LAND USE ASSOCIATIONS AND CHANGES IN POPULATION INDICES OF URBAN RACCOONS DURING A RABIES EPIZOOTIC

Authors: Anthony, Jill A., Childs, James E., Glass, Gregory E., Korch, George W., Ross, Lloyd, et al.

Source: Journal of Wildlife Diseases, 26(2) : 170-179

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-26.2.170

Journal of Wildlife Diseases, 26(2), 1990, pp. 170–179

LAND USE ASSOCIATIONS AND CHANGES IN POPULATION INDICES OF URBAN RACCOONS DURING A RABIES EPIZOOTIC

Jill A. Anthony,[1,6] James E. Childs,[2] Gregory E. Glass,[2] George W. Korch,[3] Lloyd Ross,[4] and Jack K. Grigor[5]

[1] Department of Environmental Sciences, The University of Virginia, Clark Hall, Charlottesville, Virginia 22904, USA
[2] Department of Immunology and Infectious Diseases, The Johns Hopkins University, 615 North Wolfe Street, Baltimore, Maryland 21205, USA
[3] US Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland 21010, USA
[4] The Baltimore City Health Department, Bureau of Animal Control, Baltimore, Maryland 21230, USA
[5] Division of Veterinary Medicine, Maryland Department of Health and Mental Hygiene, Baltimore, Maryland 21201, USA
[6] Present address: School of Fisheries and Ocean Sciences, The University of Alaska–Fairbanks, Fairbanks, Alaska 99775, USA

ABSTRACT: Land use associations and changes in population indices were assessed for an urban population of raccoons (*Procyon lotor*) in Baltimore, Maryland (USA), from January 1984 to December 1987. Records were examined for 1,458 raccoons trapped alive and removed dead from city streets during, and after, the peak of a rabies epizootic. The distribution of raccoons was associated with single-unit residential areas primarily along the northern and western perimeter of the city. Beginning in March 1985 an ending in May 1987, an epizootic of raccoon rabies spread through Baltimore, ultimately resulting in the identification of 95 rabid raccoons. Within the study interval, annual numbers of trapped raccoons remained stable from 1984 to 1986, before showing a marked decline in 1987. The number of raccoons removed as vehicle mortalities (road-kills) varied little from 1984–1985 but declined in the last 2 yr of study. Numbers of other road-killed species did not decrease concurrently, suggesting a specific decrease in the urban raccoon population. The rabies epizootic, in conjunction with the increased city and private control, appears to have contributed to a decline in the number of raccoons in Baltimore.

Key words: Raccoon, *Procyon lotor*, urban population, rabies, rabies epizootic, population dynamics, land use association, zoonotic disease.

INTRODUCTION

The potential for human and domestic animal exposure to wildlife and their diseases has increased with urban and suburban development. Many mammals have adapted to living in and around human communities, and the raccoon (*Procyon lotor*) is an important example (Kappus et al., 1970). Suburban-urban settings provide ample food, water and shelter to support exceptionally high raccoon population densities (Bigler et al., 1973; Hoffmann and Gottschang, 1977; Hoffmann, 1979; Rosatte, 1985).

In 1977, a wildlife rabies epizootic began in the mid-Atlantic region of the United States. This outbreak was linked to raccoons translocated from the enzootic southeastern United States focus of rabies and released to supplement populations of raccoons hunted for sport (Nettles et al., 1979; Smith et al., 1984). The first rabid raccoon in the epizootic was detected in West Virginia (Smith et al., 1984), and subsequently, cases were reported in Virginia, the District of Columbia, Maryland and Pennsylvania. Prior to 1981, there were no rabid raccoons reported in Maryland, but in 1983 Maryland reported the largest number of rabid raccoons in the country ($n = 735$; Jenkins and Winkler, 1987; Centers for Disease Control, 1988).

In March of 1985, the City Department of Health in Baltimore, Maryland (USA) detected the first rabid raccoon within the city limits. As of December 1987, 95 rabid raccoons had been reported within municipal Baltimore (Maryland Department of Health and Mental Hygiene, 1987).

Raccoons in Baltimore have been reduced in number due to the combined effects of the rabies epizootic and increased public and private control. The purpose of this study was to document land use associations of urban raccoons and patterns of abundance before, during and after the rabies epizootic. We also describe the temporal and spatial pattern of the raccoon rabies epizootic. This information may be useful in predicting the geographic spread of rabies in comparable environments and in anticipating population changes associated with disease and control. Data on the distribution and relative abundance of urban raccoons may also aid future rabies control programs aimed at delivering oral vaccines to wildlife (Winkler and Baer, 1976; Rupprecht et al., 1986; Hadidian et al., 1989).

METHODS

Study area and mapping technique

The study area encompassed municipal Baltimore, Maryland (39°22′ to 39°12′N, 76°43′ to 76°33′W) which spans approximately 227-km²; 212-km² is land intermingled with flowing water, lakes or reservoirs, and 15-km² is harbor water (Baltimore City Land Use Map, 1978, Maryland State Department of Planning, Baltimore, Maryland 21202, USA). A map of Baltimore was marked into 400 × 400 m (16 ha) grid squares. Raccoon home ranges in suburban locations have been reported as small as 5 ha, but are typically in the range of 40 ha, or more, in rural locations (Kaufmann, 1982). Each grid square was classified according to major land use and the presence of various types of water (see Childs and Ross, 1986). Land use categories were multi-unit residential, single-unit residential, open land, commercial-industrial-institutional, and water. Multi-unit residential areas were characterized by connected row house architecture with high human population density; single-unit residential consisted of unattached dwellings, most frequently located in a suburban setting. Open land included parks and cemeteries. Commercial-industrial-institutional areas were typified by low human population densities and low number of residential units.

Animal data collection

The raccoon sample was comprised of animals trapped alive or removed dead or injured from Baltimore city streets by the Municipal Animal Shelter (MAS; Baltimore City Health Department, Bureau of Animal Control, Baltimore, Maryland 21230, USA) from January 1984 to December 1987. The MAS responded to calls from residents of Baltimore City reporting dead or injured animals on city streets. From two to four vehicles, each operated by one or two city wardens, were available to respond to daily requests for dead or injured animal removal or other assistance. The city attended to all calls reporting wild or domestic animals with equal effort. Detailed records of the location, health and disposition of each animal were maintained. The MAS also supplied a single Tomahawk live trap (Tomahawk Live Trap Company, Tomahawk, Wisconsin 54487, USA) to homeowners, upon request, for trapping of raccoons. Captured animals were removed by the MAS for disposal and a replacement trap was provided. The number of available traps during the study period ranged from 35 in 1984 to 110 in 1987.

During the study period MAS daily records were examined and each raccoon was assigned a report date, a removal location, and a condition upon removal (trapped alive or removed dead). Most raccoons, other than those trapped, were removed dead or injured from city streets, probably as the result of accidents with motor vehicles. Daily records for years prior to 1984 were not examined as these were unavailable for study.

To control for changes in raccoon removal rates potentially caused by changes in MAS collection patterns, daily records for cats and dogs killed and removed from streets were examined over the same period. A previous study on road-killed cats indicated that MAS records provided a reliable and unbiased index of animal removals from different land use types in Baltimore, with approximately 50% of cats killed by vehicles (road-kills) being removed from city streets by the MAS (Childs and Ross, 1986).

Locations of raccoons collected alive or removed dead from January 1984 through June 1987 (>93% of the total sample) were determined on the city map of Baltimore with a criss-cross directory (The Baltimore City Criss-Cross Directory, 1986, Stewart Directories, Baltimore, Maryland 21204, USA). Each location was fixed in a 16-ha grid square and the resulting map was used to determine relative raccoon density and habitat distribution. Raccoons tested for rabies were plotted in an identical manner and centers of activity for the rabies epizootic were determined for 1985–1987, after the home range method of Hayne (1949). These values represent the geographic centers of all positions of rabid raccoons for each year, as computed by averaging x (west to east) and y (north to south) grid coordinates of individual locations.

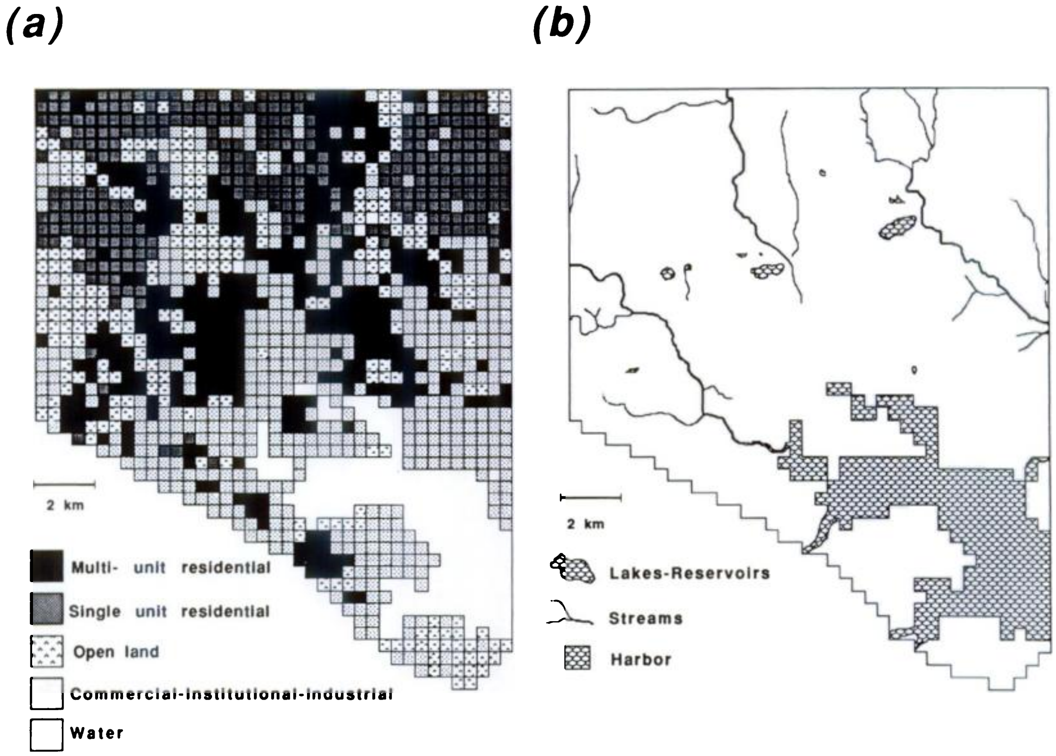

FIGURE 1. a. Land use map of Baltimore, Maryland. (1 Grid Square = 16 ha). b. Water map of Baltimore, Maryland. (1 Grid Square = 16 ha).

Rabies testing

Fluorescent rabies antibody tests (FRA; Johnson, 1969) were conducted on fresh or frozen brain impressions of raccoons by the Maryland Department of Health and Mental Hygiene. The tests used fluorescein isothyocyanate conjugated Anti-Rabies Monoclonal Globulin (Centocor, Malvern, Pennsylvania 19355, USA) for staining, and a Zeiss epi-fluorescent microscope (Baltimore Instruments, Baltimore, Maryland 21214, USA) for detection of antigen. After the confirmation of rabies in Baltimore in 1985, the majority of raccoons tested by the laboratory were either suspected of being rabid, based on clinical signs, or involved in potential exposures of humans or domestic animals. Most were submitted to the Health Department by the MAS.

Statistical methods

Fluctuations in the temporal distribution of raccoons (yearly and monthly) were examined by ANOVA and Least Significant Difference (LSD) criteria for multiple comparisons (SAS Institute, Inc., 1985). Geographical distributions were analyzed by contingency table analysis and computation of 95% Bonferroni confidence intervals for the true proportion of raccoon removals from each land use type (Byers et al., 1984; Neu et al., 1974). This method computes a "family" of confidence intervals for comparison with an expected proportion of removals based on the proportional area represented by each land use type. In these analyses, an upper standard normal table value corresponding to a probability tail area of $\alpha/2k$ ($Z_{\alpha/2k}$) was selected for $\alpha = 0.05$ and $k = 4$ classifications of land use. In this case $Z_{\alpha/2k} = Z_{0.00625} = 2.495$.

RESULTS

Numbers of raccoons

The MAS removed 1,458 raccoons between January 1984 and December 1987. Of these, 1,150 (79%) were trapped and 308 (21%) were removed as road-kills. During this interval, 438 live raccoons were submitted for rabies testing and 95 of these were positive.

Land use associations

The city was divided into 1,327 grid squares classified primarily as land (Fig.

TABLE 1. Land use occurrence and simultaneous confidence intervals for raccoons removed from Baltimore, Maryland, by trapping or as road-kills, January 1984 to June 1987.

		Raccoons			
		Trapped		Road-kills	
Land use (P)	Expected proportion[a] of removals (P_{io})	Actual proportion[b] of removals (P_i)	Bonferroni intervals for P_i	Actual proportion of removals (P_i)	Bonferroni intervals for P_i
Multi-unit (1)	0.254	0.168	$0.140 \le P_1 \le 0.197$[c]	0.192	$0.133 \le P_1 \le 0.251$[c]
Single-unit (2)	0.221	0.587	$0.550 \le P_2 \le 0.624$[c]	0.420	$0.347 \le P_2 \le 0.493$[c]
Open land (3)	0.187	0.139	$0.113 \le P_3 \le 0.165$[c]	0.199	$0.140 \le P_3 \le 0.258$
CII[d] (4)	0.338	0.106	$0.083 \le P_4 \le 0.130$[c]	0.189	$0.131 \le P_4 \le 0.247$[c]

[a] Proportions of removals expected if raccoons were trapped or road-killed in exact proportion to land area available for each use.

[b] P_i represents proportion of removals from each land use category and is compared to P_{io} to determine if proportional removal is accepted or rjected.

[c] Indicates a difference at the 0.05 level of significance.

[d] CII = commercial-industrial-institutional.

1a). An additional 93 squares were harbor water, 30 contained a lake or reservoir, and 195 squares, classified primarily as land, contained streams or rivers (Fig. 1b).

There were significant differences in the land use associations of raccoons trapped or removed dead ($\chi^2_3 = 29.87$, $P < 0.0001$; Table 1, Fig. 2a, b). In both cases the majority of animals (a total of 747; 55%) were removed from single-unit residential locations, but the road-killed animals were more equitably distributed among the land use types. The Bonferroni intervals indicated significant differences from the expected proportion of removals in all four land use classifications for trapped animals, and in three of four classifications for road-killed animals. For both trapped and road-killed raccoons, multi-unit residential and commercial-industrial-institutional areas of Baltimore provided less than expected numbers of raccoons, while single-unit residential areas provided significantly more animals (Table 1). Open land areas provided significantly fewer raccoons in the case of trapped animals but was not statistically different than the expected value for road-killed raccoons.

Raccoon rabies

The epizootic of raccoon rabies in Baltimore was clearly defined in its temporal course; beginning in March 1985 and ending in May 1987, with clear peaks in January and March 1986 (Fig. 3). In 1984 and 1985 the number of raccoons tested for rabies (49 and 202, respectively) was far in excess of those found positive (0 in 1984, 27 or 13% positive in 1985; Figs. 3, 4). Once the epizootic was clearly evident in Baltimore (mid-1985), only those raccoons suspected of being rabid or involved in potential human or domestic animal exposures were routinely tested. The number of raccoons tested for rabies in Baltimore was 152 in 1986 (63 or 41% positive) and 35 in 1987 (5 or 14% positive).

Although the geographic distribution of rabid raccoons was broadly overlapping from 1985 to 1987 and the annual total was small, there still appears to be a west to east shift in the center of rabies activity during this period (Fig. 4). The coordinates of the center of activity in 1985 were at grid 11,14 (west–east, north–south), while those in 1986 were at 21,08, and those of 1987 were at 19,06.

Annual trends in raccoon removal rates

From January 1984 to December 1987, a mean of 288 (standard deviation, SD = 166) raccoons were trapped alive/yr by the MAS (Fig. 4a). Significant annual variation in trapped raccoons was apparent (F

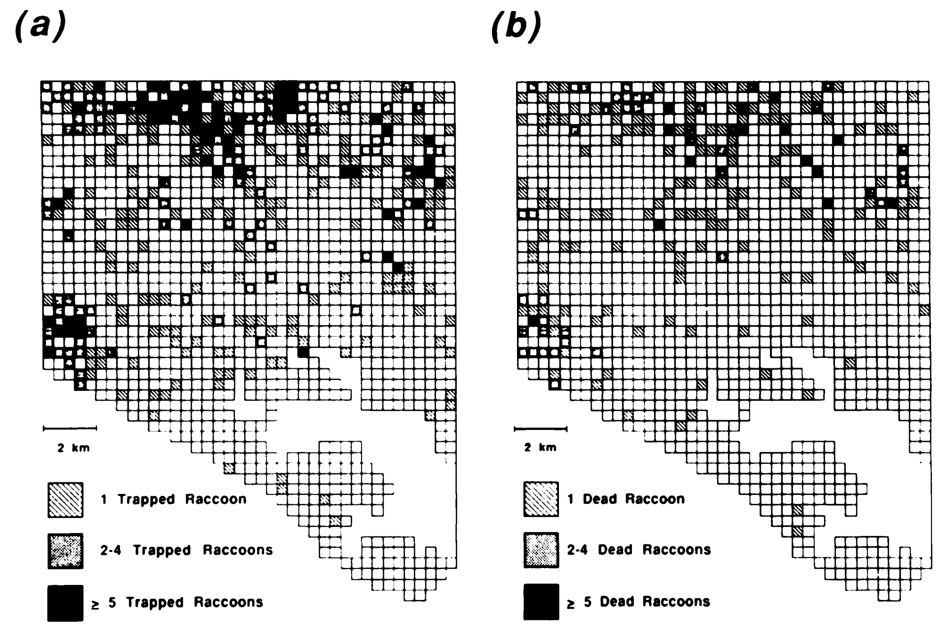

FIGURE 2. a. Distribution of 1,071 raccoons trapped alive from Baltimore, Maryland, from January 1984 to June 1987. b. Distribution of 281 road-killed raccoons removed from city streets of Baltimore from January 1984 to June 1987.

= 11.52, df = 3,47, $P < 0.0001$). The annual numbers of trapped raccoons were similar in 1984 (349), 1985 (411), and 1986 (293) and constituted a statistically homogeneous group, significantly different from the lower count in 1987 (97 raccoons; $P < 0.05$; LSD Test).

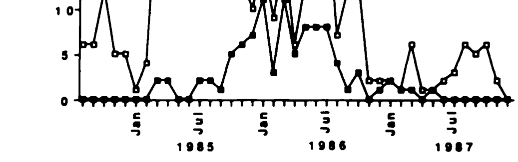

FIGURE 3. Monthly numbers of raccoons tested and found to be rabid from within the city limits of Baltimore, Maryland, from August 1984 through December 1987.

The annual trapping results, although consistent from 1984 to 1986, may actually indicate a decline in the raccoon population, because of increases in trapping effort over the 4-yr. In 1984 approximately 92 Baltimore households used traps (3.8 raccoon captures/household requesting traps); in 1985 there were 98 households (4.2); in 1986 there were 189 households, (1.5); and in 1987, there were 156 households (0.6). These values do not reflect the total number of trap nights, as those data were not available.

The number of raccoons removed annually as road-kills, with a mean of 77 (35) showed a similar decline over the 4 yr of the study (Fig. 4a; $F = 4.89$, df = 3,47, $P = 0.006$). Two statistically homogeneous, overlapping groups of years were discernable by LSD test. The first included 1984, 1985 and 1986, when 106, 88 and 75 raccoons were removed, respectively. The second included 1986 and 1987 (39 raccoons removed). These data indicate an overall trend of decreasing annual number of road-killed raccoons.

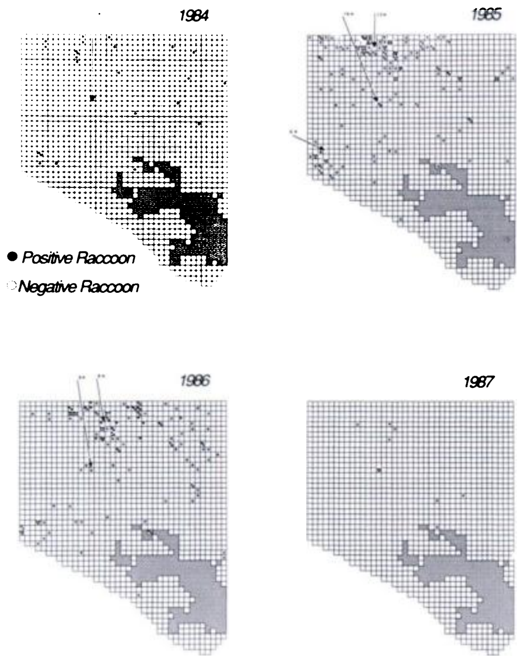

FIGURE 4. Geographic distribution of raccoons tested for rabies in Baltimore from January 1984 through June 1987. Rabies did not occur in raccoons from Baltimore until March 1985. Location data were available for 92 of 95 rabid raccoons.

Seasonal trends in raccoon removals

Monthly numbers of trapped raccoons varied significantly over the 4 yr ($F = 3.26$, df = 11,47, $P = 0.004$), and a seasonal pattern was apparent with peak captures occurring from July to September in most years (Fig. 5a). The number of raccoons removed dead from the city streets roughly paralleled the trapping data (Fig. 5a; $F = 4.18$, df = 11,37, $P = 0.0007$). Peak removals occurred from July to October.

Dog and cat removals

Numbers of dogs removed annually as road-kills from Baltimore city streets showed no significant change over the period from January 1984 to December 1987 ($F = 0.74$, df = 3,47, $P = 0.53$; 4,024 in 1984, 4,094 in 1985, 3,931 in 1986, 3,784 in 1987; Fig. 5b). The number of cats removed showed a slight, but significant increase in 1987 ($F = 5.89$, df = 3,47, $P = 0.003$; 2,768 in 1984, 2,742 in 1985, 2,928 in 1986, 3,307 in 1987; Fig. 5b). Monthly numbers of domestic animal collections varied significantly, and indicated a seasonal pattern in removals (dogs, $F = 7.32$, df = 11,47, $P = 0.0001$; cats, $F = 6.87$, df = 11,47, $P = 0.0001$). The largest collections of dogs and cats were made during the summer and early autumn, with cats peaking in July to October, and dogs in July and August (Fig. 5b).

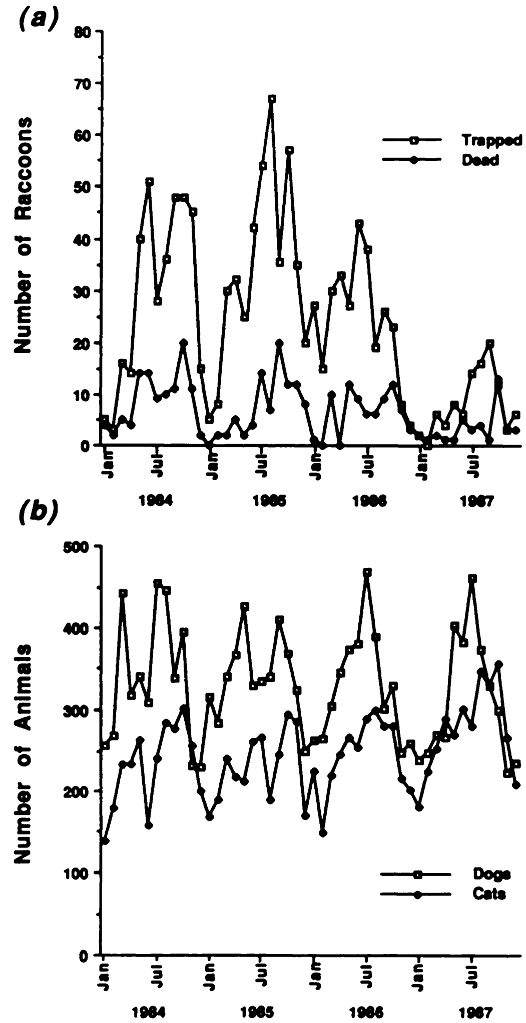

FIGURE 5. a. Numbers of raccoons trapped alive or removed dead as road-kills from Baltimore, Maryland, between January 1984 and December 1987. b. Numbers of cats and dogs removed as road-kills from Baltimore between January 1984 and December 1987.

DISCUSSION

A number of biases are inherent in the use of MAS trapping and road-kill data. Requests for traps and reporting of road-killed animals occur on a voluntary basis and collections may be limited by MAS trap and warden availability. City residents also may independently dispose of road-killed animals, and this is difficult to assess. Childs and Ross (1986) estimated by a modified mark recapture study that only 50% of the road-killed cats in Baltimore were removed by the MAS and the remainder were lost to unknown causes. However, despite this loss the proportion of tagged dead cats reported by residents from different land use areas of the city was similar, so that reporting of road-killed animals was unbiased by habitat. The situation should be similar with raccoons as equal MAS effort is expended in their removal.

Single-unit residential areas accounted for the majority of raccoons and were the only land use areas that contributed total (trapped and road-killed) raccoon numbers greater than expected (Table 1). Residents in multi-unit residential locations were equally prone to report dead animals to the MAS (Childs and Ross, 1986), so the smaller number of raccoons removed from this land use type presumably reflects lower utilization. The difference in trapping and road-kill recoveries (Table 1) probably represent the proportionally greater number of trap requests from northern Baltimore, which is primarily single-unit housing. Both of these data sets presumably indicate regions where human-raccoon overlap is greatest, rather than areas of maximal raccoon numbers, as parklands contributed relatively few animals. In urban environments, raccoons are frequently found in parks, cemeteries, and industrial parks, in addition to residential areas (Rosatte, 1985; Rosatte et al., 1985). Numbers of raccoons removed from areas of commerce and industry are understandably low because of the poor habitat and low density of human residents. The greater portion of road-killed raccoons in these areas may more accurately reflect population density and distribution than trapping records.

Multi-unit, inner city, residential areas provided few raccoons except near streams or open areas (Figs. 1, 2). Raccoon den sites are frequently located near water (Stuewer, 1943; Schneider et al., 1971; Hoffman and Gottschang, 1977). The major habitat for raccoons in Baltimore, based on mapping of trapping and road kills, is a combination of single-unit dwellings or multi-unit dwellings adjacent to parklands or cemeteries and in close proximity with streams.

Fluctuations in the population indices of raccoons can be examined in the context of targeted population control and epizootic disease. The study interval spanned from 1 yr prior to the detection of rabies in Baltimore raccoons, to 2 yr after the epizootic peak. The results indicate a significant decline in numbers of trapped raccoons and in the number of raccoons captured per household using traps, and a decline in road-killed raccoons, not apparent in domestic animals.

The rabies epizootic in raccoons of Baltimore was well defined and distinctive in its time course (Fig. 3). The epizootic lasted approximately 2 yr, which is typical, as in most locales the number of cases of raccoon rabies will decrease from 1 to 3 yr after the initial outbreak (Jenkins et al., 1988). The decline in numbers of rabid raccoons may be due to the combined effects of rabies induced mortality and post-exposure immunity in decreasing the size of the susceptible population. High prevalences (17 to 20%) of serum neutralizing antibody titers have been reported from raccoon populations sampled along the gulf coast during epizootic years (McLean, 1975). However, a serosurvey of raccoons in the nearby District of Columbia revealed only 3% of 291 raccoons had significant rabies antibody titers in 1983–

1984, during, and immediately after the epizootic period (Jenkins et al., 1988)

The overall proportion of raccoons found positive in Baltimore (95 of 438; 22%) is within the range for raccoons tested from various habitats in other mid-Atlantic studies (14 to 68%; Jenkins et al., 1988). The annual proportion of raccoons found to be positive varied from a low of 13% during 1985, the most active surveillance period, to a high of 41% in 1986 when only selected, highly suspect raccoons were tested.

In Baltimore, the peak epizootic months preceded the decline in road-killed and trapped raccoons by about 1 yr. No clear cut seasonal pattern in number of diagnosed cases of raccoon rabies is apparent, as any trend is confounded by the momentum of the epizootic. However, summary reports of cases of rabies in raccoons of the United States show a bimodal pattern with broad peaks occurring in late winter-early spring and in late summer-early fall (Centers for Disease Control, 1988); periods that coincide closely with times of maximal raccoon activity in Baltimore, as judged by trapping and road-kill data.

The overall spatial distribution of rabid raccoons closely conformed to the distribution of this species as defined by trapping and road-kills. An apparent shift in the center of activity from 1985 to 1987 may reflect the west to east, south to north movement of the rabies epizootic in the mid-Atlantic region (Jenkins and Winkler, 1987). A similar regional phenomenon was described in the 1960s with the spread of rabies northward from Florida into Georgia (McLean, 1975).

The total number of raccoons handled by the MAS appeared relatively constant over the first 2 to 3 yr of study before declining. The road-killed raccoon data provides the best evidence of a population decline as the record of cats and dogs removed from city streets provided a control for comparison. Removal rates of cats and dogs were either constant or increasing over the 4 yr period, while raccoon road-kills declined significantly. If we assume that the numbers of road-kills is proportional to number of animals present, in addition to other factors such as the number of vehicles in the city (see Childs and Ross, 1986 for further discussion), then the data indicate an overall reduction in raccoon numbers.

The decline in the numbers of trapped raccoons is more difficult to interpret. Decreases in trapping rates could indicate a decline in raccoon numbers or simply a decline in public demand for traps. However, the number of households requesting and using raccoon traps increased from 1984 (92 requests) through 1987 (156), while the average number of raccoons trapped per household showed a marked decline from 3.8 to 0.6 over the same period. In addition, trapping removals declined even during the period when rabies cases in raccoons were occurring in the city and public awareness was high. These data, in conjunction with road-kill data, strongly suggest that the portion of the raccoon population in close contact with humans in the city declined significantly.

Records of raccoon removals showed a seasonality that may be due to the reproductive and behavioral biology of the raccoons. The summer-fall peaks in trapping, and to a lesser extent road-kills, probably represent periods of increased activity and dispersal of juveniles or yearlings (Stuewer, 1943; Stains, 1956; Sanderson and Nalbandov, 1973; Kaufmann, 1982). The obvious winter nadir can be explained by reduced seasonal activity typical of raccoons (Stuewer, 1943, Schneider et al., 1971).

The results of this study suggest that urban raccoon populations, especially those in close contact with humans, can be severely decreased by the combined effects of targeted trapping and epizootic disease. Over the next few years we expect an increase in road-kills, and rabies, as the population recovers. The habitat patterns for raccoons in Baltimore may help to identify areas of significant overlap between raccoons and humans in other cities. When an oral rabies vaccine for raccoons is distributed (Hadidian et al., 1989), the habitat requirements of this species will influence the broadcasting patterns of vaccine.

ACKNOWLEDGMENTS

This work was partly supported by an award from the Brenda and Robert Dolan Endowment For Undergraduate Research. Raymond Dueser made helpful suggestions and comments during all portions of this research, and two anonymous reviewers provided valuable suggestions for improving this manuscript. We appreciate the assistance of the Baltimore City Municipal Animal Shelter staff and wardens.

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.

BYERS, C. R., R. K. STEINHORST, AND P. R. KRAUSMAN. 1984. Clarification of a technique for analysis of utilization-availability data. The Journal of Wildlife Management 48: 1050–1053.

CENTERS FOR DISEASE CONTROL. 1988. Rabies surveillance annual summary, 1987. Centers for Disease Control, Atlanta, Georgia, 19 pp.

CHILDS, J. E., AND ROSS, L. 1986. Urban cats: characteristics and estimation of mortality due to motor vehicles. American Journal of Veterinary Research 47: 1643–1648.

HADIDIAN, J., S. R. JENKINS, D. H. JOHNSON, P. J. SAVARIE, V. F. NETTLES, D. MANSKI, AND G. M. BAER. 1989. Acceptance of simulated oral rabies vaccine baits by urban raccoons. Journal of Wildlife Diseases 25: 1–9.

HAYNE, D. W. 1949. Calculation of size of home range. Journal of Mammalogy 30: 1–18.

HOFFMANN, C. O., AND J. L. GOTTSCHANG. 1977. Numbers, distribution, and movements of a raccoon population in a suburban residential community. Journal of Mammalogy 58: 623–636.

———. 1979. Weights of suburban raccoons in southwestern Ohio. Ohio Academy of Science 79: 139–142.

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.

———, B. D. PERRY, AND W. G. WINKLER. 1988. Ecology and epidemiology of raccoon rabies. Reviews of Infectious Diseases 10: S620–S625.

JOHNSON, H. N. 1969. Rabies virus. *In* Diagnostic procedures for viral and rickettsial diseases, E. H. Lennette and N. Schmidt (eds.). American Public Health Association, New York, New York, pp. 858–863.

KAPPUS, K. D., W. J. BIGLER, R. G. MCLEAN, AND H. A. TREVINO. 1970. The raccoon as an emerging rabies host. Journal of Wildlife Diseases 6: 507–509.

KAUFMANN, J. H. 1982. Raccoon and allies. *In* Wild mammals of North America, J. A. Chapman and G. A. Geldhamer (eds.). The Johns Hopkins University Press, Baltimore, Maryland, pp. 567–585.

MARYLAND DEPARTMENT OF HEALTH AND MENTAL HYGIENE. 1987. Laboratory confirmed rabies cases in Maryland, 1985–1987, Maryland Department of Health and Mental Hygiene, Baltimore, Maryland, 2 pp.

MCLEAN, R. G. 1975. Raccoon rabies. *In* The natural history of rabies, Vol. 2, G. M. Baer (ed.). Academic Press, New York, New York, pp. 53–78.

NETTLES, V. F., J. H. SHADDOCK, AND C. R. REYES. 1979. Rabies in translocated raccoons. American Journal of Public Health 69: 601–602.

NEU, C. W., C. R. BYERS, AND J. M. PEEK. 1974. A technique for analysis of utilization-availability data. The Journal of Wildlife Management. 38: 541–545.

ROSATTE, R. C. 1985. The study of rabies in urban wildlife. Environmental Health Review 1985: 5–6.

———, P. M. KELLY-WARD, AND C. D. MACINNES. 1985. A strategy for the control of rabies in two urban wildlife species: the skunk and the raccoon. *In* Proceedings of the seventh Great Plains wildlife damage control workshop, D. B. Fagre (ed.). Agricultural Communications, Texas A&M University, College Station, Texas, pp. 1–23.

RUPPRECHT, C. E., T. J. WIKTOR, D. H. JOHNSTON, A. N. HAMIR, B. DIETZSCHOLD, W. H. WUNNER, L. T. GLICKMAN, AND H. KOPROWSKI. 1986. Oral immunization and protection of raccoons (*Procyon lotor*) with a vaccinia-rabies glycoprotein recombinant virus vaccine. Proceedings of the National Academy of Science USA 83: 7947–7950.

SANDERSON, G. C., AND A. V. NALBANDOV. 1973. The reproductive cycle of the raccoon in Illinois. Illinois National History Survey Bulletin 31: 29–83.

SAS INSTITUTE, INC. 1985. SAS user's guide: Statistics, version 5 ed. Cary, North Carolina, 956 pp.

SCHNEIDER, D. G., L. D. MECH, AND J. R. TESTER. 1971. Movements of female raccoons and their young as determined by radio-tracking. Animal Behavior Monographs 4: 1–43.

SMITH, J. S., J. W. SUMMER, L. F. ROUMILLAT, G. M. BAER, AND W. G. WINKLER. 1984. Antigenic characteristics of isolates associated with a new epizootic of raccoon rabies in the U.S. Journal of Infectious Disease 149: 769–774.

STAINS, H. J. 1956. The raccoon in Kansas: Natural history, management, and economic importance. University of Kansas Museum of Natural History Survey, Miscellaneous Publications 10, Lawrence, Kansas, 76 pp.

STUEWER, F. W. 1943. Raccoons: their habits and management in Michigan. Ecological Monographs 13: 203–258.

WINKLER, W. G., AND G. M. BAER. 1976. Rabies immunization of red foxes (*Vulpes fulva*) with vaccine in sausage baits. American Journal of Epidemiology 103: 408–415.

Received for publication 7 April 1989.

BOOK REVIEW . . .

Journal of Wildlife Diseases, 26(2), 1990, p. 179

The Protozoan Phylum Apicomplexa, Norman D. Levine. CRC Press, Inc., Boca Raton, Florida. 1988. Volume I, 203 pp.; Volume II, 154 pp. Hardcover, $135.00 (Vol. 1), $110.00 (Vol. 2).

Despite the general title, the focus of this two volume set is strictly the classification of organisms in the phylum Apicomplexa. About 4,600 named species within the phylum are listed with their taxonomic authorities. In addition, the synonyms, the host(s) utilized and the site(s) of infection for each parasite are provided. Diagnoses are presented for all taxa above the species level. This impressive compendium of species is an extension of the classification provided by the author in the Society of Protozoologist's Illustrated Guide to the Protozoa (1985). Within the species listings there are a number of taxonomic and nomenclatural innovations including one new class, one new species, one new name, 16 new combinations and 54 emendations.

The two volumes are divided into 14 chapters. A short introduction (eight pages) precedes the classification proper (Chapters 2 to 14) which occupies the remainder of the first volume and 48 pages of the second. Ninety-five pages of references (approximately 2,800 entries) follow the classification. The reader is directed to the Index-Catalogue of Medical and Veterinary Zoology for citations which are not included in the references. Two useful appendices are included listing *Nomina dubia*, *Nomina nuda*, non-Apicomplexa, etc. (four pages) and Superseded Generic Names (three pages). A separate index, listing primarily taxa at the level of genus and above, is found in each volume.

In any classification of this breadth, differences of opinion will exist concerning the status and relationships of at least some of the taxa. This classification is no exception. Areas of controversy certainly exist within the arrangement of higher taxa in the subclass Coccidiasina and the class Aconoidasida. Some of these controversies reflect historical disagreements such as the species composition or taxonomic affinities of the genera *Atoxoplasma, Sarcocystis, Isospora* and *Haemohormidium*. Others reflect recent advances in our understanding of the biology and structure of some apicomplexan parasites. For example, the validity of the class Aconoidasida, which is recognized by the author, has been questioned recently because ookinetes of hemosporidian parasites have been demonstrated independently by several workers to possess conoids. As discussed by the author in the introduction, the classification presented in these volumes is only a snapshot of our current thoughts on the relationships among apicomplexan protozoa. This classification will undoubtedly be modified as our understanding of these parasites expands.

This work is not free of typographical errors. In one example from the subclass Coccidiasina, members of the genus *Schellackia* have been placed erroneously within the family Dactylosomatidae instead of within the proper family Lankesterellidae. Evidently the paragraphs concerning the Dactylosomatidae and the genus *Schellackia* have been transposed.

These volumes are definitely not directed at general readers looking for basic information concerning the phylum or even at specialists working with well known model systems. However, this two volume set will serve as a primary reference for all workers describing new species or proposing taxonomic changes within the phylum Apicomplexa. As such, these books are highly recommended for biomedical libraries and specialists of apicomplexan taxonomy and nomenclature.

John R. Barta, U.S. Department of Agriculture, Livestock and Poultry Sciences Institute, Protozoan Diseases Laboratory, BARC-East, Building 1040, Beltsville, Maryland 20705, USA.