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EPIZOOTIOLOGY OF CANINE DISTEMPER IN NEW JERSEY RACCOONS

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ABSTRACT: Seventeen epizootics of canine distemper (CD) involving at least 615 raccoons (*Procyon lotor*) were identified between 1 September 1977 and 25 March 1991 in New Jersey (USA). Epizootics occurred three times at four year intervals in three areas. Based on this cycling, the wide distribution of CD cases, and their occurrence between epizootics, I propose an enzootic status for CD in New Jersey raccoons. The peak period prevalence of raccoon canine distemper cases occurred at the end of the mating season in March. Another period of CD activity began with increased movements of the young in September. Epizootics were associated with river drainages and other wetlands. Age and sex distribution of raccoons with CD was not significantly different ($P > 0.05$) from that of an asymptomatic composite sample of four northern New Jersey raccoon populations. Lethargy was the most commonly reported clinical sign in raccoons with alert or aggressive behavior rarely observed.

Key words: Canine distemper, epizootic, epizootiology, enzootic, raccoon, *Procyon lotor*.

INTRODUCTION

Much work on canine distemper (CD) in raccoons (*Procyon lotor*) has been focused on descriptions of clinical signs, pathologic changes and diagnostic methods (Budd, 1970). Some authors have described epizootics, population densities, seasonal patterns of diagnosed cases and immunologic status of wild raccoons with CD from Florida, New York, and Missouri in the USA (Hoff et al., 1974; Monson and Stone, 1976; Evans, 1984). My objective was to identify the major epizootiologic aspects of CD in raccoons from New Jersey (USA) and to report on the entry of rabies into a raccoon population experiencing CD.

MATERIALS AND METHODS

Reports of diseased raccoons, gray foxes (*Urocyon cinereoargenteus*), striped skunks (*Mephitis mephitis*) and red foxes (*Vulpes vulpes*) were received from New Jersey (38°56′N to 41°20′N, 73°54′W to 75°30′W) between 1 September 1977 and 25 March 1991 by the Wildlife Control Unit of the New Jersey Division of Fish, Game and Wildlife. Necropsies of selected specimens were performed at the Division's Wildlife Health Project Laboratory, Clinton Wildlife Management Area, Hampton, New Jersey.

The species, date of death or submission, location, clinical signs, related cases, human or animal bite victims, age, sex and weight were determined for specimens submitted for necropsy. Gross lesions were recorded. An incisor and tissue samples from the brain, liver, kidney, spleen, lung, stomach, intestine, pancreas, lymph nodes, urinary bladder, skin and adrenal gland were fixed in 10% neutral phosphate buffered formalin. Half (sagittal section) of each brain was submitted under refrigeration to the New Jersey Department of Health Rabies Testing Laboratory (Trenton, New Jersey) for fluorescent antibody testing for rabies (Trimarchi and Debbie, 1991). The prevalence of CD cases in different species was calculated from specimens received by 30 April 1989. Based on rabies surveillance case reports, this preceded the introduction of raccoon rabies in New Jersey by 5 mo.

Fixed tissues were embedded in paraffin, sectioned at 6 μm, and stained with hematoxylin and eosin. The tissues evaluated were the epithelium of the gastrointestinal mucosa, hepatic bile ducts, urinary bladder, bronchi, bronchioles, skin, multinucleate giant cells, neurons and glial cells of the central nervous system. Eosinophilic intranuclear or intracytoplasmic inclusion bodies in at least one of these tissues were considered diagnostic of CD when associated with characteristic inflammatory responses and clinical signs (Budd, 1970; Evans, 1984). A portion of the brain, mesenteric lymph node, spleen and lung of two representative raccoons were submitted to Dr. Max Appel at the James A. Baker Institute for Animal Health (Ithaca, New York, USA) for virus isolation in mitogen-stimulated dog lymphocyte cultures (Appel et al., 1992), to confirm the histopathologic diagnosis of canine distemper.

Age determination of raccoons was based on a modification of the dental cementum method (Grau et al., 1970). An incisor was decalcified in Cal-Ex (Fisher Scientific, Orangeburg, New

York) for 24 hr, cut sagittally with a razor, embedded in paraffin, sectioned at 10 μm, stained with Leuko-Stat (Fisher Scientific) dried, and rinsed in xylene. Cementum annuli were counted. Age of each animal was estimated to the nearest month based on the capture date and April period of peak parturition of New Jersey raccoons (Slate, 1989).

Canine distemper epizootics were tentatively identified by location and duration based on reports from wildlife control officers, sportsmen, wildlife rehabilitators, municipal health officers, biologists, conservation officers, police, and the general public to the Division of Fish, Game and Wildlife's Wildlife Control Unit. The municipality, county, or drainage basin which best described the most peripheral cases, confirmed by necropsy and histopathology, defined the area of the epizootic. At each site, first time reports or ≥4-fold increases in reporting of raccoons with characteristic clinical signs of CD were used to identify the beginning of an epizootic. The epizootic's end was based on the reduction or termination of reporting.

The age and sex distributions of a sample of 86 raccoons with a histopathologic diagnosis of CD, for which both age and sex data were available and which were collected during full calendar years (1 January 1978 to 31 December 1988) were compared to a sample of 476 raccoons captured in box traps as part of a New Jersey raccoon population study (Slate, 1980a, b). These latter raccoons were asymptomatic but had been exposed to CD. One of four box-trapped populations sampled in 1977 had an antibody prevalence of 52% to CD by the serum neutralization test with a minimum titer of 1:16; it also had a low population density (1 raccoon/19 ha) (Slate, 1980b). Another population had a low CD antibody prevalence of 27% and a high population density (1 raccoon/4 ha) (Slate, 1980b). These box-trapped raccoons came from four widely separated and distinct physiographic areas in northern New Jersey and were a composite of three consecutive years (1977 to 1979) of sampling on each site. Comparison of age and sex of raccoons with CD with that of the composite asymptomatic raccoon population was done to detect any age and sex differences which could reflect a differential susceptibility to CD. Since the ages of 55 asymptomatic raccoons were given only as "adult," adults (≥1 yr) vs. juveniles (<1 yr) of both sexes were compared using the chi-square (χ^2) test (Snedecor and Cochran, 1967) with a 2 × 2 contingency table. Expected values for CD raccoons were calculated based on frequency of occurrence of juvenile males and females, and adult males and females in the composite asymptomatic raccoon population.

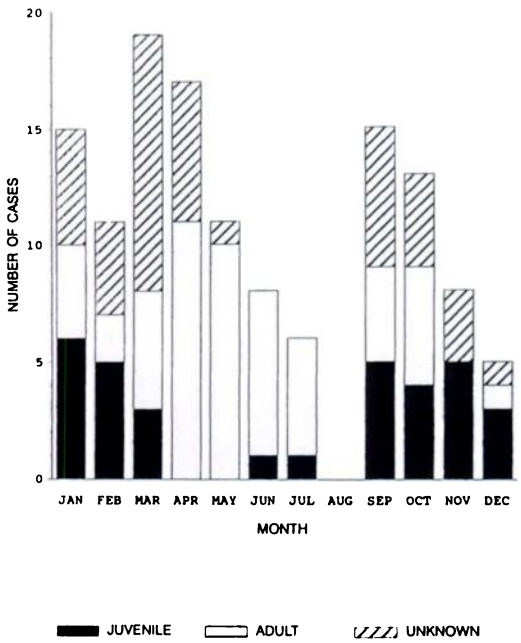

FIGURE 1. Monthly distribution of 128 raccoon canine distemper necropsy cases from New Jersey between 1 January 1978 and 31 December 1988.

RESULTS

Ninety-one (73%) of the 124 raccoons observed with clinical signs of CD were lethargic or comatose and 36 (29%) were ataxic. Intermittent seizures were reported in 30 (24%) of the cases. Four raccoons with CD bit humans.

Canine distemper virus was isolated from the tissues of two raccoons. Eosinophilic inclusion bodies were present in necrotic foci of the white matter in the cerebrum and the granular layer of the cerebellum. Encephalitis was characterized by perivascular cuffing of lymphocytes and generalized gliosis. Eosinophilic inclusion bodies also were present in the bile duct and renal tubular epithelium. Focal interstitial pneumonitis and bronchitis included multinucleate giant cells in the epithelium and infiltration of the parenchyma by neutrophils and eosinophils. White pulp was depleted in the spleen. Other raccoons in this survey had eosinophilic inclusion bodies in the epithelium of the gastrointestinal mucosa, skin, uri-

TABLE 1. Seventeen raccoon canine distemper epizootics in New Jersey.

Location*	Interval	Number of raccoons reported
Hunterdon	6 November 1978 to 20 June 1979	32
Hunterdon	8 September 1982 to 2 May 1983	36
Hunterdon	16 September 1986 to 19 May 1987	40
Rockaway	23 March to 20 October 1981	49
Rockaway	24 October 1985 to 5 July 1986	45
Rockaway	1 January to 29 March 1990	39
Rumson	16 to 26 February 1982	30
Rumson	1 September to 26 November 1986	88
Rumson	21 September 1990 to 25 March 1991	49
Helyar Woods	4 March to 23 June 1980	12
Fort Lee	2 to 16 November 1981	60
Watchung	4 April 1983 to 25 April 1984	42
Warren	7 January to 29 September 1983	17
Musconetcong	27 January to 28 May 1984	12
Vernon	1 September to 10 October 1986	16
Herbstville	1 May to 1 June 1987	32
Atlantic	6 January to 2 March 1988	16

* Locations identified in Fig. 2.

nary bladder, bronchi and alveoli in addition to brain, liver and kidney.

One hundred thirty-nine (47%) of 295 raccoons submitted for necropsy from 1 September 1977 to 30 April 1989 were diagnosed as having CD. Fourteen (52%) of 27 gray foxes and seven (30%) of 23 striped skunks necropsied during the same period as the raccoons had CD. Only one (2%) of 43 red foxes submitted had CD.

The peak month for raccoon CD was March based on the 128 raccoons with CD submitted between 1 January 1978 and 31 December 1988 (Fig. 1). Canine distemper cases decreased from June to August and abruptly increased in the fall. Thirty-nine (91%) of 43 CD cases from March to August were comprised of adults. From September through February, CD in juveniles included 28 (64%) of 44 cases (Fig. 1).

The frequency of occurrence of juvenile males, juvenile females, adult males, and adult females in the composite asymptomatic raccoon population was 0.21, 0.19, 0.31 and 0.29, respectively. The age and sex structure of the raccoons diagnosed with CD was not significantly different (χ^2 = 3.09, 1 df, $P > 0.05$) from a composite of asymptomatic New Jersey raccoon populations.

Seventeen epizootics of CD involving a minimum of 615 raccoons were recorded (Table 1, Fig. 2). The interval between reports of a raccoon with clinical signs of CD was <16 days during these epizootics. Reports for the first and second interepizootic period in the most closely monitored area (Hunterdon) were received, on the average, one every 34 and 73 days, respectively. The nonepizootic or interepizootic reporting was lower or absent for all other areas. The Hunterdon, Rockaway and Rumson epizootics occurred three times during the survey period at approximately 4-yr intervals.

Two gray foxes were the first animals to be diagnosed with CD in the first epizootic of CD in raccoons in Rockaway. Another gray fox was diagnosed with the disease from the same area 1 mo before the end of the epizootic. A gray fox was diagnosed with CD in the geographic center of the Hunterdon epizootic on 18 January 1979. The only diagnosed case of CD in a red fox was an animal from the Musconetcong epizootic.

Urban and suburban raccoon CD epizootics of Fort Lee, Rockaway, Vernon, and Helyar Woods were spatially confined by storm drains and well traveled roads in developed areas. The Rumson, Herbstville, and Atlantic epizootics were associated with populations of raccoons in tidal marshes and intruding suburban development. The Watchung, Warren, and Musconetcong CD epizootics were slightly less confined, being delineated by river drainages with moderate physical barriers in the form of bordering mountains with mixed hardwood forest. The Hunterdon CD epizootics were even less confined with the river system in this area passing through gently rolling farmland.

Two raccoons with CD were collected in December 1989 and February 1990 from an area <1 km² in Hampton, New Jersey (40°40′N, 74°57′W). Two other raccoons submitted from the same area in February and March 1990 were diagnosed as rabid.

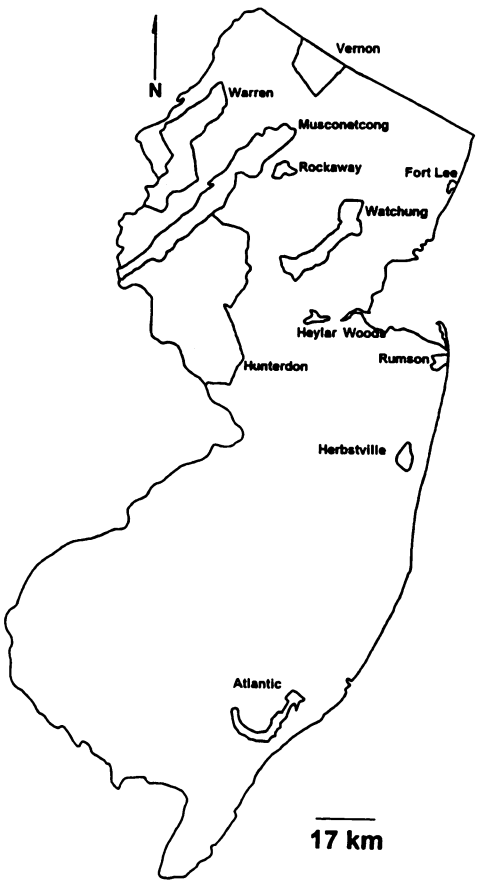

FIGURE 2. Locations of raccoon canine distemper epizootics in New Jersey.

DISCUSSION

Finding the greatest number of raccoon CD cases in the month of March and the lowest number in August was a pattern also reported for 123 gray fox CD cases from the southeastern United States (Davidson et al., 1992). Bigler et al. (1973) observed sporadic cases of rabies in raccoons throughout the year in Florida with the peak numbers in March; they correlated this peak with the breeding season. The breeding season for New Jersey raccoons is from January to March (Slate, 1989). The travel, contact, and transmission of virus by raccoons during this period may account for the March peak of CD cases.

The low numbers of juvenile raccoons among the CD cases from April through August may be partially attributed to their relative inactivity which limits opportunity for exposure and detection.

The behavior of raccoons with canine distemper enhanced their being observed. Infected raccoons frequently wandered slowly and aimlessly and repeatedly fell out of trees they attempted to climb. Bites of humans were rare and were in response to handling of recumbent animals. Evans (1984) found that depression or malaise (98%), and ataxia (95%) were the most prevalent clinical signs of CD observed in 541 raccoons from an epizootic in Missouri.

The high frequency of canine distemper diagnoses in raccoons, gray foxes, and skunks prior to 1989 made it the most important disease-induced mortality factor for these species in New Jersey. In a diagnostic case review of gray foxes, Davidson et al. (1992) found distemper to be the major disease for this species in the southeastern United States. A similar conclusion was made for New York, based on 131 gray fox cases (Monson and Stone, 1976). Reports of CD cases in gray foxes preceding

those of raccoons in the 1981 Rockaway epizootic raise questions on the possible role gray foxes might have in precipitating epizootics.

The repeated occurrence of reported raccoon CD epizootics in three locations at approximately 4-yr intervals was similar to the observations of Hoff et al. (1974) who provided evidence that concurrent CD and rabies epizootics in raccoons and gray foxes preceded a CD epizootic in these species in Sarasota, Florida by approximately 4 yr.

Raccoon rabies had approximately a 4-yr interval between peaks in diagnosed cases in Virginia (Jenkins et al., 1988). Murphy (1983) proposed that the cycling of rabies in wildlife is often due to epizootics which empty reservoir host niches. Niche repopulation is the result of migration and birth of new generations of susceptible hosts. Similar forces could have governed the periodicity of raccoon CD epizootics in New Jersey.

In spite of the sampling method (trapping) for the asymptomatic composite population which might be expected to select CD survivors and those unaffected by CD, no evidence of significant protective advantage based on the characteristics of age or sex could be inferred from the comparison with the necropsy sample. The use of other more powerful statistical tests might have altered this conclusion and could have been employed if the specific age of all the raccoons in the composite asymptomatic population had been known. The failure of raccoons to mount an effective persistent immune response also may have contributed to these results. Evans (1982) reported that 50 to 90% of raccoons and gray foxes may be incapable of producing protective levels of antibody against CD virus. Hoff et al. (1974) found a naturally acquired serum neutralizing antibody titer of 1:9 failed to protect a raccoon from an experimental CD infection and suggested that the amount of virus in the inoculum may have overwhelmed the animal's immunologic capabilities. No difference in prevalence of CD among sex and age classes was demonstrated in the gray fox case review by Davidson et al. (1992).

I propose that CD is enzootic among raccoons in New Jersey. Evidence for this is the cycling of epizootics, their wide distribution, the occurrence of diagnosed cases between epizootics, and the serologic evidence of CD exposure in four populations of New Jersey raccoons studied by Slate (1980b).

The effects of CD on raccoon populations may diminish or at least become more difficult to discern if raccoon rabies spreads throughout New Jersey and concurrent CD and rabies epizootics become more common.

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