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SURVEILLANCE AND SPATIOTEMPORAL ASSOCIATIONS OF RABIES IN RODENTS AND LAGOMORPHS IN THE UNITED STATES, 1985–1994

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ABSTRACT: Between 1985 and 1994, 368 cases of rabies in rodents (95% of reports) and lagomorphs (5%) were reported to the Centers for Disease Control and Prevention, Atlanta, Georgia (USA), from 22 states. This was a 354% increase from the period 1971 to 1984. Most reports were cases of rabies in woodchucks (*Marmota monax*) (n = 317), primarily from the eastern United States, which has been recently experiencing an epizootic of raccoon (*Procyon lotor*) rabies. Cases of rabies in woodchucks were temporally and spatially associated with reports of raccoon rabies. Antigenic or genetic characterization of variants of rabies viruses from rodents and woodchucks corresponded to the variants associated with the major terrestrial wildlife reservoir within the geographic region of specimen origin. Although rodents and lagomorphs are infrequently infected with rabies and human contact with these animals rarely requires postexposure treatment, appropriate health authorities need to evaluate individual circumstances surrounding potential exposures.

Key words: Rabies, Rodentia, Lagomorpha, zoonotic disease, Rhabdovirus, *Marmota monax*, *Procyon lotor*.

INTRODUCTION

Rodents and lagomorphs have never been implicated as a source of a human case of rabies in the United States and are not considered natural reservoirs. However, occasionally these animals are involved in potential rabies exposures to humans and other species (Winkler, 1991). Species in these two mammalian orders are susceptible to rabies (Winkler et al., 1972; Dowda and DiSalvo, 1984). They should be evaluated when the behavior of the animal and the human or domestic animal contact suggest a risk of rabies infection. Thousands of these animals are tested for rabies each year in the United States (Fishbein et al., 1986; Moro et al., 1991), and public health officials are frequently asked to evaluate the need for postexposure treatment following human exposures to these mammals.

The small size of most rodents and lagomorphs and the infrequency with which they might survive injuries sustained during encounters with rabid carnivores presumably contribute to their low numbers in annual reports of wildlife rabies. However, since 1980, rabies has been increasingly reported in one of the largest native North American rodents, the woodchuck (*Marmota monax*) (Fishbein et al., 1986). Most reports have originated from the eastern United States in areas of epizootic raccoon (*Procyon lotor*) rabies (Jenkins and Winkler, 1987; Krebs et al., 1995). This large rodent can exhibit aggressive behavior and initiate unprovoked attacks when rabid, and human exposures have resulted (Moro et al., 1991; Winkler, 1991). Here we review reports of confirmed rabies infections in rodents and lagomorphs received by the Centers for Disease Control and Prevention (CDC) from 1985 to 1994 from throughout the United States, and detail important trends in woodchuck rabies.

MATERIALS AND METHODS

Confirmed rabies cases reported to CDC by state departments of health in monthly animal rabies surveillance reports for 1985 to 1994 were compiled by year, state, county, and species. Only cases from the orders Rodentia and Lagomorpha were reviewed here, although some data from other species were used for examining corresponding disease patterns in woodchucks. All states diagnosed cases by direct immunofluorescence (Valleca and Forester, 1981). Each state that reported a rodent or lagomorph case was contacted in an attempt to obtain details on the species of animal reported. Unfortunately, most states did not speciate animals submitted for testing. In many cases an animal was identified as domestic (a pet) or nondomestic (wild or feral). The total number of rodents and lagomorphs tested was also not available, as many states reported only positive findings to CDC.

Few states identified the rabies virus variants associated with rodents or lagomorphs. However, identification of rabies virus variants obtained from rodents or lagomorph specimens submitted to CDC was made through monoclonal antibody analyses (Smith et al., 1986) or reverse transcription-polymerase chain reaction amplification of a segment of the nucleoprotein gene followed by nucleotide sequencing (Smith et al., 1992).

Statistical analyses were made by using SPSS software and specific tests are detailed in the results (Norusis, 1993). To assess the association between the number of cases of rabies in raccoons and woodchucks, raccoon cases were compiled only from states within or adjacent to the natural geographic range of woodchucks (Hall and Kelson, 1959). To establish the spatial relationship between rabies in woodchucks and the epizootic front of raccoon rabies, maps were prepared on which woodchuck and raccoon rabies cases were plotted for each year between 1991 and 1994. The temporal association between reports of rabies in woodchucks and cases in raccoons, bats (species not available), foxes (*Vulpes vulpes* or *Urocyon cinereoargenteus*), and skunks (mainly *Mephitis mephitis*) that occurred in states in, or adjacent to, the geographical range of woodchucks was assessed by time-series analysis of monthly totals for each species over the 48-mo period from 1991 to 1994 (the interval that reports of rabies in raccoons were most prevalent) (Norusis, 1993). Cross-correlations generated for reported rabies cases by month for each species pair permitted conclusions concerning whether one temporal series could be predicted from a second. Correlation-coefficients were produced for each 1-mo lag introduced into the analysis. Lags were negative or positive depending on which species was used as the lead species in predicting the future values of the second. Prior to performing time-series analyses each series of data was differenced (that is, each value in the series was replaced by the difference between adjacent values in the original series) to produce a stationary series in which the mean and variance were similar throughout the series (Norusis, 1993).

RESULTS

A total of 368 cases of rabies in rodents and lagomorphs were reported from 22 states between 1985 and 1994 (Table 1); this represents a 354% increase from the 104 reports of rabid rodents and lagomorphs in the 14-yr period from 1971 to 1984. Northeastern and mid-Atlantic states of the U.S. (Connecticut, n = 19; Delaware, n = 14; Massachusetts, n = 21; Maryland, n = 60; New Hampshire, n = 7; New Jersey, n = 56; New York, n = 66; Pennsylvania, n = 60; and Virginia, n = 17) had the majority of cases (87%). These states were within the area that experienced the recent epizootic of raccoon rabies.

The most commonly reported rabid rodent or lagomorph species was the woodchuck, accounting for 317 (86%) of the 368 cases, up 473% from the previous 14-yr period. The number of woodchuck cases reported increased to 55 in 1991 from 19 in 1984, and has remained nearly constant since 1991. The increase in cases of rabies in woodchucks was correlated with reported cases of raccoon rabies from the same geographical area ($R^2 = 0.92$, $P < 0.0001$; Fig. 1).

Reports were also markedly higher for beavers (*Castor canadensis*; n = 12), which were primarily reported from states recently experiencing the epizootic of raccoon rabies (New York, n = 5; Virginia, n = 3; New Jersey, n = 1; South Carolina, n = 1; Maryland, n = 1; and Pennsylvania, n = 1). Most small rodents were not speciated; however, all mice and rats were reported to be wild, not pets. Of the 17 rabbits reported rabid, 11 were reported as domestic and six were unidentified.

Based on monoclonal antibody or genetic characterization of six rabies virus variants obtained from woodchucks (n = 2) or domestic rabbits (n = 4), infection resulted from the predominant rabies virus variant present in terrestrial wildlife from

TABLE 1. Reported number of rabid rodents and lagomorphs in the U.S. by year, 1985 to 1994. Totals from the previous 14-yr period are also shown. Both common and scientific names, when available, are given.

Animal	Year											
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Total	1971–84[a]
Woodchuck (*Marmota monax*)	16	14	10	22	11	25	55	51	59	54	317	67
Rabbit (11 *Oryctolagus cuniculus*, domestic; 6 unknown)	2	0	0	1	3	1	2	3	1	4	17	7[b]
Beaver (*Castor canadensis*)	0	0	2	0	1	0	3	1	3	2	12	2
Squirrel (2 *Sciurus niger*, 1 *Sciurus carolinensis*, 1 *Spermophilus tridecemlineatus*, 1 *Glaucomys volans*, 7 unknown)	4	0	0	1	4	1	1	1	0	0	12	12[c]
Rat	0	0	0	1	1	0	0	0	0	0	2	4[d]
Mouse	1	0	0	0	1	0	0	0	0	0	2	1[e]
Muskrat (*Ondatra zibethicus*)	0	0	0	0	0	0	0	1	1	0	2	7
Chipmunk	0	0	0	0	0	0	0	0	0	1	1	2[f]
Nutria (*Myocastor coypus*)	0	0	0	0	0	0	1	0	0	0	1	0
Porcupine (*Erethizon dorsatum*)	0	0	0	0	0	0	1	0	0	0	1	0
Prairie dog	0	1	0	0	0	0	0	0	0	0	1	0
Total	23	15	12	25	21	27	63	57	64	61	368	104

[a] Data from Fishbein et al. (1986).
[b] 4 *Oryctolagus cuniculus*, 3 *Sylvilagus floridanus*.
[c] 6 *Sciurus carolinensis*, 1 *Sciurus niger*, 1 *Spermophilus tridecemlineatus*, 4 *Glaucomys volans*.
[d] 3 *Rattus* sp., 1 *Neotoma floridana*.
[e] 1 *Mus musculus* (White).
[f] 2 *Tamias striatus*.

the same geographic area (Table 2). All rabies variants identified from eastern states were raccoon, while skunk variants were identified from the midwestern states.

Based on maps of individual cases of rabies in woodchucks by county from 1991 to 1994, there was a strong association of reports of rabies in this species with the northern and eastern epizootic front of rabies in raccoons (Fig. 2). There were significant ($P < 0.05$) periodic cross-correlations in the time-series analyses of rabies in woodchucks with both terrestrial carnivores and bats. Based on a 1-yr (12 positive and 12 negative lags) window, cases of raccoon and skunk rabies were leading indicators of woodchuck cases with a lag of about 3 mo (−3 on lag axis; Fig. 3). With skunks there was a second strong annual cross-correlation, with woodchucks as a leading indicator, at 3 mo (3 on lag axis). Reports of rabid bats were significantly cross-correlated with woodchucks at positive and negative lags separated by about 12 mo.

DISCUSSION

Since the late 1970's, and the development of the mid-Atlantic epizootic of raccoon rabies, most rabies cases reported in rodents have been in woodchucks (Fishbein et al., 1986; Krebs et al., 1995). From 1953 to 1970, various species of squirrels accounted for 119 (32%) of 376 cases of rabies in rodents and lagomorphs, while woodchucks contributed 55 (15%) (Wink-

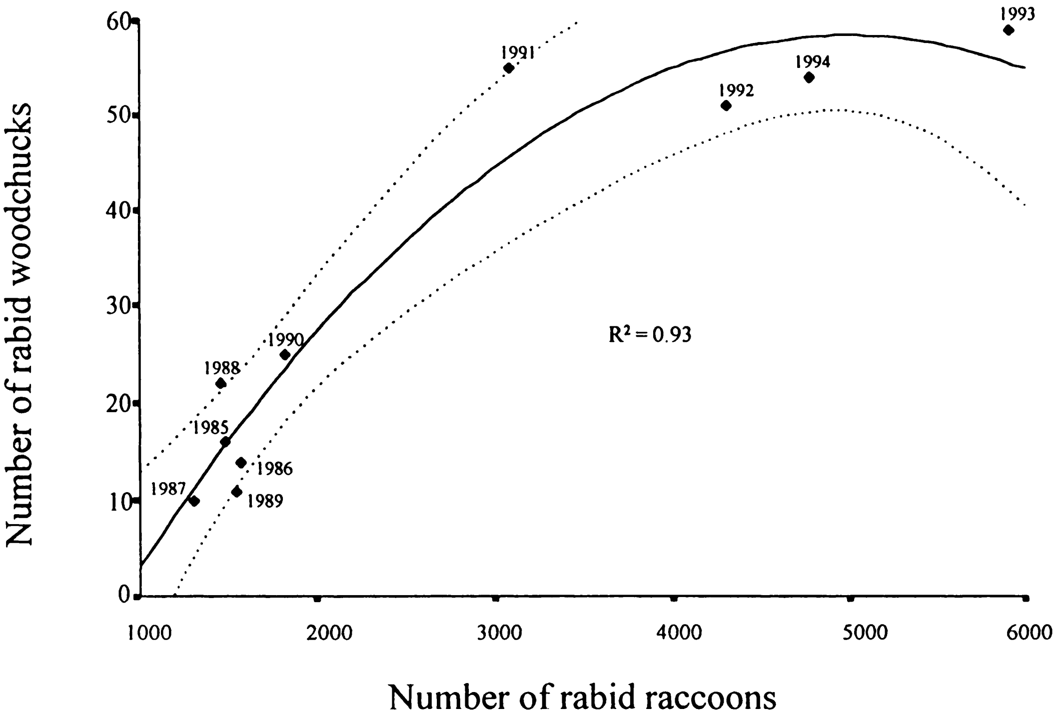

FIGURE 1. Significant correlation of reports of rabid woodchucks from 1985 to 1994 with cases of rabies in raccoons ($W = -27.93 + 0.035R - (3 \times 10^{-6})R^2$, $P < 0.001$, where W = number of rabid woodchucks and R = number of rabid raccoons). Since 1991, cases of rabies in raccoons have reached an apparent asymptote. Only rabies statistics from states within the geographical range of woodchucks were used in the analyses. The 95% confidence interval is shown by the dashed lines.

ler, 1972). In addition to woodchucks, there has been a marked increase in reports of rabies in beavers from the same region (Table 1). These two rodents are among the largest in North America (Hall and Kelson, 1959), and presumably are highly noticeable and more likely to be submitted to a state laboratory for rabies testing if involved in human or domestic pet exposures. It is also likely that these rodents may survive the bite from a rabid carnivore and live through the incubation period to develop clinical rabies. Reports of rabies in other rodents continued to be rare. No rabies was documented between 1985 and 1994 from wild, indigenous rabbits, while four eastern cottontails (*Sylvilagus floridanus*) of seven rabbits were reported rabid between 1971 and 1984 (Fishbein et al., 1986).

TABLE 2. Results of laboratory testing of rabies virus variants obtained from rodents or lagomorphs, 1985 to 1994.

Year	State	Animal	Rabies virus variant
1985	Texas	Rabbit (domestic)	Skunk (South central variant)
1989	South Dakota	Rabbit (domestic)	Skunk (North central variant)
1993	New Hampshire	Rabbit (domestic)	Raccoon
1993	Virginia	Woodchuck	Raccoon
1993	New Hampshire	Woodchuck	Raccoon
1994	Delaware	Rabbit (domestic)	Raccoon

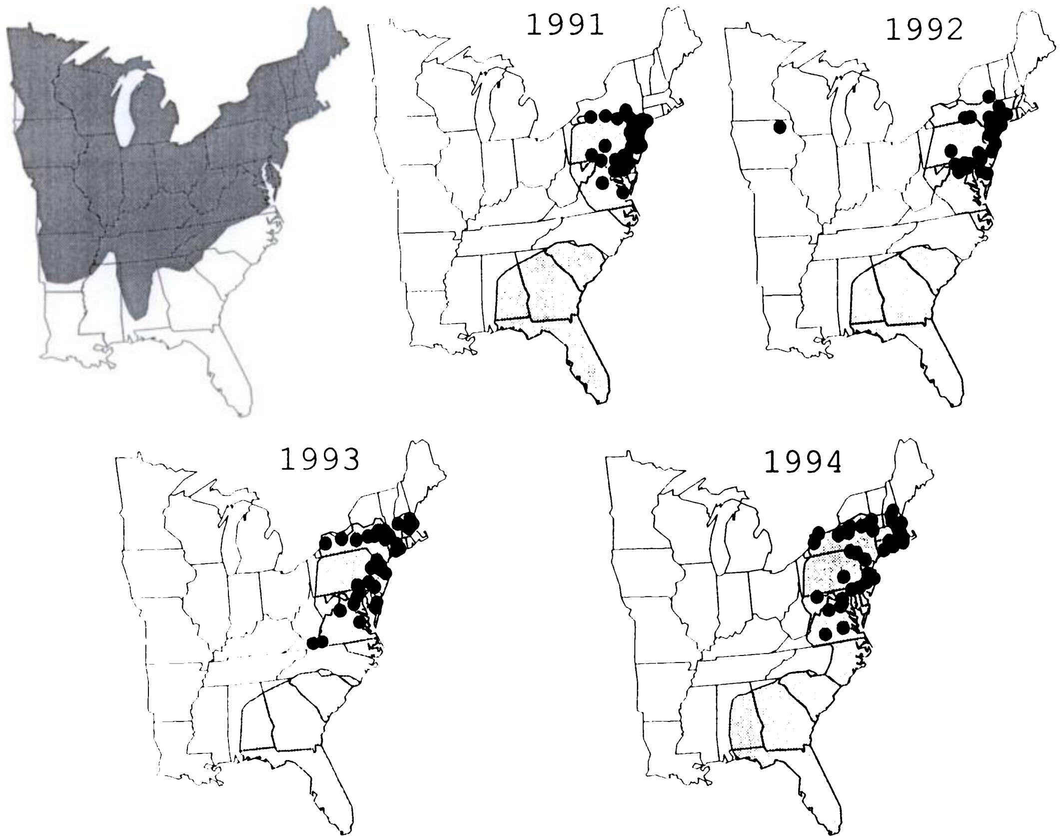

FIGURE 2. Individual reports of rabid woodchucks (●) from 1991 to 1994 and their proximity to the northern and eastern fronts of the geographic area affected by the mid-Atlantic variant of rabies virus associated with raccoons (shown by the light gray shading). The geographic range of the woodchuck in the eastern United States is shown in the dark gray area on the upper left map (Hall and Kelson, 1959).

The increase in cases among woodchucks appeared to result from interactions with raccoons or other animals (including woodchucks) that had been infected with the raccoon-associated variant of rabies virus in areas of enzootic raccoon rabies. This conclusion is based on the characterization of rabies virus variants obtained from these rodents (Table 2), as well as temporal and spatial correlations between reports of rabies in woodchucks and raccoons (Figs. 1 to 3). Woodchucks were only rarely reported from midwestern states experiencing enzootic skunk rabies; one case was reported from Iowa between 1985 and 1994. In reports on rodent and lagomorph rabies during the period 1953 to 1970, Winkler (1972) failed to find any significant geographic or temporal patterns. The fact that no cases of rabies in woodchucks were reported from the long-standing enzootic area of raccoon rabies in the southeastern United States (Bigler et al., 1973) is purely attributable to the geographic range of *M. monax* (Fig. 2), which does not include this region. As the region experiencing enzootic raccoon rabies expands, an increasing area overlapping the geographic range of woodchucks will presumably produce infected woodchucks. As raccoon rabies becomes enzootic in an area, sporadic cases of rabies in woodchucks can be anticipated; there is no indication that raccoon rabies disappears from a region once it has been introduced, although

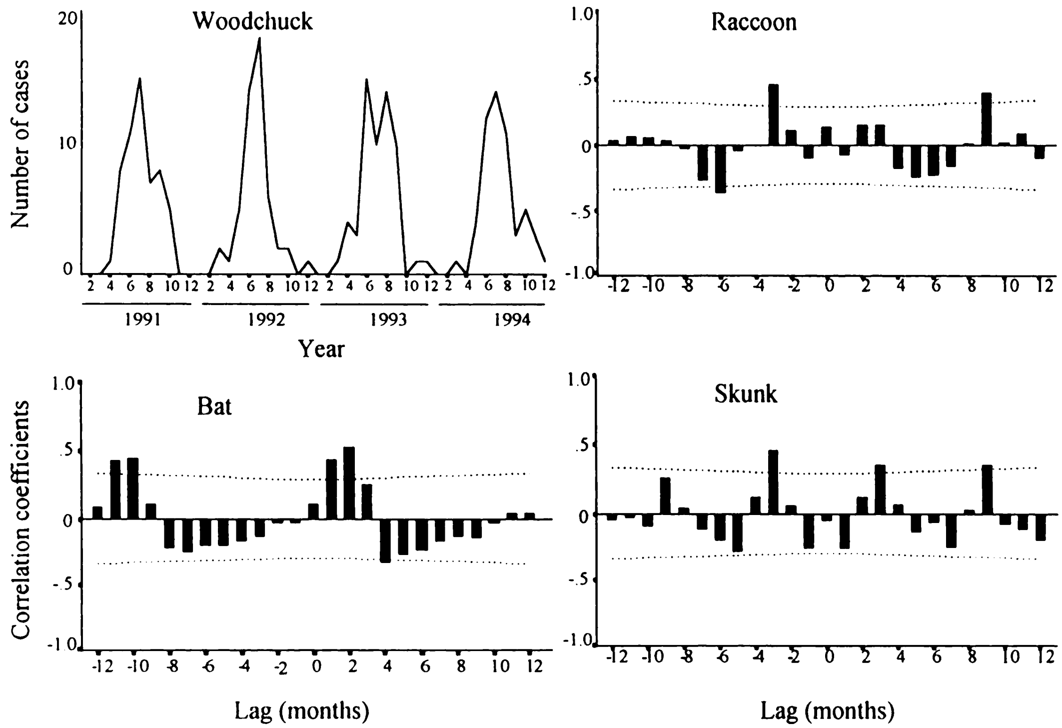

FIGURE 3. The monthly distribution of cases of rabies in woodchucks from 1991 to 1994 (upper left panel), and time-series analyses of the monthly cases of woodchuck rabies cross-correlated with monthly totals of rabid raccoons, skunks, and bats. Only rabies statistics from states within the geographical range of woodchucks were used in the analyses. Monthly lags of 12 to 12 months are represented, as patterns tended to repeat at predictable intervals due to the seasonal nature of rabies reporting in wildlife. The 95% confidence interval is shown by the dashed lines.

cases fluctuate annually (Rupprecht and Smith, 1994).

Despite these associations, the actual species that transmit rabies to woodchucks remain speculative. There were significant cross-correlations between monthly reports of rabies in woodchucks and raccoons, skunks, and bats identified by time-series analysis. These significant cross-correlations were expected, as reported cases of rabies in woodchucks had strong summer peaks (Fig. 3), and reported cases of rabies from most other wildlife had similar strong seasonal peaks. Based on annual surveillance reports such as Krebs et al. (1995), skunk rabies had two very distinct peaks, one in the spring and one in the fall. These resulted in the bimodal pattern when cross-correlated with woodchuck cases, as the spring peak in skunk cases preceded and the fall peak followed peak rabies reports in woodchucks (Krebs et al., 1995). Based on annual reports, temporal occurrence of rabies in raccoons was similar to the skunk pattern but was more evenly distributed over time (Krebs et al., 1995). Reported cases of rabid bats have dominant fall peaks (Childs et al., 1994).

Woodchucks, raccoons, and skunks share habitats such as cultivated or grassy fields surrounded by forests where interaction between species could occur. Striped skunks (*M. mephitis*) may be considered likely suspects in the transmission of rabies to woodchucks because they readily enter burrows of other animals and will use them as den sites (Godin, 1982). However, the lack of reports of rabies in woodchucks from the midwestern states where skunk rabies is common presents an interesting contrast, which may not reflect biological factors. Each state may have unique protocols dictating which animals are submitted for rabies testing. Some states will not test any rodents, while other states test hundreds each year. As most animals are submitted as a result of human or domestic animal contact, woodchucks living in areas of high human population density (such as the Northeast or the mid-Atlantic region) may be more likely to be submitted.

The apparent saturation effect, where annual numbers of reported rabies cases in woodchucks have approached an asymptote, even as numbers of other wildlife rabies cases rise (Fig. 1), may have a biological cause or may reflect the above-mentioned variation in rabies-testing procedures. The data may be evidence that contact rates among woodchucks and other rabid mammals were at a level where further increases in wildlife rabies no longer produced additional rabid woodchucks.

Rabies is reported relatively infrequently in rodents and lagomorphs, and contact with these animals rarely necessitates human postexposure treatment for rabies. However, since the possibility of rabies virus transmission to humans or domestic animals from these animals exists, testing of rodents and lagomorphs for rabies should be considered on a case-by-base basis (Centers for Disease Control and Prevention, 1991; National Association of State Public Health Veterinarians, 1994). Local health authorities should be consulted to help evaluate the circumstances leading to the contact and to assess the necessity for postexposure treatment.

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LITERATURE CITED

BIGLER, W. J., R. G. MCLEAN, AND H. A. TREVINO. 1973. Epizootiologic aspects of raccoon rabies in Florida. American Journal of Epidemiology 98: 326–335.

CENTERS FOR DISEASE CONTROL AND PREVENTION. 1991. Rabies prevention—United States, 1991. Recommendations of the Immunizations Practices Advisory Committee (ACIP). Morbidity and Mortality Weekly Report 40$_{S}$RR-3: 1–19.

CHILDS, J. E., C. V. TRIMARCHI, AND J. W. KREBS. 1994. The epidemiology of bat rabies in New York State, 1988–92. Epidemiology and Infection 113: 501–511.

DOWDA, H., AND A. F. DISALVO. 1984. Naturally acquired rabies in an eastern chipmunk (*Tamias striatus*). Journal of Clinical Microbiology 19: 281–282.

FISHBEIN, D. B., A. J. BELOTTO, R. E. PACER, J. S. SMITH, W. G. WINKLER, S. R. JENKINS, AND K. M. PORTER. 1986. Rabies in rodents and lagomorphs in the United States, 1971–1984: Increased cases in the woodchuck (*Marmota monax*) in mid-Atlantic states. Journal of Wildlife Diseases 22: 151–155.

GODIN, A. J. 1982. Striped and hooded skunks. *In* Wild mammals of North America, J. A. Chapman and G. A. Feldhamer (editors). The Johns Hopkins University Press, Baltimore, Maryland, pp. 674–687.

HALL, E. R., AND K. R. KELSON. 1959. The mammals of North America. Ronald Press, New York, New York, pp 1–1083.

JENKINS, S. R., AND W. G. WINKLER. 1987. Descriptive epidemiology from an epizootic of raccoon rabies in the Middle Atlantic States, 1982–1983. American Journal of Epidemiology 126: 429–437.

KREBS, J. W., T. W. STRINE, J. S. SMITH, C. E. RUPPRECHT, AND J. E. CHILDS. 1995. Rabies surveillance in the United States during 1994. Journal of the American Veterinary Medical Association 207: 1562–1575.

MORO, M. H., J. T. HORMAN, H. R. FISCHMAN, J. K. GRIGOR, AND E. ISRAEL. 1991. The epidemiology of rodent and lagomorph rabies in Maryland, 1981 to 1986. Journal of Wildlife Diseases 27: 452–456.

NATIONAL ASSOCIATION OF STATE PUBLIC HEALTH VETERINARIANS. 1994. Compendium of animal rabies control, 1994. Journal of the American Veterinary Medical Association 204: 173–176.

NORUSIS, M. J. 1993. SPSS for Windows base system user's guide release 6.0, SPSS Inc., Chicago, Illinois, pp. 615–624.

RUPPRECHT, C. E., AND J. S. SMITH. 1994. Raccoon rabies: The re-emergence of an epizootic in a densely populated area. Seminars in Virology 5: 155–164.

SMITH, J. S., F. L. REID SANDEN, L. F. ROUMILLAT, C. TRIMARCHI, K. CLARK, G. M. BAER, AND W. G. WINKLER. 1986. Demonstration of antigenic variation among rabies virus isolates by using monoclonal antibodies to nucleocapsid proteins. Journal of Clinical Microbiology 24: 573–580.

———, L. A. ORCIARI, P. A. YAGER, H. D. SEIDEL, AND C. K. WARNER. 1992. Epidemiologic and historical relationships among 87 rabies virus isolates as determined by limited sequence analysis. The Journal of Infectious Diseases 166: 296–307.

VALLECA, W. M., AND F. T. FORESTER. 1981. Laboratory methods for detecting rabies, U.S. Government Printing Office, Washington, D.C., pp 1–155.

WINKLER, W. G. 1972. Rodent rabies in the United States. The Journal of Infectious Diseases 126: 565–567.

———. 1991. Rodent rabies. *In* The natural history of rabies, G. M. Baer (editor). CRC Press, Boca Raton, Florida, pp. 405–410.

———, N. J. SCHNEIDER, AND W. L. JENNINGS. 1972. Experimental rabies infection in wild rodents. Journal of Wildlife Diseases 8: 99–103.

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