

## Public Veterinary Medicine: Public Health

### Rabies surveillance in the United States during 2001

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**Summary:** During 2001, 49 states and Puerto Rico reported 7,437 cases of rabies in nonhuman animals and 1 case in a human being to the Centers for Disease Control and Prevention, an increase of < 1% from 7,364 cases in nonhuman animals and 5 human cases reported in 2000. More than 93% (6,939 cases) were in wild animals, whereas 6.7% (497 cases) were in domestic species (compared with 93.0% in wild animals and 6.9% in domestic species in 2000). The number of cases reported in 2001 increased among bats, cats, skunks, rodents/lagomorphs, and swine and decreased among dogs, cattle, foxes, horses/mules, raccoons, and sheep/goats. The relative contributions of the major groups of animals were as follows: raccoons (37.2%; 2,767 cases), skunks (30.7%; 2,282), bats (17.2%; 1,281), foxes (5.9%; 437), cats (3.6%; 270), dogs (1.2%; 89), and cattle (1.1%; 82). Nine of the 19 states where the raccoon-associated variant of the rabies virus has been enzootic reported decreases in the numbers of rabid raccoons during 2001.

Among states with extensive wildlife rabies control programs, Ohio reported (other than rabies in bats) 1 case of rabies in a raccoon that was associated with the epizootic of rabies in raccoons and 1 case in a bovid that was infected with a bat variant of the rabies virus, compared with no cases reported in any terrestrial animals during 2000. Texas reported 1 case associated with the dog/coyote variant of the rabies virus (compared with no cases in 2000) and 20 cases associated with the gray fox variant of the virus (a decrease of 50% from reported cases in 2000). Reports of rabid skunks in Massachusetts and Rhode Island, states with enzootic raccoon rabies, exceeded reports of rabid raccoons for the fifth consecutive year. A similar situation may soon exist in the state of Maine (32 rabid skunks and 34 rabid raccoons during 2001).

Nationally, the number of rabies cases in skunks during 2001 increased by 2.7% over those reported in 2000. Texas reported the greatest number of rabid skunks ever documented during a single year by any state, as well as the greatest numerical increase in rabid skunks (778 cases in 2001, compared with 550 in 2000; an increase of 228 cases, or 41.5%) and the largest overall state total of rabies cases (1,043) during 2001. Arizona reported the greatest percentage increase in rabid skunks (247.1%), representing an increase from 17 rabid skunks in 2000 to 59 in 2001. Nineteen of these cases were infected with a bat variant of the rabies virus, documenting a spillover event followed by unprecedented detection of temporal enzootic transmission of a bat variant in a terrestrial species. The number of cases of rabies reported in bats during 2001 (1,281 cases) increased 3.3% and surpassed the previous year's record (1,240 cases) as the largest number of reported cases ever recorded for this group of mammals. Cases of rabies reported in dogs (89) and cattle (82) decreased by 21.9 and 1.2%, respectively; these are the lowest numbers reported for rabid cattle and dogs since the dawn of national rabies record keeping (ca 1938). Cases in cats (270) increased by 8.4% over those reported in 2000, whereas rabies among sheep and goats declined 70%, from 10 cases in 2000 to 3 cases (goats only) in 2001. Rabies among horses and mules declined 1.9% (52 cases in 2000 to 51 cases in 2001). Reported cases of rabies in mongooses in Puerto Rico increased 18.6%, compared with the previous year (70 cases in 2001 from 59 cases in 2000), whereas cases of rabies in dogs

declined 15.3% (15 to 13). One case of rabies in a human being reported by California during 2001 was the result of infection with a canine variant of the rabies virus acquired outside the United States.

Rabies in the United States and other developed nations is primarily a disease that affects and is maintained by wildlife populations. During 2001, wild animals accounted for more than 93% of all cases of rabies reported to the Centers for Disease Control and Prevention (CDC). Although the wildlife species most frequently reported rabid remain raccoons, skunks, bats, and foxes, the relative contributions of those species have continued to change in recent decades because of fluctuations in epizootics of rabies among animals infected with several distinct variants of the rabies virus.<sup>1</sup>

Vaccination campaigns and other rabies-control programs implemented during the 1940s and 1950s caused a substantial decline of rabies in domestic animals in the United States and all but eliminated the circulation of canine variants of the rabies virus in dogs (*Canis lupus*, formerly known as *C. familiaris*) by the 1960s. Programs initiated to interrupt transmission of a canine variant that re-emerged in south Texas during the late 1970s and early 1980s have substantially reduced the spread of this variant, maintained in unvaccinated dogs and coyotes (*Canis latrans*), as well as a second canine variant found mainly in gray foxes (*Urocyon cinereoargenteus*) in west and central Texas. Regulations now in place in Texas and other states that prohibit translocation of certain wild animal species for hunting and other restocking purposes have substantially reduced the likelihood of accidental introductions of rabies virus variants into unaffected areas.<sup>1-3</sup>

Various public health activities have contributed to reduced transmission of rabies virus from terrestrial animals to human beings. These activities have included vaccination of domestic animals, vaccination programs targeting wildlife, and ongoing education programs.<sup>4</sup> However, a small but increasing number of rabies cases in human beings have resulted from infection with variants of the rabies virus associated with bats,<sup>5,6</sup> a wildlife group difficult to target for rabies control by conventional methods. Prevention of rabies resulting from infection with bat-associated variants is further challenged by the frequent absence of exposure histories involving a bat bite. Since 1990, 24 of 26 human cases of indigenously acquired rabies were associated, by genetic analysis, with variants of the rabies virus maintained by bats. Only 2 of these cases involved a report of a definite history of animal bite.<sup>2,5,6</sup> The most likely route of infection remains transmission by bite during contact with a bat that either was ignored or unnoticed and subsequently forgotten.

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

Variants of the rabies virus can be identified by reaction with panels of monoclonal antibodies<sup>7</sup> or by patterns of nucleotide substitution determined by genetic analysis.<sup>1,8</sup> The spatial boundaries of enzootic rabies in a reservoir species are temporally dynamic. Affected areas usually expand gradually through transmission of the virus into previously uninfected populations.<sup>9,10</sup> Natural barriers such as mountain ranges or bodies of water that restrict animal movements or result in low population densities can slow the spread of rabies. Nevertheless, unusual animal dispersal patterns and human-mediated translocation of infected animals have resulted in more rapid and unexpected introduction of rabies into new areas.<sup>1-3,8-10</sup> Raccoons (*Procyon lotor*) have been recognized as a reservoir for rabies in the southeastern states since the 1950s. An outbreak that began during the late 1970s in the mid-Atlantic states was attributed to the translocation by humans of infected raccoons from the Southeast.<sup>11</sup> Although previously identifiable as separate foci (prior to 1994), the mid-Atlantic and southeastern foci have merged, and raccoon rabies is

now enzootic in all of the eastern coastal states as well as Alabama, Pennsylvania, Vermont, West Virginia, and possibly Ohio.

At least 3 variants of rabies virus are responsible for disease in skunks (primarily *Mephitis mephitis*) in California and the north central and south central states. A long-standing reservoir for rabies virus exists in red and arctic foxes (*Vulpes vulpes* and *Alopex lagopus*, respectively) in Alaska. Rabies spread during the 1950s to affect foxes across Canada and, intermittently, foxes in adjoining areas of the New England states. Rabies persists in foxes in Alaska, although reports of rabid foxes have declined in Canada. Two variants of rabies virus are present in geographically limited populations of gray foxes (*U. cinereoargenteus*) in Arizona and Texas. Enzootic rabies among canids in southern Texas is the result of long-standing interaction between unvaccinated domestic dogs and coyotes at the Texas-Mexico border.<sup>12</sup>

The use of long-term, widespread population-reduction programs to control rabies among wild terrestrial carnivores is not desirable nor has such an undertaking been successful in North America or elsewhere. Programs in Europe and southeastern Canada have instead used modified-live or recombinant virus vaccines for oral immunization of free-ranging wildlife reservoir species to control the disease. During the past 2 decades, more than 100 million doses of vaccine-laden bait have been distributed over 6 million square kilometers in Europe,<sup>13</sup> with promising results for controlling the disease in red foxes. The use of oral vaccination in Switzerland during the past 20 years resulted in a declaration of rabies-free status in 1998, and a similar declaration was made by France as of the end of 2000.<sup>14</sup> Substantial decreases of reported cases of rabies in fox populations in southern Ontario strongly support the observation that variants of the rabies virus associated with red foxes may be eliminated by vaccination. Distribution of an oral vaccinia-rabies glycoprotein (V-RG) recombinant vaccine targeting raccoons in the eastern United States<sup>15-17</sup> and gray foxes and coyotes in Texas<sup>18</sup> has shown promise as a complement to traditional rabies-control methods. However, products used in oral vaccination programs are self-replicating, and the unintentional exposure of nontarget species, including human beings, must be minimized and monitored.<sup>19,20</sup>

Overlaying the patterns of rabies virus maintenance among terrestrial mammals are multiple independent reservoirs for rabies virus in several species of insectivorous bats. Rabies virus transmission among bats appears to be primarily intraspecific, and distinct virus variants can be identified for 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 as the geographic ranges of the implicated host bat species. Because bat species known to be reservoirs for rabies virus are found in all areas of the continental United States, every state except Hawaii is considered enzootic for rabies. Although transmission of rabies virus from bats to terrestrial mammals occurs, there is no evidence that such spillover transmission results in frequent, sustained, independent, intraspecific cycles among terrestrial animals. Genetic analysis indicates net differences of 15 to 20% between rabies virus RNA sequences in bats, compared with those in terrestrial mammals. Thus, instances of spillover transmission of rabies virus from bats are readily detectable, as would be sustained transmission of a bat-associated variant in a terrestrial mammal population.

This report is prepared annually to inform veterinarians and public health officials of the current status of rabies in the United States. Information is provided on the geographic distribution of rabies and long- and short-term temporal patterns for reported cases of rabies in various species. Long-term trends for reported cases of rabies in animals in the United States are generated by examining reports starting in 1955. Short-term trends are determined by comparing reported cases from 2001 with those from 2000 and by examining seasonal patterns for selected species.

Summaries of 2001 surveillance data are provided for Canada and Mexico because of common borders and frequent travel between the United States and these countries. A brief update on cases of rabies and other related activities reported to CDC during 2002 is also included.

## Collection of Data

Data collection procedures were similar to those described previously.<sup>2</sup> Between Jan 1 and Dec 31, 2001, all 50 states, New York City, and Puerto Rico reported the number of cases of rabies in animals to CDC. States submitted data monthly on the number of cases by county of origin and type of animal. States report most terrestrial mammals by using the common names of these animals (usually identifiable to the taxonomic level of genus and often to the level of species); however, bats are frequently reported only to the taxonomic level of order (ie, *Chiroptera* = bats). Several states reported data by using the Public Health Laboratory Information System or the Laboratory Information Tracking System.<sup>21,22</sup> All year-end totals were confirmed by telephone verification with state or territorial health department officials. Data from Canada were obtained from Dr. Carolyn Inch, Animal Health and Production Division, Canadian Food Inspection Agency, and data from Mexico were obtained from Dr. Oscar Velazquez Monroy, Director General del Centro de Vigilancia Epidemiologica, Secretaria de Salud, Mexico.

Diagnoses in animals suspected of having rabies were made by direct immunofluorescent antibody staining of rabies viral antigen in brain material submitted to the state or local health departments. Virus isolation in neuroblastoma cell cultures of mice and nucleic acid detection via reverse transcriptase - polymerase chain reaction (RT-PCR) assays were used to confirm some cases.

## Rabies in Wild Animals

Wild animals accounted for more than 93% of the 7,437 reported cases of rabies in 2001. The 6,939 cases reported among wildlife in 2001 represented a 1.2% increase over the 6,855 cases reported in 2000. Raccoons continued to be the most frequently reported rabid wildlife species (37.2% of all animal cases during 2001), followed by skunks (30.7%), bats (17.2%), foxes (5.9%), and other wild animals, including rodents and lagomorphs (2.3%). Numbers of reported cases in bats and skunks increased 3.3 and 2.7%, respectively, over 2000 totals, whereas cases in raccoons and foxes decreased 0.4 and 3.5%, respectively.

**Raccoons** - The 2,767 cases of rabies in raccoons (*P. lotor*) reported in 2001 marked the fifth consecutive year of decreased numbers in this species. Decreases in numbers of rabid raccoons during 2001 were reported by 9 of the 19 eastern states in which raccoon rabies has been enzootic, including Alabama (57.7% decrease; 52 cases in 2000 to 22 in 2001), Connecticut (10.1%; 149 to 134), Delaware (21.2%; 33 to 26), Georgia (0.4%; 229 to 228), Maine (53.4%; 73 to 34), New Jersey (9.8%; 132 to 119), North Carolina (0.5%; 388 to 386), South Carolina (27.3%; 110 to 80), and Virginia (12.2%; 328 to 288)<sup>2,8-11,15,23</sup>. Ten states with enzootic raccoon rabies reported increases in numbers of rabid raccoons, including Florida (35.4% increase), Maryland (16.9%), Massachusetts (7.9%), New Hampshire (33.3%), New York (1.2%), Ohio (no cases in 2000 to 1 case in 2001), Pennsylvania (5.6%), Rhode Island (175%), Vermont (11.1%), and West Virginia (24.7%) as well as New York City (222%).

The states of the northeastern/mid-Atlantic focus of the epizootic, consisting of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, the District of Columbia, and New York City, accounted for 69.1% (1,912 cases) of the total rabies cases in raccoons in 2001, whereas the southeastern states of Alabama, Florida, Georgia, North Carolina, and South Carolina reported 30.6% (846 cases) of the total cases in raccoons.

Ohio reported a single case of rabies in a raccoon infected with the raccoon variant of the rabies virus. Rabid raccoons reported by Texas (9 cases) were the result of apparent spillover infection with variants of the rabies virus other than that associated with raccoons (usually the gray fox variant or the south central skunk variant). During 2001, with the exception of the rabid raccoon reported by Ohio, states west of the Ohio River in the North and west of the Appalachian Mountains in the South did not report any cases of rabies thought to be associated with the variant of the rabies virus that is epizootic in raccoons during 2001.

**Skunks** - The 2,282 cases of rabies in skunks (mainly *M mephitis*) in 2001 reported by 36 states represented a 2.7% increase over those reported in 2000. Thirteen states reported increases in numbers of rabid skunks. Texas reported the greatest number of rabid skunks ever reported during a single year by any state and the greatest numerical increase in rabid skunks (778 cases in 2001, compared with 550 in 2000; an increase of 228 cases or 41.5%). Arizona reported the largest percentage increase (247.1%; 59 cases in 2001, compared with 17 cases in 2000) in the number of rabid skunks. Louisiana (150%; 2 cases in 2000 to 5 cases) was the only other state that reported an increase of > 100% in 2001. Alabama reported 1 case of rabies in a skunk in 2001, but none in 2000. Twenty-one states and New York City reported decreases in numbers of rabid skunks in 2001. Delaware (72.7%; 11 cases to 3 cases), Minnesota (60.7%; 61 to 24), Montana (54.1%; 37 to 17), New Mexico (77.8%; 9 to 2), North Dakota (64.9%; 77 to 27), and Wyoming (51.8%; 56 to 27) reported decreases of > 50%, compared with cases reported in 2000. Florida (1 case) and Michigan (2) reported rabid skunks in 2000, but not in 2001. States where the raccoon-associated variant of the rabies virus is enzootic reported 38.2% (872/2,282) of the cases of rabies in skunks, the majority of which were presumably the result of spillover transmission of virus from raccoons. Massachusetts (132 cases) and Rhode Island (39 cases) each reported more rabid skunks than rabid raccoons for the fifth consecutive year.

**Bats** - Rabies in bats accounted for 17.2% of all cases of rabies in animals reported in 2001. The 1,281 cases were the largest number ever reported and represented a 3.3% increase over the total reported in 2000. Rabies in bats is widely distributed throughout the United States, with cases reported from 47 of the 48 contiguous states. During 2001, Texas reported the largest number of cases (194), followed by California (166) and New York (113 [includes 4 cases reported by New York City]). Nine states (Colorado, Idaho, Illinois, Indiana, Mississippi, Nevada, Oregon, Utah, and Washington) reported rabies in bats, but not in terrestrial mammals. Alaska, Hawaii, North Dakota, and Puerto Rico did not report any cases of rabies in bats.

Of the bats positive for rabies virus, 58.1% (744/1,281) were identified beyond the taxonomic level of order (22 to genus, 722 to species). Among bats identified to species level, 47.1% (340/722) were *Eptesicus fuscus*, the big brown bat; 28.3% (204/722) were *Tadarida brasiliensis*, the Brazilian (Mexican) free-tailed bat; 5.5% (40/722) were *Lasiurus cinereus*, the hoary bat; 4.3% (31/722) were *L borealis*, the red bat; 3.7% (27/722) were *Myotis lucifugus*, the little brown bat; 3.0% (22/722) were *Lasionycteris noctivagans*, the silver-haired bat; 1.7% (12/722) were *Myumanenis*, the Yuma bat; 1.7% (12/722) were *Pipistrellus hesperus*, the western pipistrelle; and 1.2% (9/722) were *P subflavus*, the eastern pipistrelle. Unspecified bats of the genus *Myotis* (3.0% [22/744]) and 11 other species (contributing < 3.5% [25/722] to the total, with no individual species in this latter group contributing > 1.0%) accounted for the remaining rabid bats. Not all states were able to speciate bats, nor did all states report total numbers of bats tested for rabies.

**Foxes** - Foxes (mainly *V vulpes*) accounted for 5.9% of all cases of rabies in animals reported in 2001. The majority of cases of rabies in foxes (360/437) were reported by states affected by the raccoon-associated variant of the rabies virus. Alaska (45 cases), Maryland (38), and North Carolina (56) reported increases of 13, 10, and 12 cases, respectively, over 2000. Arizona (6 cases), New York (36), Virginia (34), and Texas (15) reported decreases of 9, 9, 16, and 26 cases, respectively. Most cases of rabies in foxes reported by eastern states were probably caused by the rabies virus variant associated with raccoons, with the possible exception of Maine, New York, and Vermont. Rabies in gray foxes in Arizona and Texas is usually the result of infection with gray fox variants unique to independent gray fox reservoirs in each of those states, as determined by antigen typing and genetic analysis. Iowa (1 case), Missouri (1), Vermont (4), and Wyoming (1) reported rabid foxes in 2001 but did not report rabid foxes in 2000, whereas New Hampshire and Oregon reported rabid foxes in 2000, but reported none in 2001.

**Other wild animals** - Puerto Rico reported 70 rabid mongooses (*Herpestes auropunctatus*) during 2001, an 18.6% increase over those reported in 2000. Other wildlife in which rabies was reported included 49 groundhogs (*Marmota monax*), 28 bobcats (*Lynx rufus*), 7 coyotes (*C. latrans*), 5 otters (*Lontra canadensis*), 5 rabbits (*Oryctolagus cuniculus*), 3 beavers (*Castor canadensis*), 2 badgers (*Taxidea taxus*), 2

opossums (*Didelphis virginiana*), 1 chipmunk (*Tamias striatus*), 1 deer (*Odocoileus virginianus*), and 1 ringtail (*Bassariscus astutus*). All cases of rabies in rodents and lagomorphs (primarily groundhogs; 47/56 cases) were reported by states in which rabies is epizootic in raccoons.<sup>24</sup> No cases of rabies in coyotes were associated with enzootic transmission of the dog/coyote variant of the rabies virus in regions of southern Texas.

### **Rabies in Domestic Animals**

Domestic species accounted for 6.7% of all rabid animals reported in the United States in 2001. The number of domestic animals reported rabid in 2001 (497) represented a 2.4% decrease from the total reported in 2000. Cases of rabies reported in dogs and cattle decreased 21.9 and 1.2%, respectively, compared with totals reported in 2000, whereas reports of rabies in cats increased 8.4%. Numbers reported for dogs and cattle represent record lows for both species since the dawn of national rabies record keeping (ca 1938). Reported cases of rabies in cats were more than 3 times as numerous as those reported in dogs or cattle. Pennsylvania reported the largest number of rabid domestic animals (46 cases; predominantly in cats), followed by New York (43, and 1 case reported by New York City) and Texas (41).

**Cats** - Two hundred fourteen of the 270 cases of rabies in cats were reported from states where the raccoon-associated variant of the rabies virus is present. Remaining cases were reported principally by Central Plains states, where most cases were presumably the result of spillover from rabid skunks, or from rabid foxes in Texas. Ten states reported > 10 cases of rabies in cats (Pennsylvania, 33; New York, 31 [and 1 in New York City]; Georgia, 26; Maryland, 23; Virginia, 20; New Jersey, 17; Florida, 16; North Carolina, 13; Texas, 13; and Kansas, 11). Nineteen states and the District of Columbia did not report any rabid cats.

**Dogs** - Texas (16 cases) and Puerto Rico (13 cases) reported the largest numbers of cases of rabies in dogs by individual states or territories in 2001. Texas reported 1 case of rabies in a dog that was associated with the dog/coyote variant of the rabies virus evident in south Texas. Georgia (6 cases) and North Carolina (6) were the only other states that reported > 5 cases of rabies in dogs in 2000. Twenty-four states, the District of Columbia, and New York City did not report any rabid dogs.

**Other domestic animals** - The number of cases of rabies in cattle decreased from 83 in 2000 to 82 in 2001, replacing the previous year's record-low number for cattle, and distribution mirrored that of rabid skunks in the central and midwestern states and raccoons in the mid-Atlantic/northeastern region. Iowa (10 cases), Kansas (7), South Dakota (7), and Texas (7) reported the largest numbers of rabid cattle. No other state reported > 6 cases of rabies in cattle. The 51 cases of rabies reported in horses, donkeys, and mules in 2001 represented a single-digit decline from the 52 cases reported during 2000. Other reported cases of rabies in domestic animals included 3 goats and 2 swine.

### **Seasonal Trends**

The frequency of reported cases of rabies in raccoons peaked in April, followed by a lesser peak in September and a December low. The frequency of reporting for rabid skunks peaked in March, followed by a decline into the summer months prior to a second broad but lower peak in October. Reports of rabid bats showed a sharp August peak. Though largely flat, the largest numbers of rabid foxes were reported from May to July, followed by a gradual decline to a low in November.

Reporting of rabies in cats was highest during the summer and, except for a slight decline in July, was remarkably consistent from May through September. Reports of rabies cases in dogs and cattle were highest during spring and fall, probably reflecting peak interaction with rabid wildlife species, but otherwise showed no clear patterns.

### **Rabies in Human Beings**

California reported a case of rabies in a 72-year-old male resident of San Diego County during 2001.<sup>2,a</sup> The case was discovered retrospectively via ongoing activities associated with that state's unexplained encephalitis surveillance program. The patient was admitted to an emergency room on Jan 24, 2001, with low-grade fever and several days of generalized weakness accompanying complaints that may have begun approximately 5 days earlier. During his 11-day hospitalization, the patient's status deteriorated to unexplained progressive encephalopathy, decreased mental status, flaccid paralysis, respiratory failure, coma, and eventually death on February 4. The California Viral and Rickettsial Disease Laboratory performed fluorescent antibody tests on sera that had been collected as indicated for the state's unexplained encephalitis surveillance program. Sera collected 4 days and 1 day prior to the patient's death were each positive for rabies antibodies. No brain specimens were available for testing. The CDC tested a throat swab from the patient by using RT-PCR and found it to be positive for rabies virus; the variant of the virus identified was consistent with those found in rabid Philippine dogs. The patient had moved from the Philippines to San Diego in 1997 and traveled back to the Philippines for a visit between Mar 11 and May 13, 2000. Family members reported no history of a recent known animal bite or significant animal exposure, although such a bite during his more recent visit or in the past was the most plausible explanation for the patient's infection.

### **Rabies in Canada and Mexico**

Canada reported 441 laboratory-confirmed and 4 clinically diagnosed cases of rabies in domestic and wild animals in 2001. This number represented a 33.6% decrease from the 670 cases reported in 2000. Most of the decrease was attributable to a substantial decline in numbers of reported cases of rabies in skunks in the provinces of Manitoba and Saskatchewan. Reported cases in skunks decreased by 69.1% (125 cases in 2001, compared with 404 cases in 2000) and accounted for 28.1% (125/445) of all rabid animals reported in 2001. Reported cases of rabies in raccoons increased 89.4% from 47 cases in 2000 to 89 cases in 2001, making raccoons the third most commonly reported rabid animal. Reported cases of rabies in raccoons in Canada have increased for the past 4 consecutive years. Reported cases of rabies in bats increased 43.1% (103 cases in 2001, compared with 72 cases in 2000) and accounted for 23.1% (103/445) of all reported cases of rabies. Other species that contributed substantially to the 2001 total included cattle (5.8%), foxes (14.2%), dogs (3.6%), and equids (2.3%). Canada did not report any cases of rabies in human beings during 2001.

Mexico reported 354 laboratory-confirmed cases of rabies in domestic and wild animals during 2001. This total represented a 36.8% decrease from the 560 cases reported in 2000. Dogs accounted for 33.1% (117/354) of reported cases of rabies, a decrease of 52% from 2000 (244 cases). The other reported rabid animals included 190 cattle, 11 skunks (several species), 7 equids, 7 sheep, 6 goats, 4 bats, 4 wild cats (presumably bobcats [*L. rufus*]), 3 foxes, 2 coyotes (*C. latrans*), 2 swine, and 1 puma (*Puma concolor*). Seven cases of rabies were reported in human beings, a 40% increase over 2000 (5 cases). Source animals implicated in the exposure of the human beings were reported as follows: bats, 2 cases; skunk, 2 cases; dog, 1 case; puma, 1 case; and 1 case for which no animal could be implicated.

### **Discussion**

States have different algorithms for submission of specimens for rabies testing, and levels of surveillance vary. The predominantly passive nature of rabies surveillance and lack of estimates of animal population sizes dictate that prevalence or incidence of rabies cannot be determined for most species. Many rabid animals are never observed and go untested and undetected.<sup>25</sup> Thus, reported cases of rabies provide only an index of the magnitude of the disease and do not indicate the extent of viral infection among wildlife or domestic animals of any region. Cases detailed in this report include only those cases of rabies that were laboratory confirmed and reported to CDC by state and territorial health departments.

The number of cases of rabies in raccoons declined for the fifth consecutive year. Although raccoons continued to account for the highest percentage (37.2%) of rabies cases reported among animals in the United States in 2001, this ratio was the lowest percentage contribution by this species since 1990. Enzootic transmission of rabies among raccoons was apparent in 19 states and the District of Columbia in 2001 (a single case of rabies in a raccoon infected with the raccoon variant of the rabies virus was reported by Ohio during 2001). States in the affected area reported 99.7% (2,758/2,767) of all documented cases of rabies in raccoons and accounted for 65.4% (4,867/7,437) of the total cases of rabies reported in the United States during 2001. Periodic increases in numbers of reported cases of rabies in states where the disease is enzootic among raccoons can occur when populations of raccoons, decimated by a previous epizootic, again reach densities sufficient to support transmission of rabies virus.<sup>9,10</sup>

The first field release of the V-RG vaccine in the United States began during 1990.<sup>26</sup> The V-RG vaccine was conditionally licensed in April 1995 and was fully licensed in April 1997. Vaccine distribution in each state remains limited to authorized state or federal rabies-control programs. Interventions using the V-RG vaccine distributed within baits to vaccinate wild raccoons to prevent or slow the dissemination of rabies continue in a number of states and are being undertaken by additional states. The efficacy of these programs remains under assessment in Florida (Pinellas County), eastern Massachusetts (Cape Cod),<sup>17</sup> Maryland, southern New Jersey (Cape May),<sup>16</sup> New York, Ohio, Pennsylvania, Vermont, Virginia, and West Virginia.

During 2001, multiple state agencies, the USDA, and CDC collaborated on a program to establish an “immune barrier,” using oral rabies vaccine (ORV) to span the distance from the shores of Lake Erie in Ohio, Pennsylvania, and New York to the Gulf of Mexico in Alabama. Ohio rebaited a 6-county area including 4 counties bordering Pennsylvania during the spring and expanded this area further to the south to include 3 additional counties during the fall ([www.odh.state.oh.us/ODHPrograms/ZOODIS/Rabies/Pubs/ORVHIS.PDF](http://www.odh.state.oh.us/ODHPrograms/ZOODIS/Rabies/Pubs/ORVHIS.PDF); accessed Oct 16, 2002).<sup>b</sup> Also during the fall of 2001, ORV baits were distributed over a 19-mile-wide corridor along the shore of Lake Erie in Pennsylvania from the Ohio border to the New York border, thereby expanding and interconnecting the existing ORV barriers in these 3 states. The ORV baits were also distributed in 22 West Virginia counties along a region of the Appalachian ridge thought to be ahead of the raccoon rabies enzootic as determined by active rabies surveillance. The sum of these ORV programs during 2001 formed the northern portion of a continuous immune corridor, augmented by geographic barriers (lakes, rivers, and mountains), extending from the shore of Lake Erie through the state of West Virginia. This “cordone sanitaire” will be extended further south and moved eastward over time in an attempt to reduce the area of enzootic rabies in raccoons. Concerns regarding vaccine safety, efficacy, ecologic impact, and physical bait variables, which were raised during earlier trials, continue to be assessed.<sup>19,20,27-29</sup>

Although the total number of rabid skunks reported in 2001 was 2.7% greater than that reported in 2000, only 13 states reported increases, compared with 21 that reported decreases (4 reported no change). Only Arizona and Louisiana reported increases of > 100%, and approximately half of the increase reported by Arizona was the result of active surveillance that resulted from the discovery of a skunk found to be infected with a bat variant of the rabies virus. Nineteen rabid skunks in the Flagstaff area were infected with a bat variant of the rabies virus, documenting a rare spillover event followed by the unprecedented discovery of temporal enzootic transmission of a bat variant in a terrestrial species. Other than Arizona (up 42 cases), only California (up 53 cases) and Texas (up 228 cases) reported numerical increases of any great consequence. Only 4 of the remaining 10 states reported increases of more than 5 rabid skunks over those reported in 2000. Michigan, a state that reported an increase of 950% in rabid skunks (probably because of active surveillance) in 1999, did not report any cases of rabies in skunks during 2001.

Rabid skunks outnumbered reported rabid raccoons in Massachusetts (132 cases in skunks, compared with 82 in raccoons) and Rhode Island (39 cases in skunks, compared with 22 cases in raccoons) for the fifth consecutive year. This trend further fueled concerns that skunks may be involved in enzootic transmission of the raccoon variant of the rabies virus. Analyses comparing data from these states and data from other

states where rabies in raccoons is enzootic have thus far failed to demonstrate evidence of adaptation of the raccoon variant of the rabies virus to maintenance by and circulation in regional skunk populations.<sup>c</sup>

Cases of rabies in foxes decreased 3.5%. Because of control of rabies resulting from the red fox variant of the rabies virus in Canada and New England, most cases of rabies in foxes reported by eastern states were probably caused by the rabies virus variant associated with raccoons. Rabies in gray foxes in Arizona and Texas is usually the result of infection with gray fox variants found in each of those states; however, Texas has had considerable success in reducing infections resulting from the Texas gray fox variant of the rabies virus via the use of an ORV in baits targeted at gray foxes.<sup>d</sup> Thirteen states reported decreases in cases of rabies in foxes; Texas (41 cases in 2000 to 15 in 2001; -63.4%) and Virginia (50 cases to 34; -32%) reported decreases of more than 9 cases. In contrast, 15 states reported increases in numbers of rabid foxes, although increases were usually small. Alaska, Maryland, and North Carolina reported increases of 13, 10, and 12 cases, respectively; only New Jersey (2 cases in 2000 to 5 in 2001) reported an increase of > 100%.

The occurrence of rabies in various species of bats fluctuates by geographic region. The continued and increasing association of bat rabies virus variants with human rabies infections in the United States during recent years has brought increased publicity and changes in public health recommendations proposed when rabies exposures involving bats may have occurred.<sup>30,31</sup> Rabies among rodents and lagomorphs reflects spillover infection, predominantly from regional terrestrial reservoir species. Reported cases among rodents occur primarily in groundhogs in areas of the country affected by the raccoon-associated variant of the rabies virus.<sup>24</sup> Rabies is occasionally reported in other large members of this group such as beavers.<sup>32</sup> Large species of rodents and lagomorphs, or those kept in outdoor cages, may become infected and survive long enough to pose a risk to other species. Rabies is seldom reported in smaller rodents, presumably because of the high degree of mortality and severe trauma that usually result from an attack by a rabid carnivore; however, Maryland reported a case of rabies in a chipmunk (*T striatus*) in 2001. There has been no documentation of rabies transmission from a rodent to a human being.

Additional distributions of ORV (1.67 million baits delivered over > 26,000 square miles) were completed during 2001 in Texas to interrupt the transmission of rabies virus in gray foxes and in dogs and coyotes.<sup>18,33,34,d</sup> Translocations of animals infected with canid variants of the rabies virus found in Texas have been documented.<sup>2,3</sup> These events involved infected animals placed in outdoor enclosures prior to release at the intended location. Rapid responses to these events may have prevented establishment and spread of the involved variants.

Rabies in domestic animals decreased 2.4% in 2001. Reported cases of rabies in dogs (89 cases) and cattle (82) decreased by 21.9% and 1.2%, respectively; both of these are record-low numbers. Cases of rabies in cats (270) increased by 8.4% over those reported in 2000, whereas rabies among sheep and goats declined 70%, from 10 cases in 2000 to 3 cases (representing goats only) in 2001. Numbers of cases of rabies in horses/mules reported in 2001 declined 1.9% from 52 cases in 2000 to 51 cases in 2001. Cases of rabies were distributed among 25 states and Puerto Rico. Only Puerto Rico (6 cases) and Texas (5 cases) reported more than 4 cases of rabies in horses. Continued low numbers of reported cases of rabies in dogs and cattle attest to the effectiveness of a public health strategy aimed at preventing rabies in domestic animals through spillover from infected wildlife. Vaccination remains a crucial element in this effort.

In 1999, a study was undertaken to evaluate the epidemiologic features of variants of the rabies virus responsible for cases of rabies reported in cats and dogs and to assess what contribution, if any, was the result of bat-associated variants of the rabies virus.<sup>35</sup> Nearly all animals (229 cats and 78 dogs) were infected via spillover with the predicted terrestrial variant of the rabies virus, ie, the variant maintained by and circulated in the dominant terrestrial reservoir species in the geographic location where the infection occurred. A single cat from Maryland was found to be infected with a bat-associated variant of the rabies virus. This important study lends support to earlier hypotheses based mainly on small local samples and presumption.

Vaccination of pet animals and livestock that have regular contact with human beings provides a barrier to protect human beings from infection with rabies. This fact cannot be overemphasized. A single incident involving a case of rabies in a companion species can result in large expenditures in dollars and public health efforts to ensure that human disease does not occur.<sup>36-38</sup> 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 in rabies-epizootic areas should be considered.<sup>30</sup>

With the report of 1 human rabies case in 2001, the total number of cases of rabies diagnosed in human beings in the United States since 1990 increased to 33. Seven of these 33 (21.2%) individuals were infected outside the United States. Human rabies cases that are the result of infections abroad usually occur in developing nations where rabies in dogs is enzootic, involve regional canine variants of the rabies virus, and have a history of dog bite (5/7). Twenty-six of the 33 (78.8%) individuals were infected with variants of the rabies virus indigenous to the United States. Monoclonal antibody analysis and genetic sequencing indicated that 24 of these 26 (92.3%) persons were infected with variants of the rabies virus associated with bats.<sup>5,6</sup> The prevention of infection of human beings with rabies virus from bats, although a rare occurrence, remains an important public health concern.<sup>31</sup>

Rabies in bats is epidemiologically distinct from terrestrial rabies maintained by carnivores. Understanding of the circulation of variants of the rabies virus in bat species remains less well developed than that in carnivores. Successful control of terrestrial rabies in the United States through the use of oral vaccines, as has been accomplished in Europe<sup>13,39</sup> and southeastern Canada,<sup>40</sup> will have no effect on enzootic rabies in bats and the associated risk of human disease.

## **2002 Rabies Update**

During the first 9 months of 2002, no cases of rabies were reported that were attributable to infection with the raccoon variant of the rabies virus in Ohio. Ohio rabies-control programs distribute V-RG baits on the basis of data gathered via active surveillance programs implemented in affected areas and a statewide passive surveillance system. The single case of raccoon rabies reported by Ohio in 2001 near the Pennsylvania border serves as a reminder that immune corridors will not remain so without continued surveillance, as well as cooperation and participation with neighboring states. In Ohio, > 638,000 additional doses of ORV baits were distributed during the late summer-fall of 2002 over a total of > 3,200 square miles in 9 eastern Ohio counties ([www.odh.state.oh.us/ODHPrograms/ZOODIS/Rabies/Pubs/ORVHIS.PDF](http://www.odh.state.oh.us/ODHPrograms/ZOODIS/Rabies/Pubs/ORVHIS.PDF); accessed Oct 16, 2002).<sup>b</sup> Bait distribution continues along the front of the raccoon rabies epizootic, extending from the shore of Lake Erie in the north, southwest across West Virginia, through westernmost Virginia, and currently terminating in the eastern corner of Tennessee (see map at [www.aphis.usda.gov/mpls/contracts/solicitations/6stateswibarriers.PDF](http://www.aphis.usda.gov/mpls/contracts/solicitations/6stateswibarriers.PDF); accessed Oct 16, 2002). Rabid raccoons have been reported in several counties in northern Georgia, very close to the Tennessee border. Thus, raccoon rabies may soon be detected in Kentucky and Tennessee. The risk for introduction of the raccoon-associated variant of the rabies virus into other midwestern states and into routinely terrestrial rabies-free Mississippi remains a major concern.

In Texas, an additional 2.7 million doses of V-RG vaccine were distributed over > 33,000 square miles during 2002. During the first 9 months of 2002, no cases of rabies attributable to the dog/coyote variant of the rabies virus were reported in Texas. During this same period, 50 cases of rabies attributable to the variant of the rabies virus associated with gray foxes were reported in foxes and other species; however, no cases were reported outside of the original ORV treatment area. Since the programs were initiated in 1995, almost 17.45 million doses of V-RG vaccine have been distributed over > 255,400 square miles in Texas.<sup>d</sup> Canadian officials indicate that the area of Ontario affected by the epizootic of rabies in raccoons has stabilized and that ORV programs are at least partly responsible for this success. Reported cases of rabies associated with a second focus of the raccoon rabies epizootic in Canada that originated from the state of

Maine and entered Canada via New Brunswick have decreased in 2002 ([www.gis.queensu.ca/rreporter](http://www.gis.queensu.ca/rreporter); accessed Oct 16, 2002).

Three cases of rabies in human beings caused by bat variants of the rabies virus have been reported during 2002. California reported a case that was the result of infection with the Brazilian free-tailed (*T. brasiliensis*) virus variant, whereas Tennessee and Iowa each reported a case that resulted from infection with the variant of the rabies virus associated with silver-haired and eastern pipistrelle (*L. noctivagans* and *P. subflavus*) bats.<sup>6,41,42,c</sup>

On Mar 31, 2002, a 28-year-old man residing in Glenn County, Calif, died of rabies. The patient's family reported that he had killed a bat in his house earlier that month. An investigation revealed a bat colony in the attic of the man's house.<sup>41</sup>

On Aug 31, 2002, a 13-year-old boy residing in Franklin County, Tenn, died of rabies. The patient's parents reported that he had found a bat on the ground during the previous month and brought it home, prior to releasing it later in the nearby woods.<sup>42</sup>

On Sept 28, 2002, a 20-year-old man residing in Linn County, Iowa, died of rabies. County health officials tested several dogs with which the patient had contact, including one that bit him, but found no evidence of rabies in the tested animals.<sup>e</sup>

A history of bite was indicated for only 1 of these cases, and the involved dog tested negative for rabies virus. The patients either did not notice the actual events that exposed them to rabies or judged them as too insignificant to be of any consequence with regard to the possibility of causing rabies infection and forgot about them. Nonetheless, the most plausible explanation for the cause of these cases remains infection via bat bite. These latest cases bring the total number of cases of rabies diagnosed in human beings in the United States since 1990 to 36. Twenty-nine of these individuals were infected with variants of the rabies virus indigenous to the United States. Monoclonal antibody analysis and genetic sequencing indicated that 27 of these 29 (93%) persons were infected with variants of the rabies virus associated with bats.

<sup>a</sup>Sun B, California Department of Health Services, Sacramento, Calif: Personal communication, 2002.

<sup>b</sup>Smith KA, Krogwold R, Collart M, Ohio Department of Health, Columbus, Ohio: Personal communication, 2002.

<sup>c</sup>Guerra MA, Centers for Disease Control and Prevention, Atlanta, Ga: Personal communication, 2002.

<sup>d</sup>Wilson PJ, Texas Department of Health, Austin, Tex: Personal communication, 2002.

<sup>e</sup>Currier RW, Iowa Department of Public Health, Des Moines, Iowa: Personal communication, 2002.

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