Rabies surveillance in the United States during 1998

Public Veterinary Medicine: Public Health

JAVMA 215(12):1786-98 (1999)

John W. Krebs, MS; Jean S. Smith, MS; Charles E. Rupprecht, VMD, PhD; James E. Childs, ScD

Summary: During 1998, 49 states, the District of Columbia, and Puerto Rico reported 7,961 cases of rabies in nonhuman animals and 1 case in a human being to the Centers for Disease Control and Prevention, a decrease of 6.5% from 8,509 cases in nonhuman animals and 4 cases in human beings reported in 1997. More than 92% (7,358 cases) were in wild animals, whereas > 7.5% (603 cases) were in domestic species (compared with 93% in wild animals and 7% in domestic species in 1997). Decreases were evident in all of the major contributing species groups, with the exception of skunks and bats. The relative contributions of the major groups to the total reported for 1998 were raccoons (44.0%; 3,502 cases), skunks (28.5%; 2,272), bats (12.5%; 992), foxes (5.5%; 435), cats (3.5%; 282), cattle (1.5%; 116), and dogs (11.5%; 113). No further discernable westward extension of the epizootic of rabies in raccoons in Ohio was reported. Twelve of the 19 states enzootic for the raccoon variant of the rabies virus and the District of Columbia reported decreased numbers of cases of rabies during 1998, compared with 13 states and the District of Columbia that reported increases during 1997. Three states, Rhode Island (143.2%), Massachusetts (77.2%), and New Hampshire (69.4%), reported increases of > 50% during 1998, compared with totals reported for 1997. In Texas, the number of cases of rabies associated with enzootic canine variants of the rabies virus remained greatly diminished; however, overall totals of reported cases of rabies increased in Texas and 12 other states where skunks are the major terrestrial reservoir of rabies. At the national level, the total of 82 reported cases of rabies among horses and mules was greater than that reported for any year since 1981 (88 cases) and represented a 74.5% increase, compared with the total for 1997. The 992 cases of rabies reported in bats during 1998 were the greatest proportionate contribution by bats since 1990. Reported cases of rabies in cats (282), dogs (113), and cattle (116) decreased 6.0%, 10.3%, and 4.9%, respectively. One indigenously acquired case of rabies reported in a human being during 1998 was the result of infection with a rabies virus variant associated with silver-haired and eastern pipistrelle bats.

From the Viral and Rickettsial Zoonoses Branch, Division of Viral and Rickettsial Diseases, National Center for Infectious Diseases, Centers for Disease Control and Prevention, 1600 Clifton Rd NE, Atlanta, GA 30333.

For almost 40 years, rabies in the United States has been reported more frequently in wild animals than in domestic animals. During 1998, wild animals accounted for 92.4% of all

cases reported to the **Centers for Disease Control and Prevention (CDC)**. The relative contributions of those species most frequently reported rabid have changed markedly since 1955 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 during the 1940s and 1950s effectively controlled and all but eliminated the circulation of canine variants of the rabies virus in canids by the 1960s. However, the reemergence of a variant well adapted to dogs during the late 1970s and early 1980s in south Texas demonstrated that optimism regarding elimination of rabies in canids in that region was premature. Programs were initiated to interrupt transmission of the virus, circulating among dogs (*Canis lupus*) and coyotes (*C latrans*), as well as a second canine variant found mainly in gray foxes (*Urocyon cinereoargenteus*) in Texas. In addition, regulations in Texas and a growing number of other states now prohibit translocation of certain wild animal species for hunting and other restocking purposes because of the possibility that animals incubating rabies virus might introduce variants of the rabies virus into areas of the United States where they do not presently exist.[1-3]

Vaccination of domestic animals, oral wildlife vaccination programs, ongoing education programs, and continued support for an efficient public health infrastructure have been used as effective strategies for preventing transmission of terrestrial rabies variants to human beings.[4] However, a disproportionate and increasing number of cases of rabies in human beings since 1990 have resulted from infection with variants of the rabies virus associated with bats,[5,6] a wildlife group difficult to target for rabies control by conventional methods. Compounding the difficulties inherent in preventing rabies transmission from bats is a developing pattern in which the exposure history that led to the infection in most of these human cases remains unknown. An additional case of rabies in a human being infected with a bat variant was reported during 1998. Since 1990, 20 of 22 cases of indigenously acquired rabies reported in human beings have been found, by genetic analysis, to be the result of infection with variants of the rabies virus associated with bats, and in only 1 instance was there a definite history of animal bite.[5,6] The most likely route of infection remains transmission by bite during contact with a bat that either was unnoticed or ignored and subsequently forgotten.

Within most areas of the United States, rabies infections of terrestrial animals occur in geographically discrete regions where virus transmission is primarily between members of the same species. Spillover infection from these species to other animal species may occur in a region, but such instances are sporadic and rarely initiate sustained intraspecific transmission. Once established, it is possible for virus transmission within a species to persist at enzootic levels for decades or even for centuries.

Compartmentalization of the virus by species and geographic area has led to the evolution of distinctive variants. These variants can be identified by reaction with panels of monoclonal antibodies[7] or by patterns of nucleotide substitution identified by genetic analysis.[1,8] Temporally dynamic boundaries can be identified for the principal terrestrial animal species, or reservoir for rabies, in a given geographic area and the variant of rabies

virus associated with the reservoir species. Affected areas usually expand gradually and are bounded by natural barriers that restrict animal movements, such as mountain ranges or bodies of water; however, unusual animal dispersal patterns or human-mediated translocation of infected animals can result 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.[9] Although previously identifiable as separate foci, the 2 foci have merged, and the raccoon variant of the rabies virus is now enzootic in all of the eastern coastal states, as well as Alabama, Pennsylvania, Vermont, West Virginia, and most recently, parts of Ohio.

Three 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 exists in red and arctic foxes (*Vulpes vulpes* and *Alopex lagopus*, respectively) in Alaska. The disease spread during the 1950s, affecting foxes across Canada and adjoining areas of the New England states. Rabies remains a persistent problem in foxes in Alaska; however, reports of rabid foxes have declined in Canada. Foxes infected with this rabies virus variant are only intermittently reported in New England. Two variants of rabies virus are in small, but persistent reservoirs in gray foxes (*U cinereoargenteus*) in Arizona and Texas. Enzootic rabies in coyotes (*C latrans*) and dogs (*C lupus*) in southern Texas is the result of long-standing interaction between unvaccinated domestic dogs and coyotes at the Texas-Mexico border.[10]

In general, long-term rabies control in wild terrestrial carnivores by widespread sustainable population reduction has not been successful in North America or elsewhere. Field programs in Europe and southeastern Canada have used modified-live or recombinant virus vaccines for oral immunization of free-ranging wildlife reservoir species, such as the red fox (*V vulpes),* to control the disease. During the past 2 decades, > 100 million doses of vaccine-laden bait have been distributed over 6 million square kilometers in Europe,[11] with promising results. Specifically, the use of dedicated oral vaccination in Switzerland during the past 20 years finally resulted in a declaration of rabies-free status in 1998. Similarly, France is well on the way toward elimination of the disease among foxes. Substantial decreases of reported cases of rabies in Europe and southern Ontario strongly suggest variants of the rabies virus associated with red foxes may be eliminated from these areas within the next several years. Application of an oral **vaccinia-rabies glycoprotein (V-RG)** recombinant virus vaccine to raccoons in the eastern United States[12-14] and to gray foxes and coyotes in Texas[15] has shown promise as a complement to traditional rabies control methods. Public health professionals are reminded that current biological methods used in oral vaccination programs are self-replicating microbes intended for use in national or state wildlife rabies control programs, and efforts should be made to reduce the unintentional exposure of nontarget species, such as domestic animals and human beings.[16]

Overlaying the disease in terrestrial mammals are multiple independent reservoirs for rabies in several species of insectivorous bats. Rabies virus transmission in 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 much greater mobility of bats precludes range-mapping of different variants, other than as the distribution of the bat species themselves. Because bat species known to be reservoirs for rabies are found in all areas of the continental United States, every state except Hawaii is enzootic for a number of variants of rabies virus. Although transmission of rabies from bats to terrestrial mammals is known to occur, there is no evidence that sustained transmission (enzootic maintenance) of variants of the rabies virus associated with bats takes place in terrestrial animals. Genetic analysis indicates net differences of 15 to 20% between rabies virus sequences in bats, compared with those in terrestrial mammals.

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 in reported cases of rabies in various species. Long-term trends in 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 1998 with those from 1997 and by examining seasonal patterns for selected species.

Summaries of 1998 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 1999 is also included.

Collection of Data

Data-collection procedures were largely similar to those described previously.[2] Between January 1 and December 31, 1998, 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, using the common names of these animals (usually definable at least 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. States reported year-end information by use of various mechanisms, including facsimile, electronic mail, and computer diskette. Several states reported data by use of the **Public Health Laboratory Information System (PHLIS)** data management software to record and report results for animals submitted for rabies testing or the **Laboratory Information Tracking System (LITS)**, which contains relevant PHLIS categories.[17,18] All data were confirmed by telephone verification of year-end totals with state or territorial health department officials. Data from Canada were obtained from Dr. Ron Rogers, Animal Health and Production Division, Canadian Food Inspection Agency, and data from Mexico were obtained from Dr. Oscar Velazquez Monroy, Coordinador 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 state or local

health departments. Virus isolation in neuroblastoma cell cultures of mice and nucleic acid detection via **reverse transcriptase (RT)-polymerase chain reaction (PCR)** assays were used to confirm some cases.

Rabies in Wild Animals

Wild animals accounted for > 92% of reported cases of rabies in 1998. The 7,358 cases reported in 1998 represented a 6.9% decrease from the 7,899 cases reported in 1997. Raccoons continued to be the most frequently reported rabid wildlife species (44.0% of all animal cases during 1998), followed by skunks (28.5%), bats (12.5%), foxes (5.5%), and other wild animals, including rodents and lagomorphs (2.0%). Reported cases in skunks and bats increased 11.4 and 3.6%, respectively, whereas those in raccoons and foxes decreased 18.6 and 2.9%, from 1997 totals, respectively.

Raccoons—The 3,502 cases of rabies in raccoons (*P lotor*) reported in 1998 represented the smallest number of cases reported since the peak of 5,912 cases in 1993. Most of this decrease was the result of fewer cases reported from eastern states affected by the epizootic of rabies in raccoons. Decreases in rabid raccoons during 1998 were reported by more than half (58%) of the states with enzootic transmission of rabies in raccoons, including Connecticut (10.6%; 349 cases in 1997 to 312 in 1998), the District of Columbia (93.8%; 16 to 1), Florida (22.3%; 197 to 153), Georgia (6.7%; 224 to 209), Maryland (30.0%; 494 to 346), New York (17.6%; 836 to 689), North Carolina (43.2%; 678 to 385), Ohio (66.1%; 59 to 20), Pennsylvania (17.6%; 272 to 224), South Carolina (25.2%; 127 to 95), Vermont (48.9%; 90 to 46), and Virginia (24.0%; 429 to 326; and.[2,8,9,12,19] In 1997, California and Michigan reported cases of rabies in raccoons that resulted from spillover infection from regional terrestrial reservoirs but did not report any cases of rabies in raccoons during 1998. The District of Columbia and the states of the northeastern and 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, and West Virginia, reported 2,579 cases (73.6% of total cases in raccoons) in 1998, whereas the southeastern states of Alabama, Florida, Georgia, North Carolina, and South Carolina reported 911 cases (26.0% of total cases in raccoons).

Increases in numbers of rabid raccoons, compared with 1997 figures, were reported by Alabama (68.3%; 41 cases to 69), Delaware (10%; 40 to 44), Maine (10%; 130 to 143), Massachusetts (71.6%; 109 to 187), New Jersey (12.1%; 124 to 139), Rhode Island (190.0%; 10 to 29), and West Virginia (2.0%; 49 to 50). Rabid raccoons reported by Iowa (3), Kansas (1), North Dakota (2), Texas (5), and Wyoming (1) were infected with different variants of the rabies virus (usually the north central skunk variant, except for Texas, where such spillover infection could involve either the gray fox variant or the south central skunk variant), as the raccoon variant of the rabies virus is not enzootic at these locations. Other than Ohio, states west of the Ohio River in the North and west of the Appalachian Mountains in the South apparently remained free of the raccoon variant of the rabies virus during 1998.

Skunks—The 2,272 reported cases of rabies in skunks (mainly *M mephitis*) were reported

from 39 states in 1998. Nine states reported > 100 cases of rabies in skunks (California, 185 cases; Connecticut, 104; Massachusetts, 248; New York, 196; North Dakota, 116; South Dakota, 137; Tennessee, 127; Texas, 116; and Virginia, 112) and together accounted for 59.0% (1,341/2,272) of all cases of rabies in skunks. Four states reported increases of > 100%, compared with reported cases in 1997 (Rhode Island, 152.0% [27 cases to 68]; South Dakota, 114.1% [64 to 137]; Wisconsin, 300.0% [2 to 8]; and Wyoming 116.7% [24 to 52]). Three states reported decreases of > 50% in cases of rabies in skunks (Illinois, 75.0% [4 cases to 1]; Indiana, 75.0% [4 to 1]; and West Virginia, 68.2% [22 to 7]). Two states and New York City did not report any cases of rabies in skunks during 1997 but reported rabid skunks during 1998 (Michigan [2 cases], New Mexico [1], and New York City [1]). Louisiana reported 2 cases of rabies in skunks during 1997 but did not report rabid skunks in 1998. States with enzootic or epizootic rabies in raccoons reported 48.5% (1,103/2,272) of the cases of rabies in skunks, the majority of which were presumably the result of spillover transmission of virus from raccoons. Massachusetts and Rhode Island, however, reported more rabid skunks than rabid raccoons.

Bats—Rabies in bats accounted for 12.5% of all cases of rabies in animals reported in 1998, and the 992 reported cases represented a 3.6% increase over those reported in 1997. Rabies in bats remained widely distributed throughout the United States, with cases reported from 46 of the 48 contiguous states. During 1998, California reported the largest number of cases (185), followed by New York (109) and Texas (104). Eight states (Colorado, Idaho, Louisiana, Mississippi, Nevada, Oregon, Utah, and Washington) reported rabies in bats but not in terrestrial mammals. Alaska, Hawaii, North Dakota, Vermont, and Puerto Rico did not report any cases of rabies in bats.

Of those bats reported that tested positive for rabies virus, 33.9% (336/992) were not identified beyond the taxonomic level of order. Of the 656 bats reported positive that were further identified (8 to genus, 648 to species), 42.4% (278/656) were *Eptesicus fuscus*, the big brown bat; 30.0% (197/656) were *Tadarida brasiliensis*, the Brazilian (Mexican) free-tailed bat; 5.3% (35/656) were *Myotis lucifugus*, the little brown bat; 5.2% (34/656) were *Lasiurus cinereus*, the hoary bat; 3.5% (23/656) were *Lasionycteris noctivagans*, the silver-haired bat; 2.6% (17/656) were *L borealis*, the red bat; and 1.8% (12/656) were *Pipistrellus hesperus*, the western pipistrelle. Unspeciated bats of the genus *Myotis* (1.1% [7/656]) and 15 other species (contributing < 10% [48/656] to the total, with no individual species in this latter group contributing > 1.1%) 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. Some states reported all bats tested for rabies but speciated only those that tested positive, and some states indicated that data for bats that tested negative for rabies were incomplete.

Foxes—Foxes (mainly *V vulpes*) accounted for 5.5% of all cases of rabies in animals reported in 1998. The majority of cases of rabies in foxes were reported by states affected by the epizootic of rabies in raccoons. Florida (21 cases), Maryland (27), and North Carolina (34) reported decreases of 17, 17, and 14 cases, respectively, compared with cases reported in 1997. New Hampshire (29 cases), Massachusetts (12), and Texas (21) reported increases of 18, 9, and 8 cases, respectively. With the possible exception of the northeastern focus that includes parts of Maine, New Hampshire, New York, and Vermont, most cases

of rabies in foxes reported by eastern states (87.6% of all cases of rabies in foxes) were probably caused by infection with the rabies virus variant associated with raccoons, which is enzootic in the area. Rabies in gray foxes in Texas is usually the result of infection with the gray fox variant that is enzootic in that species in west central Texas. Arizona did not report rabies in foxes during 1998.

Other wild animals—Puerto Rico reported 35 cases of rabies in mongooses (*Herpestes auropunctatus)*, a 34.0% decrease from the 53 cases reported in 1997. Rodents, lagomorphs, and other wildlife in which rabies was reported included 63 groundhogs (*Marmota monax)*, 35 bobcats (*Felis rufus*), 8 coyotes (*C latrans*), 3 beavers (*Castor canadensis*), 3 deer (*Odocoileus virginianus*), 3 opossums (*Didelphis virginiana*), 2 rabbits (*Oryctolagus cuniculus*), 1 bison (*Bison bison*), 1 wapiti (*Cervus elephas*), 1 otter (*Lutra canadensis*), 1 ringtail (*Bassariscus astutus*), and 1 wolf (*C lupus*). All cases of rabies in rodents and lagomorphs (primarily groundhogs, 63/68 cases) were reported by states in which rabies is enzootic in raccoons.[20] Cases of rabies in coyotes associated with enzootic transmission of the dog and coyote variant of the rabies virus in coyotes in regions of southern Texas remained low (4/6 cases in coyotes in Texas during 1998.

Rabies in Domestic Animals

Domestic species accounted for 7.6% of all rabid animals reported in the United States in 1998. The number of domestic animals reported rabid decreased 1.2% from 610 cases reported in 1997 to 603 in 1998. Cases of rabies reported in dogs, cats, and cattle decreased 10.3, 6.0, and 4.9%, respectively, compared with those reported in 1997. Reported cases of rabies in cats were more than twice as numerous as those reported in dogs or cattle. Iowa reported the largest number of rabid domestic animals (70), followed by Pennsylvania (50), Texas (45), and New York (41).

Cats—The majority of the 282 cases of rabies in cats were reported from states experiencing epizootics of rabies in raccoons. Remaining cases were reported principally by Central Plains states, where most cases are presumably the result of spillover from rabid skunks (and possibly from foxes in Texas). Ten states reported > 10 cases of rabies in cats (Florida, 13 cases; Georgia, 12; Iowa, 29; Maryland, 12; Massachusetts, 14; New Jersey, 12; New York, 28; North Carolina, 25; Pennsylvania, 32; and Virginia, 21). Nineteen states and the District of Columbia did not report any rabid cats.

Dogs—Texas reported the largest number of cases of rabies in dogs (15 cases). Three of these cases occurred within an area of west central Texas where rabies in gray foxes is enzootic; 1 case was associated with enzootic transmission of rabies in coyotes and dogs in southern Texas. Iowa and Puerto Rico each reported 12 cases of rabies in dogs during 1998. Only 3 other states, Minnesota, North Dakota, and Tennessee, each with 6 cases, reported > 5 cases of rabies in dogs during 1998. Twenty-five states and the District of Columbia did not report any rabid dogs.

Other domestic animals—The number of cases of rabies in cattle decreased from 122 in 1997 to 116 in 1998. Distribution of cases of rabies in cattle followed that of skunks in the

central and midwestern states (Fig 6 and 13) and that of raccoons in the mid-Atlantic and northeastern regions. Iowa (21 cases), Minnesota (8), New York (8), North Dakota (12), Oklahoma (7) Pennsylvania (8), and South Dakota (10) reported the largest numbers of rabid cattle. No other state reported > 5 cases of rabies in cattle. The 82 cases of rabies reported in equids (horses, donkeys, and mules) in 1998 represented a 74.5% increase over the 47 cases reported during 1997 and the greatest number of reported cases in this group of animals since 1981 (88 cases). Other reported cases of rabies in domestic animals included 6 goats, 2 sheep, 1 ferret, and 1 swine.

Seasonal Trends

The frequency of reported cases of rabies in raccoons was bimodal, reaching a spring peak in March, followed by a decline to a summer low in July before increasing again to a second smaller peak in late summer and early fall. The frequency of reporting for rabid skunks was similar, although the numbers were lower, with a spring peak in March, followed by a period of early summer low reporting from May through July and a second lower peak during August and September. Reports of rabid bats gradually increased from a January low to an August high, followed by a precipitous decline to a winter low in December. Monthly reports of rabid foxes were low and broadly unimodal, with the highest numbers reported during June and July.

Rabies in cats was highest in June, followed by a sharp decline in July, increased reporting in August, and then a continued decline to a winter low in November. Reports of rabies in dogs and cattle showed no clear pattern. Reports of rabies in cattle showed an undulating spring pattern, reaching highs in March and May (probably reflecting spring interaction with rabid skunks), followed by a decline to a very low level during August before increasing again in the fall.

Rabies in Human Beings

One death in a human being as a result of rabies was reported in 1998. On December 31, 1998, a 29-year-old man died from rabies encephalitis in Richmond, Va. The man was an inmate at a correctional institution in Nottoway County. A clinical prodrome compatible with that of rabies apparently began on December 14, with malaise and back pain that developed while he was working on a roadside cleanup crew. He was later admitted to an emergency room, and his condition worsened; on December 20, he was sedated and intubated. A diagnosis of rabies was considered, and samples were sent to CDC, where they tested positive for rabies by DFA and RT-PCR. Sedatives were discontinued, and the patient died.[6]

The rabies virus variant involved with this case was identified by RT-PCR and genetic analysis to be that associated with silver-haired (*L noctivagans*) and eastern pipistrelle (*P subflavus*) bats. Epidemiologic investigations failed to elicit a history of animal bite, although an unnoticed bite sustained during ignored or forgotten contact with a bat remains the most plausible explanation for this infection. This death continued the trend for human deaths from rabies of indigenous origin; it was associated with bat variants of the rabies

virus, and it lacked a clear exposure history involving animal bite.

Rabies in Canada and Mexico

Canada reported 370 laboratory-confirmed and 2 clinically diagnosed cases of rabies in domestic and wild animals in 1998. This represented a 56.3% increase over the 238 cases reported in 1997. Most of this increase was attributable to increases in numbers of reported cases of rabies in skunks in Manitoba and Saskatchewan. Reported cases in skunks increased by 142.7% (233 in 1998, compared with 96 cases in 1997) and accounted for 62.6% (233/372) of all rabid animals reported in 1998. Reported cases of rabies in foxes decreased 30.0% (28 cases in 1998, compared with 40 in 1997) and accounted for 7.5% (28/372) of all reported cases of rabies. This was the sixth consecutive year of decline in reported numbers of rabid foxes. Other species that contributed substantially to the 1998 total included bats (15.1%), cattle (7.8%), dogs (3.0%), and cats (2.2%). Canada did not report any cases of rabies in human beings for 1998.

Mexico reported 463 laboratory-confirmed cases of rabies in domestic and wild animals during 1998. This total represented a 35.2% decrease, compared with the 715 confirmed cases reported in 1997. Dogs accounted for 72.4% (335/463) of the confirmed cases of rabies in animals. The number of confirmed cases of rabies in dogs decreased 35.9%, compared with those reported in 1997 (523 cases). The other reported rabid animals included 73 cattle, 16 cats, 11 skunks, 7 bats, 7 equids, 3 swine, 2 goats, 1 coyote, 1 fox, and 7 unidentified species. Fifteen confirmed cases of rabies were reported in human beings, a 34.8% decrease from 1997 (23 cases). Source animals implicated in the exposure of human beings were reported as bats (7 cases), dogs (7), and skunk (1).

Discussion

States have different algorithms for submission of specimens for rabies testing, and levels of surveillance vary. The predominantly passive nature of rabies surveillance dictates that prevalence or incidence of rabies cannot be determined for most species. Reported cases of rabies provide a rough 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 the CDC by state, territory, and the District of Columbia health departments. Many rabid animals are never observed and, thus, go untested and undetected.[21]

Although the percentage contribution of reported cases of rabies in raccoons has continued to decline from a high of > 62% in 1993, raccoons continued to account for the highest percentage (approx 44%) of rabies cases among animals in the United States in 1998 (Fig 2). Enzootic transmission of rabies among raccoons was evident in 19 states and the District of Columbia in 1998. States in the affected area reported 99.7% (3,490/3,502) of all cases of rabies in raccoons and were responsible for 72.1% (5,742/7,962) of the total cases of rabies reported in the United States during 1998. Sharp increases in numbers of reported cases of rabies in states where the disease is enzootic among raccoons result from reemergence of disease when populations of raccoons, decimated by a previous epizootic,

again reach densities sufficient to support epizootic transmission of rabies.

Interventions continue in a number of states to vaccinate wild raccoons to prevent or slow the dissemination of rabies. The efficacy of these programs, using the V-RG virus vaccine contained within baits for ingestion by raccoons, is under assessment in Florida (Pinellas County), eastern Massachusetts (Cape Cod),[14] southern New Jersey (Cape May),[13] New York, and Vermont.[22] In Ohio, > 725,000 additional doses of the V-RG vaccine were distributed over > 1,500 square miles in 4 counties during the spring and fall of 1998; this was an effort to halt further spread of rabies in raccoons within Ohio and other midwestern states. Additional states are expected to use the V-RG virus vaccine for raccoon rabies control in the future. Concerns regarding vaccine safety, efficacy, ecologic impact, and physical bait variables were addressed during earlier trials.[23-25] The V-RG virus 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.

Reported cases of rabies in skunks in 1998 increased primarily because of increased reporting of rabid skunks from Central Plains and midwestern states where skunks are the predominant terrestrial rabies reservoir (an additional 226 cases were reported; 1,169 in 1998, compared with 943 in 1997). Reports of rabid skunks from states affected by the epizootic of rabies in raccoons remained almost unchanged (an additional 6 cases were reported; 1,103 in 1998, compared with 1,097 in 1997). The only states with enzootic rabies in raccoons that reported increases of > 5 cases in numbers of rabid skunks were Massachusetts (248 cases in 1998, compared with 133 in 1997), New Jersey (62, compared with 36), and Rhode Island (68, compared with 27). Reports of rabid skunks outnumbered those of rabid raccoons in Massachusetts (248 cases in skunks, compared with 187 cases in raccoons) and Rhode Island (68 cases in skunks, compared with 29 in raccoons). There has been concern that skunks may be involved in enzootic transmission of the raccoon variant of the rabies virus because of disproportionately high numbers of reported rabid skunks relative to numbers of reported rabid raccoons. Verification of this concern will remain elusive, because reported cases of rabies in skunks and raccoons overlap temporally and geographically.

The occurrence of rabies in various species of bats may fluctuate temporally, as it does in terrestrial reservoir species. However, there can be little doubt that the continued disproportionate contribution of bat variants of the rabies virus to human rabies infections during recent years has brought increased publicity, and changes in public health recommendations regarding possible rabies exposures that involve bats have played an important role.

Rabies among rodents and lagomorphs reflects spillover infection, predominantly from regional terrestrial reservoir species. Reported cases in this group occur primarily in groundhogs in areas affected by the epizootic of rabies in raccoons. In 1998, Maryland reported 2 cases of rabies in captive rabbits (*O cuniculus*) that had been caged outdoors. Cases like these serve as reminders that certain species of rodents and lagomorphs, especially large or caged animals, may become infected and survive long enough to become

ill and pose a risk to other species.[20,a]

Additional applications of oral rabies vaccine (V-RG; 2.6 million baits distributed over > 41,000 square miles) were completed during 1998 as part of ongoing programs to interrupt the transmission cycles of rabies in gray foxes, dogs, and coyotes.[15,26,27] Human translocations of animals infected with canid variants of the rabies virus of Texas origin have been documented.[2,3] These events involved infected animals that were placed in enclosures or whose infections were discovered prior to release at the intended location. Rapid responses to these events prevented establishment and spread of the involved variants.

Reported cases of rabies among domestic animals decreased by almost 1.2%, whereas reported cases among wildlife decreased by slightly < 6.9%. The number of rabid cats decreased 6.0%; this can possibly be credited to higher cat vaccination levels stimulated by public health education programs and vaccination clinics, but it can more likely be attributed to declines in numbers of rabid raccoons. Vaccination of pets provides a barrier to infection of human beings with rabies via their pets, and this fact cannot be overemphasized. A single incident involving a case of rabies in a companion species can result in tremendous expenditures in dollars and public health efforts to ensure that even the remotest possibility of transmission of the disease to humans is eliminated.[28-30] 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.[31]

Reports of rabid dogs remain uncommon in the western United States. Ever lower numbers of reported cases of rabies in dogs attest to the effectiveness of a public health infrastructure and policies aimed at preventing a resurgence of rabies in this species through spillover from infected wild animals.

Forty-four of the 82 cases of rabies in equids (horses, donkeys, and mules) in 1998 were reported by 5 states (Iowa, North Dakota, Oklahoma, South Dakota, and Texas). Discussions with various state health department officials revealed that, although antigenic typing or genetic analysis of the variants of the rabies virus responsible for these animals' infections was in most instances not performed, when tests had been performed the most likely sources of infections were demonstrated to be skunks.

The case of rabies in a human being reported in 1998 brought the total number of cases of rabies diagnosed in human beings in the United States from 1990 through 1998 to 27. Twenty-two of these individuals were infected with variants of the rabies virus indigenous to the United States. Monoclonal antibody analysis and genetic sequencing indicated that 20 of these 22 persons were infected with variants of the rabies virus associated with bats (Table 2).[5,6] The possibility of infection of human beings with rabies virus from bats remains a considerable public health concern.[32] Activities that have potential to increase the likelihood of contact with bats should be carefully evaluated.

Rabies in bats is epidemiologically distinct from terrestrial rabies maintained by carnivores.

Understanding of the circulation of rabies variants in bat species remains less well developed, compared with knowledge of circulation in carnivores. Successful control of terrestrial rabies in the United States through the use of oral vaccines, as has been accomplished in Europe[11,33] and southeastern Canada,[34] will have no effect on enzootic rabies in bats and the associated risk of human disease.

1999 Rabies Update

During the first 8 months of 1999, only 4 cases of rabies in raccoons (of a total of 5 cases in terrestrial animals) were detected in Ohio, compared with 18 cases in raccoons (of 22 cases in terrestrial animals) reported during the same period in 1998. Ohio orchestrates distribution of V-RG baits by use of data gathered via active surveillance programs implemented in affected areas, as well as data gathered via passive surveillance statewide. Approximately 1.5 million doses of the V-RG vaccine were distributed over a total of > 2,500 square miles in 6 counties during 1999; this was an effort to halt further spread of rabies in raccoons into the remainder of Ohio and other midwestern states.[b]

West Virginia, Virginia, and North Carolina have reported cases of rabies in raccoons from counties along a front that borders Ohio in the north and stretches across West Virginia to border the states of Kentucky and Tennessee in the south. Thus, raccoon rabies may soon enter presently unaffected parts of Ohio, as well as these latter two states.

Although reported cases of rabies in Texas during 1998 increased by 13.5% over 1997, marked reductions in totals of reported cases of rabies in Texas for 1996 (40.5%) and 1997 (24.0%) were encouraging, and an additional 2.7 million doses of the V-RG vaccine were distributed over 48 counties covering > 33,000 square miles in south, central, and western Texas during 1999. During the first 6 months of 1999, no cases of rabies attributable to the dog-coyote variant of the rabies virus have been reported north of the **oral rabies vaccination program (ORVP)** treatment area for coyotes, and only 3 cases have been documented within the area. During this same period, 42 cases of rabies attributable to the variant of the rabies virus associated with gray foxes were reported in several species; however, no cases associated with this variant were reported outside of the original ORVP treatment area for gray foxes. Since the programs were initiated in 1995, 11.3 million doses of the V-RG vaccine have been distributed over 171,000 square miles.[c] Anticipated expansion of the epizootic of rabies in raccoons beyond the northernmost counties of New York was confirmed during July 1999, when Canadian officials reported that the first case of rabies associated with the raccoon variant of the rabies virus had been detected in a raccoon in Ontario.

As of October 1, no cases of rabies in human beings in the United States had been reported to the CDC during 1999.

[a]Karp B, Maryland Department of Health and Mental Hygiene, Baltimore, Md: Personal communication, 1999.

[b]Smith KA, Ohio Department of Health, Columbus, Ohio: Personal communication, 1999.

[c]Wilson PJ, Texas Department of Health, Austin, Tex: Personal communication, 1999.

The authors thank the state and territorial health and agriculture departments and laboratories for their contributions of rabies surveillance data; the governments of Canada and Mexico for supplying summaries of rabies surveillance data; Karoyle Colbert, Biometrics Activity, Division of Viral and Rickettsial Diseases, National Center for Infectious Diseases, and Van Munn, Information Resources Management Office, Office of Program Services, Office of the Director, Centers for Disease Control and Prevention, for assistance with graphics; and John P. O'Connor, Office of the Director, Division of Viral and Rickettsial Diseases, National Center for Infectious Diseases, Centers for Disease Control and Prevention, for editing and critical input.

References

1. Smith JS, Orciari LA, Yager PA. Molecular epidemiology of rabies in the United States. *Semin Virol* 1995;6:387–400.

2. Krebs JW, Smith JS, Rupprecht CE, et al. Rabies surveillance in the United States during 1997. *J Am Vet Med Assoc* 1998;213:1713–1728.

3. Centers for Disease Control and Prevention. Translocation of coyote rabies—Florida, 1994. *MMWR Morb Mortal Wkly Rep* 1995;44:580–583.

4. Meltzer MI. Assessing the cost and benefits of an oral vaccine for raccoon rabies: a possible model. *Emerg Infect Dis* 1996;2:343–349.

5. Noah DL, Smith MG, Gotthardt JC, et al. Mass human exposure to rabies in New Hampshire: exposure, treatment, and cost. *Am J Public Health* 1996;86:1149–1151.

6. Centers for Disease Control and Prevention. Human rabies—Virginia, 1998. *MMWR Morb Mortal Wkly Rep* 1999;48:95–97.

7. Smith JS. Rabies virus epitopic variation: use in ecologic studies. *Adv Virus Res* 1989;36:215–253.

8. Rupprecht CE, Smith JS. Raccoon rabies: the re-emergence of an epizootic in a densely populated area. *Semin Virol* 1994;5:155–264.

9. Jenkins SR, Perry BD, Winkler WG. Ecology and epidemiology of raccoon rabies. *Rev Infect Dis* 1988;10:S620–S625.

10. Smith JS, Orciari LA, Yager PA, et al. Epidemiologic and historical relationships among 87 rabies virus isolates determined by limited sequence analysis. *J Infect Dis* 1992;166:296–307.

11. Stohr K, Meslin FX. Progress and setbacks in oral immunization of foxes against rabies in Europe. *Vet Rec* 1996;139:32–35.

12. Hanlon CA, Rupprecht CE. The reemergence of rabies. In: Scheld WM, Armstrong D, Hughes JB, eds. *Emerging infections 1*. Washington, DC: American Society for Microbiology, 1998;59–80.

13. Roscoe DE, Holste WC, Sorhage FE, et al. Efficacy of an oral vaccinia-rabies glycoprotein recombinant vaccine in controlling epidemic raccoon rabies in New Jersey. *J Wildl Dis* 1998;34:752–763.

14. Robbins AH, Borden MD, Windmiller BS, et al. Prevention of the spread of rabies to wildlife by oral vaccination of raccoons in Massachusetts. *J Am Vet Med Assoc* 1998;213:1407–1412.

15. Fearneyhough MG, Wilson PJ, Clark KA, et al. Results of an oral rabies vaccination program for coyotes. *J Am Vet Med Assoc* 1998;212:498–502.

16. McGuill MW, Kreindel SM, DeMaria A Jr, et al. Human contact with bait containing vaccine for control of rabies in wildlife. *J Am Vet Med*

Assoc 1998;213:1413–1417.

17. Bean NH, Martin SM, Bradford H. PHLIS: an electronic system for reporting public health data from remote sites. *Am J Public Health* 1992;82:1273–1276.

18. Martin SM, Bean NH. Data management issues for emerging diseases and new tools for managing surveillance and laboratory data. *Emerg Infect Dis* 1995;1:124–128.

19. Fischman HR, Grigor JK, Horman JT, et al. Epizootic of rabies in raccoons in Maryland from 1981 to 1987. *J Am Vet Med Assoc* 1992;201:1883–1886.

20. Childs JE, Colby L, Krebs JW, et al. Surveillance and spatiotemporal associations of rabies in rodents and lagomorphs in the United States, 1985–1994. *J Wildl Dis* 1997;33:20–27.

21. Greenwood RJ, Newton WE, Pearson GL, et al. Population and movement characteristics of radio-collared striped skunks in North Dakota during an epizootic of rabies. *J Wildl Dis* 1997;33:226–241.

22. Hanlon CA, Neizgoda M, Hamir AN, et al. First North American field release of a vaccinia-rabies glycoprotein recombinant virus. *J Wildl Dis* 1998;34:228–239.

23. Rupprecht CE, Hanlon CA, Hamir AN, et al. Oral wildlife rabies vaccination: development of a recombinant rabies vaccine. *Trans North Am Wildl Natl Res Conf* 1992;57:439–452.

24. Rupprecht CE, Hanlon CA, Niezgoda M, et al. Recombinant rabies vaccine: efficacy assessment in free ranging animals. *Onderstepoort J Vet Res* 1993;60:463–468.

25. Hanlon CA, Niezgoda M, Shankar V, et al. A recombinant vaccinia-rabies virus in the immunocompromised host: oral innocuity, progressive parenteral infection and therapeutics. *Vaccine* 1997;15:140–148.

26. Clark KA, Neill SU, Smith JS, et al. Epizootic canine rabies transmitted by coyotes in south Texas. *J Am Vet Med Assoc* 1994;204:536–540.

27. Meehan SK. Rabies epizootic in coyotes combated with oral vaccination program. *J Am Vet Med Assoc* 1995;206:1097–1099.

28. Centers for Disease Control and Prevention. Mass treatment of humans exposed to rabies—New Hampshire, 1994. *MMWR Morb Mortal Wkly Rep* 1995;44:484–486.

29. Rotz LD, Hensley JA, Rupprecht CE, et al. Large-scale human exposures to rabid or presumed rabid animals in the United States: 22 cases (1990–1996). *J Am Vet Med Assoc* 1998;212:1198–1200.

30. Krebs JW, Long-Marin SC, Childs JE. Causes, costs, and estimates of rabies postexposure prophylaxis treatments in the United States. *J Public Health Manag Pract* 1998;4:56–62.

31. The NASPHV Committee. Compendium of animal rabies control, 1998. *J Am Vet Med Assoc* 1998;212:213–217.

32. Centers for Disease Control and Prevention. Human rabies prevention—United States, 1999. *MMWR Morb Mortal Wkly Rep* 1999;48:(RR-1)1–21.

33. Muller WW. Oral vaccination of foxes in Europe, 1992. *Rabies Bull Eur* 1992;16:12–13.

34. Macinnes CD. Control of wildlife rabies: the Americas. In: Campbell JB, Charlton KM, eds. *Rabies*. Norwell, Mass: Kluwer Academic Publishers, 1988;381–405.