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A DESCRIPTIVE EPIDEMIOLOGICAL STUDY OF RACCOON RABIES IN A RURAL ENVIRONMENT

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ABSTRACT: A recent outbreak of rabies in raccoons, *Procyon lotor* (L.), in Loudoun County, Virginia (1981–82), prompted a study of the epidemiology of the disease. Parameters studied included the occurrence and movement of the disease over time, sex and age relationships, and behavior patterns of raccoons. During the 18 mo, 427 raccoons were tested, of which 75% were infected with rabies virus. Interpretation of rainfall data and the subsequent spatial occurrence of infected raccoons within the county indicated a cause and effect relationship. The submission rate of female raccoons was greater than that of males. The female raccoons (adult and juvenile) were also found to be infected with the virus more often than the males. Behavior of infected raccoons in a rural environment was similar to those observed in the southeastern United States during earlier epizootics of rabies. The presence of a skunky odor on infected raccoons may be a characteristic of raccoon rabies.

INTRODUCTION

The current rabies epizootic in raccoons in the Mid-Atlantic region of the United States began in 1977 with one confirmed rabid raccoon from West Virginia. By 1980 35 rabid raccoons had been confirmed in West Virginia and Virginia, with evidence that the disease was progressing primarily eastward into Virginia. The disease spread rapidly through northern Virginia in 1981–82 before crossing the Potomac River into Maryland (Jenkins, 1984). In the 5-yr period (1978–82), over 760 rabid raccoons were confirmed in Virginia, 745 of which occurred in 1981–82. Before this epizootic began, Virginia had recorded only 29 rabid raccoons during the previous 30 yr (1950–80) (Virginia Department of Health, 1983).

Most of the previous epidemiological data on raccoon rabies has been collected from the southeastern region of the United States, particularly from Florida and Georgia (McLean et al., 1971; Bigler et al., 1973; McLean, 1975). Prior to 1981, over 90% of all the reported cases of raccoon rabies in the United States were from the southeastern region (Centers for Disease Control, 1981).

The county in Virginia that reported the largest number of cases during 1981–82 was Loudoun County, located approximately 40 km northwest of Washington, D.C., in a rural area (Fig. 1). Approximately 42% of the infected raccoons reported in Virginia in 1981–82 were from Loudoun County (Virginia Department of Health, 1983). The Loudoun County Health Department began a study of raccoon rabies in 1981 when it became apparent that the confirmed cases were not sporadic in occurrence. The objectives of the study were fourfold: to identify the current areas affected within the county and to monitor trends of occurrence in the disease; to determine if the prevalence of rabies in raccoons varied with gender or age; and, to compare behavior patterns of rabid and non-rabid raccoons.

The chi square test was used to test the significance of "skunky odor" on rabid vs. non-rabid raccoons. Statements of statistical significance refer to $P < 0.05$.

MATERIALS AND METHODS

To determine the severity of the problem and the areas affected within the county, all raccoons that were submitted were tested, includ-

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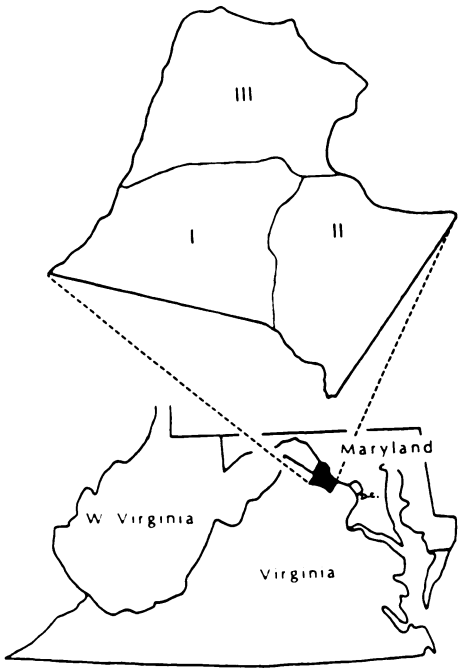

FIGURE 1. Map showing location of Loudoun County, Virginia. Insert shows the three sections of Loudoun County where comparisons were made during the study.

ing road-kills and those found dead. This method of sampling was a departure from normal health department procedures; in the past only those animals which had contact with humans or their pets were tested.

Raccoons submitted for testing were collected by the Loudoun County Health Department with assistance from local law enforcement officers, county animal wardens, and the general public. The Fairfax County Health Department Laboratory performed the fluorescent antibody (FA) test on all the samples. Future reference to a "positive" or "infected" raccoon indicates a positive FA test.

In 1981 general locations of positive raccoons were recorded. This was further refined in early 1982 to include distances from the nearest road intersection to the location of the sample. Monthly maps and quarterly maps were composed to show trends throughout 1982.

The intersection of two major highways divided the county into three sections of approximately equal areas (Fig. 1). This division also marked the "confirmed limits" of the disease as observed in 1981, and was the approximate division line between two major geologic provinces (upland Piedmont and lowland Piedmont) (=triassic) (Weber, 1982). The location of each positive raccoon was placed in the appropriate section. Each section was then compared to the other two sections by quarter in terms of raccoons submitted, number of positive raccoons, and spatial occurrence to determine trends. The sex and age (adult or juvenile) of raccoons were determined using the methods described by Sanderson (1961) and Grau et al. (1970).

A list of behavioral characteristics used by McLean (1975) was modified to include human contact, contact with dogs, acted strange, "drunk," appeared normal, and skunk odor. Questions regarding the behavior of the raccoons were structured so as to limit bias in the answers. The observer was asked only to describe what was observed, including the location and the time the animal was observed.

RESULTS

The first lab-confirmed rabid raccoon was in July 1981. Prior to this, only seven raccoons were submitted for testing (January–June). During the next 6 mo, 70 raccoons were tested, 46 of which were infected. In 1982 352 raccoons were tested with 268 confirmed positive (76%).

Raccoon submissions varied by season as 13% of the 427 raccoons were submitted during the winter months (December–February), 23% during the spring (March–May), 30% during the summer (June–August), and 34% during the fall months (September–November). Although the submissions varied seasonally, the percentages of infected raccoons by season remained constant (74%).

In 1981 raccoons were submitted almost entirely from section I and the western area of section II (Fig. 1). Ninety-three percent of the raccoons tested (71 of 76) and 98% (46 of 47) of the infected raccoons were submitted from this area, which encompassed a single watershed (Goose Creek). Only five raccoons were submitted from section III during 1981, all of which were negative. During 1982, however, the number of raccoons submitted from section III was equal to the number submitted from sections I and II combined. Table 1 illustrates movement of the

disease through the three sections of the county on a quarterly basis.

Accurate records on the sex and age of raccoons submitted were not initiated until March 1982. Data on sex and age were recorded for 97% of the raccoons submitted between March and December 1982 ($n = 318$). Females comprised 60% of our samples and 64% of the positive raccoons ($P < 0.05$). The prevalence in females was 81% compared with 69% for the males. Adult raccoons had a slightly higher prevalence than juveniles (78% to 73%).

The female to male ratio was 2:1 during the early summer–early fall months. Prior to and after this period, both sexes were submitted in approximately equal numbers.

The submission rate of kits began to increase during September 1982 (4), peaked in October (11), and decreased in November–December (5 and 3). During this period, 23 kits were submitted and 18 were positive. The prevalence of infection of kits reached a peak in October, when all 11 submitted were found to be infected.

In 1981 only those raccoons which were confirmed to be positive for rabies were documented as to behavior exhibited. Forty-seven percent were observed during the day, 24% appeared aggressive, 39% acted drunk/strange, 29% had contact with dogs, and 24% had a skunky odor. Behaviors that appeared to characterize rabid raccoons in 1981 were prevalent in 1982 also. Characteristics most often reported in 1982 were acting "drunk" or "strange." The percentages of infected and non-infected raccoons exhibiting various behaviors are shown in Table 3. Approximately 25% of the infected raccoons in 1982 were noted to have a "skunky odor" as compared with 6% of the non-infected raccoons ($P < 0.05$).

DISCUSSION

The results of this sampling program (75% of the raccoons tested were infected) indicated that rabies was widespread in the raccoon population of Loudoun County, whereas previous studies in Florida indicated that 3% to 36% of the raccoons tested were positive (McLean, 1975). Although a slight seasonal trend was observed in the submission of raccoons (summer–fall), submissions were not influenced by the raccoon breeding season as indicated in Florida (Bigler et al., 1973). The raccoon breeding season in Virginia occurs during January–March (Bromley et al., 1979). Only 16% (67 out of 427) of the raccoons tested (1981–82) were submitted during this period. This variation between Bigler's studies and the results obtained in Loudoun County was probably due to the late seasonal initiation of the disease (July) and that the submissions of raccoons during the breeding season were generally from the less populated areas of the county.

The initiation of the disease in 1981, and its rapid progression through the county in 1982, appeared to be linked to environmental and geographical factors. Precipitation data from the National Weather Service Station at Dulles International Airport (1983) and Gregg (1983) showed that between September 1980 and July 1981 the county received only 85% of the normal amount of rainfall (−13.75 cm).

TABLE 1. Geographical progression of rabies as indicated by the prevalence of infected raccoons found in the three sections of Loudoun County, Virginia, by quarter (1981–82).

	Prevalence (%) of rabies infection					
	1981		1982			
Section	3rd qtr	4th qtr	1st qtr	2nd qtr	3rd qtr	4th qtr
I	86*	88	51	36	14	20
II	14	12	25	31	24	14
III	0	0	24	33	62	66
No. of infected raccoons	21	26	47	86	79	56

* Percentage of the quarter's infected raccoons found in each section.

TABLE 2. Sex and age composition of all raccoons and of infected raccoons submitted during March–December 1982, Loudoun County, Virginia.

	Total no. sexed or aged	Percentage of total	
		Males	Females
Sex	311	40	60
Sex, infected	238	36	64
Adult	203	43	57
Adult, infected	159	40	60
Juvenile	106	33	67
Juvenile, infected	77	27	73

TABLE 3. Behavior of raccoons that were submitted for suspected rabies from Loudoun County, Virginia, in 1982.

Behavior[a]	% Positive[b] (n = 226)	% Negative (n = 55)
Out during day	78	40
Observed near dwelling	44	33
Contact with dogs	37	10
"Drunk"[c]	28	15
Acted "strange"[d]	26	7
Out during night	20	29
Aggressive	11	7
Appeared "normal"	6	38
Human contact	3	19
Skunk odor[e]	25	6

[a] Adapted and modified from McLean (1975).
[b] Percentages do not include those raccoons found dead (20%).
[c] Unsteady or wobbling gait, including signs of paralysis or appearing sick.
[d] Erratic behavior, confused, indifferent to human or animal presence.
[e] Skunk odor noted, including those found dead.

The Goose Creek watershed, the only area in which the disease was confirmed in 1981, is the largest watershed in the county. The reduction of favorable habitats and the influx of displaced raccoons into the area due to the rainfall deficit may have led to physiological stress in the form of increased intra-specific competition, hormonal, and neurological changes. Subsequently, a lower resistance to an introduced disease such as rabies may result (Kendeigh, 1974; Vaughan, 1978). A stress-related rabies epizootic in raccoons in Florida in 1969 was also suggested by McLean (1975) although the major factor appeared to be related to habitat destruction (Bigler et al., 1973).

Quarterly analyses of the locations of submitted raccoons in 1982 indicated that the disease progressed predominately northward with a slight movement eastward. Geology and geography appear to have been major factors as both section I and III are part of the upland Piedmont province with rolling to steep topography (Weber, 1982). Both are characterized by large tracts of cultivated land (corn), pastures, hardwoods, and many streams which would be considered good habitats (Bromley et al., 1979; Kaufmann, 1982). Section II, however, lies in the lowland Piedmont province which is predominately flat topographically with few streams. Approximately 40% of the human population of Loudoun County resides in section II (U.S. Census, 1980), therefore, the low number of raccoons submitted from this area would appear to be habitat-related. Studies have indicated that suburban areas generally maintain higher raccoon population densities than found in rural areas (Bromley et al., 1979; Lotze and Anderson, 1979; Kaufman, 1982).

The Loudoun County study, conducted at the height of the epizootic and geographically limited, indicated slight differences in the apparent sex and age structure of the raccoon population from those in Florida and Georgia. Bigler et al. (1973) observed that in most of the epizootic areas in Florida and Georgia, adult males were sampled at a higher frequency than females, although females were found to have a higher prevalence than males. Data collected in Loudoun County supported this last observation, as 64% of the positive raccoons were females (Table 2).

Although the breeding cycle (mating, pregnancy, and parturition) appears to be a major factor in the transmission of the virus (Bigler et al., 1973; McLean, 1975), other factors should not be overlooked.

The male population (density and age structure) may be another factor, as a sexually mature male raccoon may mate with several females (Kaufmann, 1982). It is possible, therefore, for an infected male to transmit the virus to more than one female. Stress of pregnancy may also make the female more susceptible to the infection. However, 34% of the raccoons tested in 1982 were juvenile (sub-adult and kits). The prevalence for the juvenile females tested was 72% (56 out of 77), indicating that the breeding cycle is not the major factor for the high prevalence rate in females. As this group had not reached sexual maturity, other factors must be considered.

The results of our studies on the behavior of infected raccoons in a rural environment were similar to the data on infected raccoons from areas of dense human population as reported from Florida and Georgia (Kappus et al., 1970; Bigler et al., 1973). Raccoons observed during daylight hours close to human dwellings or having contact with dogs were major factors in the submission of these animals rather than the fact that they were exhibiting clinical signs. Eighty percent of the raccoons submitted for the above reasons were positive for rabies virus.

One characteristic that was noted early in the epizootic in Loudoun County was a "skunky odor" that was found predominately on infected raccoons. The odor appeared to be related to anal gland secretion and hygiene of the infected raccoon (Carey and Hubbard, pers. comm.). Loss of voluntary muscle control to the anal glands would result in the raccoon fouling itself unintentionally and, thereby, producing the odor. Hyperstimulation of the glands due to hyperexcitability also causes excessive secretions of the glands. With the obvious exception of skunks, this odor was detected on raccoons only. Further studies are needed to determine if this observation can be reliably used as an additional characteristic of raccoon rabies.

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BOOK REVIEW . . .

Chemical Immobilization of North American Wildlife, L. Nielson, J. C. Haigh, and M. E. Fowler, eds. Wisconsin Humane Society, Inc., 4151 North Humboldt Avenue, Milwaukee, Wisconsin 53212, USA. 1982. 447 pp. $18.50 US.

The book, "Chemical Immobilization of North American Wildlife" is a compilation of 29 manuscripts written by researchers, veterinarians and wildlife biologists which form the proceedings of the North American Symposium: Chemical Immobilization of Wildlife held April 4–6, 1982 in Milwaukee, Wisconsin and sponsored by the Wisconsin Humane Society.

This publication represents the first readily accessible source of information specifically relating to the chemical restraint of North American species of mammals, birds and reptiles. The first 164 pages deal with technological, pharmacological, medical and physiological aspects of restraint relating primarily to mammalian species. The subsequent 284 pages of this lengthy proceedings focus on chemical and physical restraint of North American species including, most specifically ruminants, carnivores and very generally birds and reptiles. Although this represents the general format a few papers are unfortunately out of sequence. The text contains a large number of charts (some of which are confusing), line drawings, and black and white photographs of moderate quality. As with most symposia proceedings no index is provided. The text does suffer some of the problems inherent to proceedings of symposia including: (1) the formats of the papers are inconsistent, (2) the quality of the papers varies greatly, and (3) some of the papers are highly technical and well edited while a few are superficial, contain erroneous information, and are poorly edited. Additionally, much of the initial 164 pages contains information which has been published previously in other texts dealing with chemical restraint and medical care for captive and free-living wildlife. In contrast some papers, such as "Mechanical Capture as a Preliminary to Chemical Immobilization and the Use of Taming and Training to Prevent Post Capture Stress" and "Chemical Immobilization of Captive White-tailed Deer and the Use of Automatic Blood Samplers," present recent and novel approaches to problems which have persisted in the arena of chemical restraint for years. Although the title of the text identifies chemical immobilization as the major topic, inhalation (volatile) anesthesia is only mentioned in the paper titled "Chemical Immobilization of Birds." It is unfortunate that the critical topics of respiratory physiology, assisted ventilation, and remedial respiratory therapy were not addressed as important aspects of chemical restraint in animals.

Overall, this publication provides valuable information which is of practical and scientific value and should be included in the library of wildlife veterinarians, field biologists, and investigators concerned with the chemical restraint of wildlife.

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