Public Veterinary Medicine:
Public Health

Rabies surveillance in the United States during 2000

John W. Krebs, MS; Alison M. Mondul, BS; Charles E. Rupprecht, VMD, PhD; James E. Childs, ScD

Summary: During 2000, 49 states, the District of Columbia, and Puerto Rico reported 73,664 cases of rabies in nonhuman animals and 5 cases in human beings to the Centers for Disease Control and Prevention, an increase of 4.3% from 70,677 cases in nonhuman animals reported in 1999. Ninety-three percent (68,855 cases) were in wild animals, whereas 6.9% (509 cases) were in domestic species (compared with 91.5% in wild animals and 8.5% in domestic species in 1999). Compared with cases reported in 1999, the number of cases reported in 2000 increased among bats, dogs, foxes, skunks, and sheep/goats and decreased among cats, cattle, horses/mules, raccoons, and swine. The relative contributions of the major groups of animals were as follows: raccoons (37.7%; 2,778 cases), skunks (30.2%; 2,223), bats (16.8%; 1,240), foxes (6.2%; 453), cats (3.4%; 249), dogs (1.6%; 114), and cattle (1.1%; 83). Ten of the 19 states where the raccoon-associated variant of the rabies virus has been epizootically reported increased in the numbers of cases of rabies during 2000.

Among those states that have engaged in extensive wildlife rabies control programs, no cases of rabies associated with the epizootic of raccoons in raccoons (or in any other terrestrial species) were reported in Ohio, compared with 6 cases reported in 1999. No rabies cases associated with the dog/coyote variant (compared with 10 cases in 1999, including 5 in dog) were reported in Texas, and cases associated with the gray fox variant of the virus decreased (8 cases in 2000, including 38 among foxes). Reports of rabid skunks exceeded those of rabid raccoons in Massachusetts and Rhode Island, states with enzootic raccoon rabies, for the fourth consecutive year.

Nationally, the number of rabies cases in skunks increased by 7.1% from that reported in 1999. The greatest numerical increase in rabid skunks (550 cases in 2000, compared with 192 in 1999) was reported in Texas. The number of cases of rabies reported in bats (1,240) during 2000 increased 25.4% over the number reported during 1999 (989) and represented the greatest contribution (16.8% of the total number of rabid animals) ever recorded for this group of mammals. Cases of rabies reported in cattle (83) and cats (249) decreased by 38.5% and 10.4%, respectively, whereas cases in dogs (114) increased by 2.7% over those reported in 1999. Reported cases of rabies among horses and mules declined 20% from 65 cases in 1999 to 52 cases in 2000. Four indigenous confirmed cases of rabies in human beings were caused by variants of the raccoon virus associated with bats. One case of human rabies acquired outside the United States that resulted from a dog bite was caused by the canine variant of the rabies virus.

In the United States and other developed nations, rabies is primarily a disease that affects and is maintained by wildlife populations (Fig 1). During 2000, wild animals accounted for 93% (68,855) of all cases of rabies and reported to the Centers for Disease Control and Prevention (CDC). The relative contributions of those species most frequently reported rabid have continued to change in recent decades (Fig 2) because of fluctuations in epizootics of rabies among animals infected with several distinct variants of the rabies virus.1

Vaccination campaigns and control programs implemented in the United States during the 1940s and 1950s effectively controlled and all but eliminated the circulation of canine variants of the rabies virus in dogs (Canis familiaris) by the 1960s. Programs initiated to interrupt transmission of a canine variant that reemerged in south Texas during the late 1970s and early 1980s have been credited with reducing the spread of this variant, maintained in 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 in Texas and other states that prohibit translocation of certain wild animal species for hunting and other restocking purposes have reduced the likelihood of accidental introductions of rabies virus variants into unaffected areas.1,2

Various activities conducted by public health authorities have contributed to reduced transmission of rabies virus to human beings. These activities have included vaccination of domestic livestock and companion animals, vaccination programs targeting wildlife, and ongoing educational programs.3 Nonetheless, a small but increasing number of cases of rabies in human beings during the previous decade have resulted from infection with variants of the rabies virus that are associated with bats,3,4 a wildlife group difficult to target for rabies control by conventional methods. An additional challenge to the prevention of rabies from bat-associated variants is the frequent absence of exposure histories involving a bite. Since 1990, 24 of 26 human cases of indigenously acquired rabies were associated, by genetic analysis, with vari-
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 or by patterns of nucleotide substitution identified by genetic analysis. The spatial boundaries of enzootic rabies in a reservoir species are temporally dynamic (Fig 3). Affected areas usually expand gradually through transmission of virus into previously uninfected populations. 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 or human-mediated translocation of infected animals have resulted in more rapid and unexpected introduction of rabies into new areas.

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. Although previously identifiable as separate foci, 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, and West Virginia.

Three different 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, while reports of rabid foxes have declined in Canada. Two different 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.

The use of 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, with promising results for controlling the disease in...
This report was prepared 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 1935. Short-term trends are determined by comparing reported cases from 2000 with those from 1999 and by examining seasonal patterns for selected species.

Summaries of 2000 surveillance data are provided for Canada and Mexico because of common borders and frequent travel between the United States and these countries. A brief update on cases of rabies and other related activities reported to the CDC during 2001 is also included.

**Collection of Data**

Data collection procedures were similar to those described previously. Between Jan 1 and Dec 31, 2000, all 50 states, the District of Columbia, and Puerto Rico reported the number of cases of rabies in animals to the 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. Several states reported data by using the Public Health Laboratory Information System or the Laboratory Information System. All year-end totals were confirmed by telephone verification with state or territorial health department officials. 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 (DFA) 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 assays were used to confirm some cases.

**Rabies in Wild Animals**

Wild animals accounted for 93% of the 7,369 reported cases of rabies in 2000 (Fig 1). The 6,855 cases reported among wildlife in 2000 were a 4.3% increase over the 6,466 cases reported in 1999 (Table 1). Raccoons continued to be the most frequently reported rabid wildlife species (37.7% of all animal cases reported in 2000). The use of oral vaccination in Switzerland during the past 20 years resulted in a declaration of rabies-free status in 1998 and in France’s similar declaration as of the end of 2000. Substantial decreases of reported cases of rabies in fox populations in southern Ontario strongly supports 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 and gray foxes and coyotes in Texas 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.

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 viral 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 transmission results in 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.
cases during 2000), followed by skunks (30.2%), bats (16.8%), foxes (6.2%), and other wild animals including rodents and lagomorphs (2.2%). Numbers of reported cases in raccoons decreased 3.3%, whereas cases in bats, foxes, and skunks increased 25.4, 18, and 7.1%, respectively, over 1999 totals.
Raccoons—The 2,778 cases of rabies in raccoons (P lotor) reported in 2000 marked the fourth consecutive year of decreased numbers in this species (Fig 2 and 4). Decreases in numbers of rabid raccoons during 2000 were reported by 11 of the 19 eastern states in which raccoon rabies has been enzootic, including Alabama (35.8% decrease; 81 cases in 1999 to 52 in 2000), Delaware (15.4%; 39 to 33), Florida (23.8%; 126 to 96), Maine (37.1%; 116 to 73), Massachusetts (2.5%; 78 to 76), New Hampshire (66.7%; 18 to 6), New York (19.9%; 512 to 410), Rhode Island (77.1%; 35 to 8), Vermont (43.8%; 64 to 36), Virginia (7.3%; 354 to 328), and Ohio (5 cases in 1999), which did not report any cases of raccoon rabies in 2000 (Fig 4 and 5; Table 1). 2,8-10,14,22 Eight states with enzootic raccoon rabies reported increases in numbers of rabid raccoons, including Connecticut (< 1% increase), Georgia (33.2%), Maryland (< 1%), New Jersey (8.2%), North Carolina (27.6%), Pennsylvania (19.1%), South Carolina (23.6%), and West Virginia (2.7%), as well as the District of Columbia (20.0%) and New York City (12.5%).

The states of the northeastern/mid-Atlantic focus of the epizootic, consisting of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, New York City, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, the District of Columbia, and West Virginia, reported 68.1% (1,893 cases) of the total rabies cases in raccoons in 2000, whereas the southeastern states of Alabama, Florida, Georgia, North Carolina, and South Carolina reported 31.5% (875 cases) of the total cases in raccoons. Rabid raccoons reported by Iowa (1 case) and Texas (9) were the result of spillover infection with variants of the rabies virus other than that associated with raccoons (usually the north central skunk variant in Iowa and either the gray fox variant or the south central skunk variant in Texas). In 2000, 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 enzootic among raccoons.

Skunks—The 2,223 cases of rabies in skunks (mainly M mephitis) reported from 37 states in 2000 were a 7.1% increase over those reported in 1999 (Fig 6). Fifteen states reported increases in numbers of rabid skunks. Only Texas (186.5%; 192 cases in 1999 to 550 cases in 2000) reported an increase of > 100%. Florida (1 case), New Mexico (9), and New York City (9) reported cases in 2000 but not in 1999. Twenty-one states reported decreases in numbers of rabid skunks in 2000. Kentucky (52.4%; 21 cases to 10 cases), Michigan (90.5%; 21 to 2), Missouri (54.5%; 11 to 5), and Wisconsin (92.3%; 13 to 1) reported decreases of > 50%, compared with cases reported in 1999, although absolute numbers were small. States where the raccoon-associated variant of the rabies virus is enzootic reported 39.6% (881/2,223) of the cases of rabies in skunks, the majority of which were presumably the result of spillover transmission of virus from raccoons. Massachusetts (141 cases) and Rhode Island (44) each reported more rabid skunks than rabid raccoons for the fourth consecutive year.

Bats—Rabies in bats accounted for 16.8% of all cases of rabies in animals reported in 2000. The 1,240 states reported decreases in numbers of rabid skunks in 2000. Kentucky (52.4%; 21 cases to 10 cases), Michigan (90.5%; 21 to 2), Missouri (54.5%; 11 to 5), and Wisconsin (92.3%; 13 to 1) reported decreases of > 50%, compared with cases reported in 1999, although absolute numbers were small. States where the raccoon-associated variant of the rabies virus is enzootic reported 39.6% (881/2,223) of the cases of rabies in skunks, the majority of which were presumably the result of spillover transmission of virus from raccoons. Massachusetts (141 cases) and Rhode Island (44) each reported more rabid skunks than rabid raccoons for the fourth consecutive year.
sented a 25.4% increase over the total reported in 1999. Rabies in bats is widely distributed throughout the United States, with cases reported from all 48 contiguous states (Fig 7). During 2000, California reported the largest number of cases (167), followed by Texas (164) and New York (122). Nine states (Colorado, Idaho, Illinois, Indiana, Mississippi, Nevada, Ohio, Utah, and Washington) reported rabies in bats but not in terrestrial mammals. Alaska, Hawaii, and Puerto Rico did not report any cases of rabies in bats.

Of the bats positive for rabies virus, 52.7% (653/1,240) were identified beyond the taxonomic level of order (15 to genus, 638 to species). Among bats identified to species level, 60.8% (388/638) were Eptesicus fuscus, the big brown bat; 12.3% (80/638) were Tadarida brasiliensis, the Brazilian (Mexican) free-tailed bat; 5.8% (37/638) were Lasius cinereus, the hoary bat; 3.9% (25/638) were Myotis lucifugus, the little brown bat; 3.3% (21/638) were Pipistrellus hesperus, the western pipistrelle; 2.5% (16/638) were Myotis yumanensis, the Yuma bat; 2.2% (14/638) were Lasius borealis, the red bat; 2.0% (13/638) were Lasionycteris noctivagans, the silver-haired bat; 1.7% (11/638) were Antrozous pallidus, the desert pallid bat; and 1.7% (11/638) were Myotis californicus, the California bat.

Unspeciated bats of the genus Myotis (2.3% [15/653]) and 9 other species (contributing < 3.5% [22/638] 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 6.2% of all cases of rabies in animals reported in 2000. The majority of cases of rabies in foxes (353/453) were reported by states affected by the raccoon-associated variant of the rabies virus (Fig 8). Alaska (32 cases), Georgia (50), and Massachusetts (15) reported increases of 22, 36, and 10 cases, respectively, over the cases reported in 1999. Alabama (4 cases), New Hampshire (2), and Texas (41) reported decreases of 10, 8, and 15 cases, respectively. Foxes infected with the red fox variant of the rabies variant were reported by Maine, New Hampshire, New York, and Vermont as recently as the past decade. However, during 2000, most cases of rabies in foxes reported by eastern states were probably caused by the raccoons. 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 Arizona and west central Texas, respectively, on the basis of antigen typing and genetic analysis. Michigan (2 cases) and Oregon (1) reported rabies in foxes in 2000 but did not report any cases of rabies in foxes during 1999.

Other wild animals—The total of 59 rabid mongooses (Herpestes auropunctatus) reported by Puerto Rico was identical to that reported during 1999 (Fig 9). Other wildlife in which rabies was reported included 48 groundhogs (Marmota monax), 32 bobcats (Felis rufus), 8 coyotes (C latrans), 2 badgers (Taxidea taxus), 3 opossums (Didelphis virginiana), 2 otters (Lutra canadensis), 2 rabbits (Oryctolagus cuniculus), 1 bison
Bison bison, 1 chinchilla (Chinchilla lanigera), 1 deer (Odocoileus virginianus), 1 mink (Mustela vison), and 1 ground squirrel (Spermophilus sp). All except 1 of the cases of rabies in rodents and lagomorphs (primarily groundhogs; 48/52 cases) were reported by states in which rabies is epizootic in raccoons.23 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 (Fig 9).

Rabies in Domestic Animals

Domestic species accounted for 6.9% of all rabid animals reported in the United States in 2000. The number of domestic animals reported rabid in 2000 (509) represented a 15.3% decrease from the total reported in 1999 (Fig 10). Cases of rabies reported in cattle and cats decreased 38.5 and 10.4%, respectively, compared with totals reported in 1999, whereas reports of rabies in dogs increased 2.7%. Reported cases of rabies in cats, however, remained more than twice as numerous as those reported in dogs or cattle. Texas reported the largest number of rabid domestic animals (56 cases), followed by Virginia (41) and Pennsylvania (40).

Cats—One hundred eighty-six of the 249 cases of rabies in cats were reported from states where the raccoon-associated variant of the rabies virus is present (Fig 11). 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. Six states reported >10 cases of rabies in cats (Pennsylvania, 34; New York, 29; Virginia, 27; Maryland, 18; Texas, 17; and New Jersey, 13). Twenty-two states, New York City, and the District of Columbia did not report any rabid cats.

Dogs—Texas (19 cases) and Puerto Rico (15) reported the largest numbers of cases of rabies in dogs by individual states or territories in 2000. None of the cases in dogs reported by Texas were associated with enzootic transmission of rabies virus previously evident in south Texas (Fig 12). Georgia (9 cases), North Dakota (8), Virginia (7), Florida (6), and Minnesota (6) were the only other states that reported >5 cases of rabies in dogs in 2000. Twenty-four states, New York City, and the District of Columbia did not report any rabid dogs.

Other domestic animals—The number of cases of rabies in cattle decreased from 135 in 1999 to 83 in 2000 (Fig 13), the lowest number ever recorded for cattle, and distribution mirrored that of rabid skunks in the central and midwestern states (Fig 6 and 13) and raccoons in the mid-Atlantic/northeastern region (Fig 5 and 13). North Dakota (14 cases), Texas (11), and Iowa (10) reported the largest numbers of rabid cattle. No other state reported >9 cases of rabies in cattle. The 52 cases of rabies reported in horses, donkeys, and mules in 2000 were a 38.3% decrease from the 65 cases reported during 1999. Other reported cases of rabies in domestic animals included 6 goats, 4 sheep, and 1 camel (Camelus dromedarius).

Seasonal Trends

The frequency of reported cases of rabies in raccoons peaked in March and May, prior to a broad
decline, and then decreased to a December low (Fig 14). The frequency of reporting for rabid skunks was bimodal, with a peak in April and a second broad peak in October. Reports of rabid bats show a sharp peak in August. The largest number of rabid foxes was reported in May, followed by a gradual decline during summer and autumn to a low in December.

Reporting of rabies in cats was highest during the summer and was remarkably consistent from June through October. Reports of rabies cases in dogs and cattle were highest during spring, reflecting peak activity in wildlife and, although cases were reported every month, otherwise showed no clear pattern (Fig 15).

Rabies in Human Beings

Five cases of rabies in human beings were reported in the United States during 2000.2,6 One of these resulted from rabies infection that was acquired abroad and involved a 54-year-old man who had recently arrived in New York from Ghana. On Sep 26, 2000, the man reported discomfort in his right lower back. His condition worsened and finally deteriorated to a level necessitating artificial life support on Oct 1. Rabies tests were positive on Oct 3, and the man died in Warren County, New York, on Oct 9. The patient’s employer indicated that he had been bitten in May by his unvaccinated puppy in Ghana. Genetic analysis of specimens from the patient identified a variant of the rabies virus consistent with those recovered from rabid dogs in that area of Africa.

The remaining 4 cases were the result of rabies infections that were acquired within the United States. Genetic analysis of samples obtained from these patients determined that their infections were the result of variants of the rabies virus associated with bats.

On Sep 15, 2000, a 49-year-old man from Amador County, Calif, visited a neurologist after 2 days of increasing right arm pain and paresthesia. The patient’s condition continued to worsen and, after 2 emergency room visits, he was admitted to a hospital on Sep 16. There, on the basis of a neurologist’s suspicion of rabies, rabies immune globulin, vaccine, and acyclovir were administered. The patient required mechanical ventilation on Sep 17 and, following renal failure, he died on Sep 20.

On Oct 3, 2000, a 26-year-old man from Taylor County, Ga, developed intractable vomiting and hematemesis. The man was hospitalized, his condition continued to deteriorate, and after transfer to a second hospital for ventilatory support, he died with respiratory and renal failure on Oct 10. Although the man did not report a bite, he reported to coworkers that bats from the attic of his residence had entered his living quarters and landed on him while he slept. Subsequent investigation of the house occupied by the patient revealed a colony of approximately 200 Brazilian (Mexican) free-tailed bats (T brasiliensis) in the attic and multiple openings between the attic and the patient’s living quarters.

Genetic analyses of samples obtained from the California and Georgia patients identified the variant of the rabies virus involved in each of these cases to be that associated with rabid Brazilian (Mexican) free-tailed bats (T brasiliensis).
On Oct 14, 2000, a 47-year-old man from Becker County, Minn, visited a local clinic with right arm pain and paresthesia. On Oct 19, while traveling in North Dakota, the man was admitted to a local hospital with a temperature of 103 F and additional neurological problems. On Oct 20, the patient developed respiratory failure and was intubated. He died on Oct 25. A friend told the family the patient had awakened from sleep during August to find that a bat had alighted on his right hand. He killed the bat and was bitten in the process. The patient did not seek medical advice. Retrospective examination of the patient’s house revealed multiple external portals of entry, openings between the attic and living areas, and extensive deposits of guano in the attic and living areas.

On Oct 14, 2000, a 54-year-old man from Sauk County, Wis, was admitted to a local hospital for cardiac evaluation because of a 2-day history of chest discomfort and numbness, tingling, and tremors of his left arm. His condition continued to worsen in spite of treatment with antibiotics for possible sepsis and acyclovir for suspected herpes. A test of the patient’s serum for rabies antibodies was negative on Oct 18. The patient died on Nov 1, and rabies was diagnosed from postmortem brain specimens. The patient did not mention being bitten by an animal but told a friend that 2 or 3 times a year he had removed bats from his house with his bare hands and asked a friend a week before he was admitted to the hospital if rabies could be acquired from an insect bite.

Genetic analyses of samples obtained from the Minnesota and Wisconsin patients identified the variant of the rabies virus involved in each of these cases to be that associated with silver-haired (L noctivagans) and eastern pipistrelle bats (P subflavus).

Rabies in Canada and Mexico

Canada reported 663 laboratory-confirmed and 7 clinically diagnosed cases of rabies in domestic and wild animals in 2000. This number represented a 34% increase over the 500 cases reported in 1999. Most of this increase was attributable to increases in numbers of reported cases of rabies in skunks in the provinces of Manitoba and Saskatchewan. Reported cases in skunks increased by 13.8% (404 in 2000, compared with 355 cases in 1999) and accounted for 60.3% (404/670) of all rabid animals reported in 2000. Reported cases of rabies in bats increased 71.4% (72 cases in 2000, compared with 42 cases in 1999) and accounted for 10.7% (72/670) of all reported cases of rabies. Other species that contributed substantially to the 2000 total included cattle (6.4%), foxes (8.7%), raccoons (7.1%), and dogs (3.4%). Canada reported one case of rabies in a 9-year-old boy who died on Oct 6, 2000. The variant of the rabies virus involved in this infection was that associated with silver-haired (L noctivagans) and eastern pipistrelle (P subflavus) bats.

Mexico reported 560 laboratory-confirmed cases of rabies in domestic and wild animals during 2000. This total represented a 15.2% increase, compared with the 486 cases reported in 1999. Dogs accounted for 43.6% (244/560) of reported cases of rabies, a decrease of 23% from 1999 (317 cases). The other reported
rabid animals included 270 cattle, 12 sheep, 8 skunks, 7 equids, 6 cats, 5 bats, 2 swine, 1 badger (Taxus), 1 coatimundi (Nasua narica), 1 coyote, 1 fox, 1 goat, and 2 unidentified species. Five cases of rabies were reported in human beings, a 44.4% decrease from 1999 (9 cases). Source animals implicated in the exposure to the human beings were reported as follows: bats, 3 cases; fox, 1 case; and skunk, 1 case.

Discussion

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 confirmed by a laboratory and reported to the CDC by state, territorial, and the District of Columbia health departments. 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 dictates that prevalence or incidence of rabies cannot be determined for most species. Many rabid animals are never observed and go untested and undetected.

The number of cases of rabies in raccoons declined for a fourth consecutive year. Raccoons continued to account for the highest percentage (37.7%) of rabies cases reported among animals in the United States in 2000, the lowest percentage contribution by this species since 1990 (Fig 2). Enzootic transmission of rabies among raccoons continued in 18 states and the District of Columbia in 2000 (no detectable raccoon rabies activity was reported in Ohio during 2000). States in the affected area reported 99.6% (2,213/2,223) of all documented cases of rabies in raccoons and accounted for 67.6% (4,831/7,369) of the total cases of rabies reported in the United States during 2000. 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.

The first release of the V-RG vaccine in the United States began during 1990. Interventions to vaccinate wild raccoons to prevent or slow the dissemination of rabies continue in a number of states. The efficacy of these programs, using the V-RG vaccine distributed within baits, remains under assessment in Florida (Pinellas County), eastern Massachusetts (Cape Cod), southern New Jersey (Cape May), New York, Vermont, Virginia, and West Virginia. During 2000, 1 million additional doses of V-RG vaccine were distributed over the > 2,500 square miles in the 6 counties in Ohio previously treated in 1999 in an effort to maintain the immune barrier established to block further westward spread of raccoon rabies. In January 2000, the Ohio Department of Health hosted a meeting attended by officials from several neighboring and nearby states, the CDC, and the US Department of Agriculture, at which consensus was reached to pursue additional federal funds for multistate regional rabies prevention and control efforts. Additional states are expected to use the V-RG vaccine for raccoon rabies control in the future. A conceptual plan is envisioned that may eventually result in an immune barrier, maintained using the V-RG vaccine, spanning the distance from the shores of Lake Erie in Ohio to the Gulf of Mexico in Alabama. This “cordone sanitaire” will be

Figure 14—Cases of rabies in wild animals in the United States, by month, 2000.

Figure 15—Cases of rabies in domestic animals in the United States, by month, 2000.
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 addressed during earlier trials remain. 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.

Although the total number of rabid skunks reported in 2000 was 7.1% greater than that reported in 1999, only 13 states reported increases, compared with 21 that reported decreases. Only Texas reported an increase of > 100%. In Michigan, a state that reported an increase of 950% in rabid skunks in 1999 primarily because of enhanced surveillance,2 numbers of rabid skunks returned to pre-1999 levels. Indeed, nationally, if the increase in rabid skunks reported by Texas in 2000 (+358 cases) were to be discounted, the overall total of rabid skunks reported during 2000 would be 10.1% less than that of 1999 (2,076 cases in skunks vs 2,223 – 358 = 1,865).

Rabid skunks outnumbered reported rabid raccoons in Massachusetts (141 cases skunks, compared with 76 in raccoons) and Rhode Island (44 cases in skunks, compared with 8 cases in raccoons) for the fourth consecutive year, and the magnitudes of these differences again increased. This trend further fueled concerns that skunks may be involved in enzootic transmission of the raccoon variant of the rabies virus. Verification of this concern remains elusive, because reported cases of rabies in skunks and raccoons overlap temporally and geographically.

Sixteen states reported increases in numbers of rabid foxes. Increases of 18 and 36 cases were reported by Alaska and Georgia, respectively, and smaller increases also exceeding 100% were reported by Maine (4 to 9 cases) and Massachusetts (5 to 15).

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. 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. 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, Wyoming reported a case of rabies in a ground squirrel (Spermophilus sp) in 2000. There has been no documentation of rabies transmission from a rodent to a human being. Large species of rodents and lagomorphs, or those kept in cages, may become infected and survive long enough to pose a risk to other species.

Additional distributions of oral V-RG vaccine (1.83 million baits delivered over > 25,000 square miles) were completed during 2000 in Texas to interrupt the transmission of rabies virus in gray foxes and in dogs and coyotes. Translocations of animals infected with canid variants of the rabies virus found in Texas have been documented. These events involved infected animals placed in 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 15.3% in 2000. Reported cases of rabies in cattle decreased 38.5% to 83 cases, the lowest number of rabid cattle recorded since the initiation of record keeping. Numbers of rabid cats decreased 10.4% from 1999, most likely because of continued declines in numbers of rabid raccoons.

Reports of rabid dogs increased only slightly (2.7%) from 111 cases in 1999 to 114 during 2000. Reports of rabid cats and dogs remained least common in the western United States. Continued low numbers of reported cases of rabies in dogs and diminishing numbers in cats and cattle attest to the effectiveness of a public health strategy aimed at preventing rabies in domestic animals through spillover from infected wild animals. 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 rabies cases reported in cats and dogs and to assess what contribution, if any, was the result of bat-associated variants of the rabies virus. Nearly all animals (229 cats and 78 dogs) were infected via spillover with the predicted terrestrial variant of the rabies virus; the variant maintained (ie, 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. While 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.

Numbers of cases of rabies in horses/mules declined 20% from those reported in 1999. Thirty-two of the 52 cases were reported by 6 states (Iowa, Kansas, Minnesota, North Dakota, South Dakota, and Texas).

The total number of cases of rabies diagnosed in human beings in the United States since 1990 has increased to 32. Twenty-six of these 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%) persons were infected with variants of the rabies virus indigenous to the United States.
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 has used the basis of data gathered via active surveillance programs implemented in affected areas and a statewide passive surveillance system. Thus, even in the presence of enhanced awareness and active surveillance, no detectable transmission of terrestrial rabies has occurred for over 21 months. More than 1 million additional doses of V-RG vaccine were distributed in 2 operations (spring and fall) over a total of > 3,242 square miles in 9 eastern Ohio counties during the first 9 months of 2001.

The front of the raccoon rabies epizootic extending from the Ohio border in the north and across West Virginia south almost to the borders of the states of Kentucky and Tennessee has continued to advance westward in those areas south of Ohio. 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 must be considered.

In Texas, an additional 1.67 million doses of V-RG vaccine were distributed over > 26,000 square miles during 2001. During the first 7 months of 2001, 1 case of rabies attributable to the dog/coyote variant of the rabies virus was reported in Texas. During this same period, 13 cases of rabies attributable to the variant of the virus associated with coyotes were reported in foxes and other species; however, no cases were reported outside of the original treatment area. Since the programs were initiated in 1995, almost 15 million doses of V-RG vaccine have been distributed over > 222,000 square miles. The area in Canada affected by the epizootic of rabies in raccoons has expanded beyond southern Ontario. Extension of the raccoon rabies epizootic originating from the state of Maine into Canada via New Brunswick represents a second zone of expansion.

California reported a case of rabies in a human being to the CDC during 2001. The case was discovered via retrospective surveillance activity, and follow-up activity remains in progress.

Table 2—Cases of rabies in human beings in the United States, by circumstances of exposure and rabies virus variant, 1990 to 2000

<table>
<thead>
<tr>
<th>Date of death</th>
<th>State of residence</th>
<th>Exposure history†</th>
<th>Rabies virus variant‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Jun 96</td>
<td>TX</td>
<td>Bat bite—TX</td>
<td>Bat, Tb</td>
</tr>
<tr>
<td>20 Aug 91</td>
<td>TX</td>
<td>Unknown</td>
<td>Dog/coyote</td>
</tr>
<tr>
<td>20 Aug 91</td>
<td>AR</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>8 Oct 91</td>
<td>GA</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>8 May 92</td>
<td>CA</td>
<td>Dog bite—India</td>
<td>Dog, India</td>
</tr>
<tr>
<td>11 Jul 93</td>
<td>NY</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>9 Nov 93</td>
<td>TX</td>
<td>Unknown Bat</td>
<td>Ln/Ps</td>
</tr>
<tr>
<td>21 Nov 93</td>
<td>CA</td>
<td>Dog bite—Mexico</td>
<td>Dog, Mexico</td>
</tr>
<tr>
<td>18 Jan 94</td>
<td>CA</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>21 Jun 94</td>
<td>FL</td>
<td>Unknown—Haiti</td>
<td>Dog, Haiti</td>
</tr>
<tr>
<td>11 Oct 94</td>
<td>AL</td>
<td>Unknown</td>
<td>Bat, Tb</td>
</tr>
<tr>
<td>15 Oct 94</td>
<td>WV</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>23 Nov 94</td>
<td>TN</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>27 Nov 94</td>
<td>TX</td>
<td>Unknown</td>
<td>Dog/coyote</td>
</tr>
<tr>
<td>15 Mar 95</td>
<td>WA</td>
<td>Unknown</td>
<td>Bat, Map</td>
</tr>
<tr>
<td>23 Sep 95</td>
<td>CA</td>
<td>Unknown</td>
<td>Bat, Tb</td>
</tr>
<tr>
<td>23 Oct 95</td>
<td>CT</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>9 Nov 95</td>
<td>CA</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>8 Feb 96</td>
<td>FL</td>
<td>Dog bite—Mexico</td>
<td>Dog, Mexico</td>
</tr>
<tr>
<td>20 Aug 96</td>
<td>NH</td>
<td>Dog bite—Nepal</td>
<td>Dog, SE Asia</td>
</tr>
<tr>
<td>15 Nov 96</td>
<td>KY</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>10 Dec 96</td>
<td>MT</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>5 Jan 97</td>
<td>MT</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>18 Jan 97</td>
<td>WA</td>
<td>Unknown</td>
<td>Bat, Ef</td>
</tr>
<tr>
<td>17 Oct 97</td>
<td>TX</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>23 Oct 97</td>
<td>NJ</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>31 Dec 98</td>
<td>VA</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>20 Sep 99</td>
<td>CA</td>
<td>Unknown</td>
<td>Bat, Tb</td>
</tr>
<tr>
<td>9 Oct 00</td>
<td>NY</td>
<td>Dog bite—Ghana</td>
<td>Dog, Africa</td>
</tr>
<tr>
<td>10 Oct 00</td>
<td>GA</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>25 Oct 00</td>
<td>MN</td>
<td>Bat bite—MN</td>
<td>Bat, Ln/Ps</td>
</tr>
<tr>
<td>1 Nov 00</td>
<td>WI</td>
<td>Unknown</td>
<td>Bat, Ln/Ps</td>
</tr>
</tbody>
</table>

†All laboratory-confirmed cases of rabies in human beings who developed the disease in the United States, 1990–2000. Data for exposure history are reported only when the biting animal was available and tested positive for rabies; or when plausible information was reported directly by the patient (if lucid or credible); or when a reliable account of an incident consistent with rabies exposure (eg, dog bite) was reported by an independent witness (usually a family member). Variants of the rabies virus associated with terrestrial animals in the United States are identified with the names of the reservoir animal (dog or dog/coyote, in all cases shown), followed by the name of the most definitive geographic entity (usually the county) from which the variant has been identified. Variants of the rabies virus associated with bats are identified with the name(s) of the species of bat(s) in which they have been found to be circulating. Because information regarding the location of the exposure and the identity of the exposing bat(s) is almost always retrospective and much information is frequently unavailable, the location of the exposure and the identity of the animal responsible for the infection are often limited to deduction. In some instances for which the exposure history is unknown, there may have been known or inferred interaction that, especially for bats, could have involved an unrecognized bite.

‡Rabies virus associated with bats (Table 2). Association with bats is epidemiologically different than with other species; however, no cases were reported outside of the original treatment area. Since the programs were initiated in 1995, almost 15 million doses of V-RG vaccine have been distributed over > 222,000 square miles. The area in Canada affected by the epizootic of raccoons has expanded beyond southern Ontario. Extension of the raccoon rabies epizootic originating from the state of Maine into Canada via New Brunswick represents a second zone of expansion. California reported a case of rabies in a human being to the CDC during 2001. The case was discovered via retrospective surveillance activity, and follow-up activity remains in progress.

References