15	1.12	0.60	0.10	0.02	36.49	23.23	23.53	6.97	1.30	0.54	0.03			
11.20	1.13	6.04	0.28	4.21	1.27	0.39	15.64	5.89	27.40	25.06	3.57	1.21	—			
6,185	300	74	81	41	8	1	2,327	1,625	1,603	504	88	38	4			
−8.39	1.00	−4.05	−14.81	−9.76	−25.00	0.00	−3.48	−12.00	−9.67	−14.88	−9.09	−13.16	−50.00			

J Am Vet Med Assoc. Author manuscript; available in PMC 2016 November 23.

[q] 6 deer;

[r] 25 mongooses;

[s] 1 bobcat;

[t] 1 bobcat;

[u] 2 bobcats, 1 deer, 1 opossum;

[v] 1 bobcat.

‡Rodents and lagomorphs include:

[w] 1 muskrat;

[x] 1 groundhog;

[y] 1 groundhog;

[z] 1 squirrel;

[aa] 5 groundhogs;

[bb] 5 groundhogs, 1 rabbit;

[cc] 1 groundhog;

[dd] 1 groundhog;

[ee] 1 groundhog;

[ff] 5 groundhogs;

[gg] 5 groundhogs;

[hh] 4 groundhogs;

[ii] 1 groundhog.

Table 2

Species of bats submitted for rabies testing in the United States during 2010.

Species (common name)	No. tested	No. positive	Percentage positive
Unspeciated	13,342	648	4.9
Eptesicus fuscus (big brown bat)	8,568	324	3.8
Myotis lucifigus (little brown bat)	911	26	2.9
Tadarida brasiliensis (Mexican free-tailed bat)	437	286	65.4
Lasionycteris noctivagans (silver-haired bat)	208	14	6.7
Lasiurus borealis (red bat)	170	40	23.5
Myotis spp (not further speciated)	107	9	8.4
Nycticeius humeralis (evening bat)	105	5	4.8
Lasiurus intermedius (northern yellow bat)	85	16	18.8
Parastrellus hesperus (canyon bat)	65	14	21.5
Lasiurus cinereus (hoary bat)	48	16	33.3
Myotis evotis (long-eared myotis)	41	6	14.6
Myotis californicus (California myotis)	40	0	0.0
Antrozous pallidus (desert pallid bat)	29	2	6.9
Lasiurus seminolus (seminole bat)	20	6	30.0
Perimyotis subflavus (tri-colored bat)	20	5	25.0
Myotis yumanensis (Yuma myotis)	17	1	5.9
Myotis septentrionalis (northern long-eared myotis)	15	0	0.0
Myotis ciliolabrum (western small-footed myotis)	11	0	0.0
Myotis austroriparius (southeastern myotis)	9	1	11.1
Plecotus townsendii (Townsend's big-eared bat)	8	0	0.0
Nyctinomops macrotis (big free-tailed bat)	7	4	57.1
Lasiurus ega (southern yellow bat)	6	2	33.3
Leptonycteris yerbabuenae (lesser long-nosed bat)	6	0	0.0
Myotis volans (long-legged myotis)	6	1	16.7
Lasiurus blossevillii (western red bat)	5	0	0.0
Lasiurus xanthinus (western yellow bat)	3	3	100.0
Myotis thysanodes (fringed myotis)	2	1	50.0
Pteropus giganteus (Indian flying fox) *	2	0	0.0
Rousettus aegyptiacus (Egyptian rousette) *	2	0	0.0
Choeronycteris mexicana (Mexican long-tongued bat)	1	0	0.0
Eumops perotis (western mastiff bat)	1	0	0.0
Myotis leibii (eastern small-footed myotis)	1	0	0.0
Total	**24,298**	**1,430**	**5.9**

* Exotic species submitted by zoos.

Table 3

Cases of rabies in humans in the United States and Puerto Rico, 2001 through June 2011, by circumstances of exposure and rabies virus variant.

Date of onset	Date of death	Reporting state	Age (y)	Sex	Exposure history*	Rabies virus variant†
19 Jan 01	4 Feb 2001	CA	72	M	Unknown-Phillipines	Dog, Phillipines
18 Mar 02	31 Mar 2002	CA	28	M	Unknown	Bat, Tb
21 Aug 02	31 Aug 2002	TN	13	M	Contact	Bat, Ps
14 Sep 02	28 Sep 2002	IA	20	M	Unknown	Bat, Ln/Ps
10 Feb 03	10 Mar 2003	VA	25	M	Unknown	Raccoon, eastern United States
28 May 03	5 Jun 2003	PR	64	M	Bite-Puerto Rico	Dog/mongoose, Puerto Rico
23 Aug 03	14 Sep 2003	CA	66	M	Bite	Bat, Ln
9 Feb 04	15 Feb 2004	FL	41	M	Bite-Haiti	Dog, Haiti
27 Apr 04	3 May 2004	AR	20	M	Bite (organ donor)	Bat, Tb
25 May 04	31 May 2004	OK	53	M	Liver transplant	Bat, Tb
29 May 04	9 Jun 2004	TX	50	F	Kidney transplant	Bat, Tb
2 Jun 04	10 Jun 2004	TX	55	F	Arterial transplant	Bat, Tb
27 May 04	21 Jun 2004	TX	18	M	Kidney transplant	Bat, Tb
12 Oct 04	Survived	WI	15	F	Bite	Bat, unknown
19 Oct 04	26 Oct 2004	CA	22	M	Unknown-El Salvador	Dog, El Salvador
27 Sep 05	27 Sep 2005	MS	10	M	Contact	Bat, unknown
4 May 06	12 May 2006	TX	16	M	Contact	Bat, Tb
30 Sep 06	2 Nov 2006	IN	10	F	Bite	Bat, Ln
15 Nov 06	14 Dec 2006	CA	11	M	Bite-Philippines	Dog, Philippines
19 Sep 07	20 Oct 2007	MN	46	M	Bite	Bat, unknown
16 Mar 08	18 Mar 2008	CA	16	M	Bite-Mexico	Fox, Tb related
19 Nov 08	30 Nov 2008	MO	55	M	Bite	Bat, Ln
25 Feb 09	Survived	TX	17	F	Contact	Bat, unknown
5 Oct 09	20 Oct 2009	IN	43	M	Unknown	Bat, Ps
23 Oct 09	20 Nov 2009	VA	42	M	Contact-India	Dog, India
20 Oct 09	11 Nov 2009	MI	55	M	Contact	Bat, Ln
2 Aug 10	21 Aug 2010	LA	19	M	Bite-Mexico	Bat, Dr
24 Dec 10	10 Jan 2011	WI	70	M	Unknown	Bat, Ps

J Am Vet Med Assoc. Author manuscript; available in PMC 2016 November 23.

Date of onset	Date of death	Reporting state	Age (y)	Sex	Exposure history*	Rabies virus variant†
30 Apr 11	Survived	CA	8	F	Unknown	Unknown

*Data for exposure history are reported 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). Exposure histories are categorized as bite, contact (eg, waking to find bat on exposed skin) but no known bite acknowledged, or unknown (ie, no known contact with an animal was elicited during case investigation).

†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.

Ln = *Lasionycteris noctivagans*. Ps = *Perimyotis subfavus*. Tb = *Tadarida brasiliensis*. Dr = *Desmodus rotundus*.

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