SEASONAL WEIGHT CHANGES, MORTALITY, AND POPULATION STRUCTURE OF RACCOONS IN MINNESOTA

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Abstract.—A population of raccoons (*Procyon lotor*) in east-central Minnesota was studied from September 1964 through October 1966. Sixty-three individuals were radio-tagged, and an automatic tracking system monitored their presence in the population for 3367 raccoon days for yearlings and adults and 3518 days for juveniles. Data are presented on weight loss and mortality in this population. Juveniles, yearlings, and adults lost about half their weight during winter dormancy, and many juveniles died from starvation and parasitism, the most important mortality factors in this relatively unhunted population. Late winter and early spring were the most critical periods for juveniles. Limited data on population structure indicated an even ratio of yearlings to adults and an even sex ratio in yearlings and adults, although there was a heavy bias toward males in a sample of 20 raccoons born on the study area in 1965.

In September 1964, an investigation utilizing telemetry was undertaken to determine the factors affecting the movements and home ranges of raccoons in east-central Minnesota (Mech and Tester, 1965). This paper, covering mainly the period through June 1966, reports on the following background information on this population: seasonal weight changes of individual members, causes and extent of mortality, and population size and structure.

The study was conducted on the Cedar Creek Natural History Area in Anoka and Isanti counties, 30 miles north of Minneapolis. The 9.5-sq-mile study area (Fig. 1) has been described by Pierce (1954) and Mech *et al.* (1966). During the winter of 1964–1965, temperatures varied from –37°F to +42°F, and 63 inches of snow fell. By the end of March, 30 inches had accumulated on the level, and it did not disappear from the woods until late April. Temperatures during summer 1965 ranged from 33°F to 90°F. During the winter of 1965–1966, 39 inches of snow fell, but the greatest accumulation was 9 inches. Temperatures varied from –36°F to +65°F. All weather data are from the official U. S. Weather Bureau Station on the study area.

Methods

Most of the raccoons involved in this study were captured in wire live traps set in semipermanent locations from April through November 1965 (Fig. 1) and checked daily. The total number of traps in this trapline (designated the "standard trapline") was 66, and an average of 56.5 of these were in operation each month, or a mean density of 5.9 traps per sq mile. A total of 7172 trap nights were available for capturing raccoons (Table 1).

Individual raccoons were also procured by several other methods. Live traps were sometimes set especially for certain individuals, for example, at the bases of trees the animals were known to inhabit. Some individuals, especially juveniles, were caught by hand or by dip net while they were foraging or denning on the ground. Many were extracted from den trees via a noose, and some were shaken out of squirrel nests into nets.

For examination and radio-tagging, the animals were anesthetized. Sodium pento-

TABLE 1.—*Number of sets and trap nights, and success rate of the standard trapline.*

Month	Number of sets	Number of trap nights	Number of captures	Per cent success	Adjusted[1] per cent success
April	21	136	12	8.83	—
May	52	738	17	2.30	—
June	59	1122	7	.62	—
July	61	1165	11	.94	—
August	61	1003	11	1.10	1.00
September	66	1034	7	.68	.26
October	66	1147	11	.96	.00
November	66	827	12	1.45	.08
Total		7172	88	1.2	

[1] Excluding young-of-the-year.

barbital (Mech, 1965) was administered to several raccoons successfully, but after two emaciated individuals were killed by minimal doses, ether was used in an anesthesia box (Balser and Kinsey, 1962). When anesthetized, the animals were ear-tagged, weighed, and measured, and notes were taken on general condition, reproductive status, and age based on methods described by Sanderson (1961). Radio transmitters of individual frequencies (Cochran and Lord, 1963) molded in collars of dental acrylic (Mech *et al.*, 1965), weighing 75 to 125 g, were then applied; the animals were released where captured.

An automatic radio-tracking system (Cochran *et al.*, 1965) monitored the movements of these animals and recorded their locations on microfilm. Whenever a raccoon unexpectedly failed to move for several days, an attempt was made to observe it in the field by locating it with a portable direction-finding receiver. Time of death was estimated by determining from the film record when the animal moved last. All raccoons found dead or incapacitated were collected; those intact were autopsied by Dr. D. M. Barnes of the University of Minnesota Veterinary Diagnostic Laboratory.

Necropsy of each animal included scrutiny for external lesions and parasites as well as for disease of internal tissues. The buccal cavity was especially evaluated to assure that the emaciated state characteristic of many specimens was not due to defective dentition. As soon as the body cavity was opened, the liver was cultured by searing its surface and heavily streaking liver fragments on tryptic soy agar plates containing 5% citrated sheep blood. These plates were incubated for 48 hr at 37°C in a 10% carbon dioxide incubator. Where indicated, intestinal cultures were also taken in Selenite F enrichment broth which was incubated overnight and plated on brilliant green agar. Because of the frozen condition of many carcasses, histologic studies were made on a limited number of animals; in these cases, tissues were fixed in 10% buffered formalin, embedded in paraffin, cut at 6 microns, and stained with hematoxylin and eosin. Blood studies were made on two live (euthanatized) animals by routine laboratory procedures.

RESULTS

A total of 72 raccoons were taken in 165 captures throughout the study, not including retrieval of dead animals. Of this total, 41 individuals were caught in the standard trapline, in a total of 88 captures. Some of the raccoons caught in the standard trapline had already been captured by other methods. Nine animals, live-trapped on the edge of the study area,

FIG. 1.—Aerial view of the study area; white triangles indicate trap locations.

were ear-tagged only. The other 63 were radio-tagged, some of them several times. The radios transmitted an average of 76 days, but attempts were made to recapture each animal before its transmitter expired and to replace its batteries. Animal 608, an adult female, was radio-tagged most frequently —seven times. Her movements were monitored continually from November 1964 through October 1966, except for 50 days when her transmitter was not functioning.

Adult and yearling raccoons were monitored for 3367 days, and juveniles for 3518 days. During that time, 17 animals died of causes unrelated to capture or handling; of these, 11 were autopsied by the Veterinary Diagnostic Laboratory. In addition, 11 other dead individuals, which were either found without the aid of telemetry or which died in live traps or under anesthesia, or of unknown causes, also were examined, five of these by the Veterinary Diagnostic Laboratory.

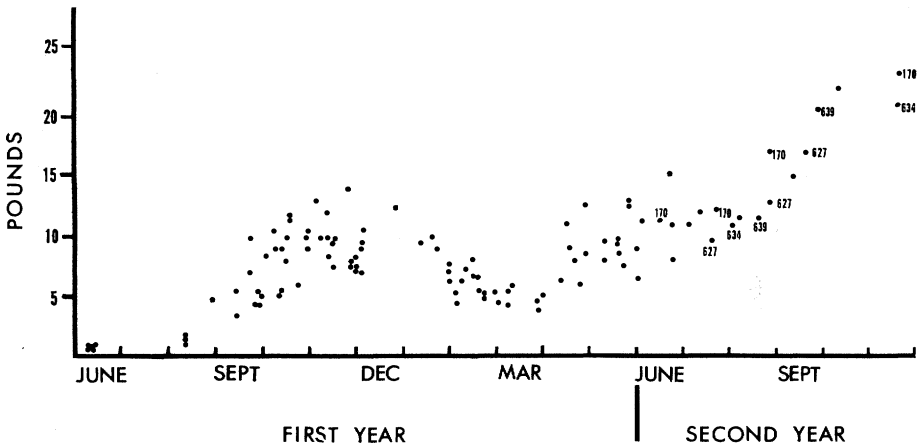

FIG. 2.—Weights of individual juvenile and yearling raccoons. Numbers identify specific animals to show striking weight changes in the second year.

Seasonal Weight Changes

The following conclusions are based on 109 weights of juvenile and yearling animals (Fig. 2) and 57 weights of adults. Juveniles gained weight almost linearly until mid-November, when they began losing; they did not gain again until April. Adults and yearlings also lost much weight while dormant over winter and did not begin to regain it until April. It was not unusual for a raccoon of any age to lose 50% of its weight from late November to late March. One adult female, no. 608 (Fig. 2), weighed 19.00 pounds on 11 November 1964. On 26 March 1965, she weighed 7.25 and was weak and extremely emaciated. Nevertheless, she had already conceived a litter of at least four young. On 5 June, she weighed 10.50, and on 2 September, 11.70. By 1 November 1965 she was up to 19.00 again, but on 31 January 1966, she weighed 10.50. On 19 April, she was 11.00. As far as known she did not bear young in 1966, and on 5 October she weighed 21.00 pounds.

These data corroborate Steuwer's (1943) findings on raccoons in southern Michigan, although it appears that weight changes in our animals were more extreme than those in Michigan. Of particular note are the spectacular gains in the weights of yearlings in early autumn. For example, female no. 639 increased from 11.50 pounds on 17 August to 20.75 on 27 September. Changes in weights of other yearlings can be seen in Fig. 2.

A young female, no. 611, decreased in weight from 9.50 pounds on 12 January to 8.00 on 15 February. This average daily loss of 20 g occurred while the animal was curled up at rest at the base of an alder clump apparently for all 34 days. The animal went there after her release about one-eighth mile away on 14 January. Snow built up around her until we recaptured her on 15 February, when she was covered by about 6 inches of snow, except for a breathing hole. She had been checked three times in the interim, and

no evidence was found of her leaving this den. Thus this appears to be a record of the weight loss of a completely inactive raccoon having no food intake over this period.

Mortality

Raccoon mortality on this study area can be divided into three types: (1) nestling; (2) first-year, post-nestling; and (3) adult (including yearlings).

Of seven litters known to have been born on the study area in 1965, two were raised at least until winter, two were lost before leaving the nest, and the fate of the other three was unknown. One of the lost litters was abandoned at the estimated age of 4 weeks, after the female ingested a tab of the tranquilizer "diazapam" (Balser, 1965) attached to a steel trap in which she had been accidentally captured. The other unsuccessful litter was lost in an unknown manner when about 18 days old, 4 days after humans had looked into the den tree while the female was absent.

One of the litters whose fate was unknown lived at least until 3 weeks old; after this time the young either died or were moved to a new den. The existence of the other two litters was inferred from the condition of that teats of two other adult females captured after the families had left their natal den trees. If any members of these three litters survived, they probably left the study area while quite young, for only three unaccounted-for juveniles were captured in the standard trapline even though eight of the nine young from the two successful litters were captured in this trapline. The three young whose mothers were unknown left the study area soon after release, so possibly they were only transient individuals when captured on the area. Thus it appears that only two of seven litters survived and remained on the study area until winter.

TABLE 2.—*Monthly mortality of adult and young raccoons from September 1964 through September 1966.*

Month	Adults			Young		
	Number transmitting	Number dying	Per cent mortality	Number transmitting	Number dying	Per cent mortality
January	6	1	.16	13	0	
February	4	0		17	1	.06
March	6	0		13	5	.39
April	14	1	.09	9	1	.11
May	16	0		12	0	
June	27	2	.08	0	0	
July	15	0		3	0	
August	18	0		11	2	.18
September[1]	16	0		13	0	
October	12	1	.08	13	0	
November	10	1	.10	16	0	
December	6	0		16	0	

[1] Values represent sum of data for three Septembers; all others are sums of two monthly values.

TABLE 3.—*Characteristics of raccoons sustaining mortality.*

No.	Sex	Age	Approximate date died	Weight (pounds)	Condition	Cause of death
603	M	Ad	3/18/65	14.25	Emaciated	Anesthesia and poor condition[2]
605	F	Ad	3/19/65	9.75	Emaciated	Anesthesia and poor condition[2]
606	F	Juv	2/22/65	5.25	Emaciated	Live trap and poor condition
608	F	Ad	10/3/66	21.00	Excellent	Shot[2]
609[1]	M	Juv	3/12/65	—	Emaciated	Predation and/or starvation[2]
610	M	Juv	2/20/65	4.75	Emaciated	Starvation and parasitism[2]
611[1]	F	Juv	4/1/65	5.00	Emaciated	Starvation and parasitism[2]
613[1]	F	Juv	3/14/65	4.25	Emaciated	Predation and/or starvation[2]
614[1]	M	Juv	3/27/65	3.90	Emaciated	Starvation and parasitism[2]
615	F	Juv	3/10/65	6.00	Emaciated	Live trap and poor condition[2]
617[1]	M	Juv	3/24/65	4.50	Emaciated	Starvation and parasitism[2]
618[1]	M	Ad	4/6/65	8.20	Emaciated	Starvation and parasitism[2]
625	M	Ad	10/1/66	23.00	Excellent	Shot[2]
629	F	Ad	8/11/66	12.00	—	Distemper[2]
632	M	Ad	12/7/65	25.00	Excellent	Steel-trapped
634[1]	F	Yrl	11/17/65	21.00	Excellent	Steel-trapped
637[1]	M	Juv	3/1/66	4.50	Emaciated	Starvation and parasitism[2]
642[1]	F	Ad	1/9/66	—	—	Shot
643[1]	M	Yrl	10/11/65	22.50	Excellent	Roadkill
644[1]	M	Juv	2/13/66	—	—	Humans killed with shovel
651[1]	M	Yrl	6/1/66	6.50	Emaciated	Distemper
655[1]	M	Yrl	6/20/66	15.40	Excellent	Roadkill
658[1]	F	Juv	8/26/66	—	—	Unknown
659[1]	M	Juv	8/20/66	—	—	Unknown
663	F	Juv	10/4/66	7.00	Good	Roadkill
170	M	Yrl	11/24/65	24.75	Excellent	Steel-trapped
153	M	Ad	5/21/65	9.00	Emaciated	Live trap and poor condition[2]
66-0422-1	F	Juv	4/15/66	5.75	Emaciated	Distemper[2]

[1] Radio was transmitting when dead animal was found.
[2] Autopsied by Veterinary Diagnostic Laboratory.

An attempt was made to determine post-nestling and adult mortality on a monthly basis. Post-nestling mortality is that which occurs from the time the young leave the natal den, about 60 days after birth (Whitney and Underwood, 1952), until they reach one year of age. The seasonal distribution of mortality was determined by calculating ratios between the number of deaths of radio-tagged animals in each month and the number of individuals monitored during that month (Table 2). The results indicate that March is the most critical month for juveniles since five of 13 individuals succumbed during that month. July, August, and September appear relatively safe for adults.

To determine the causes and conditions of mortality on our study area, we examined 28 dead raccoons (Table 3). Ten had succumbed to automobiles, hunters, and trappers, and no doubt there would have been more mortality from human activity if the study area were not closed to hunting and trapping.

The most important mortality factor was starvation and extreme parasitism, to which 13 individuals succumbed directly or indirectly. Most of these were juveniles, which are much less capable of storing fat than are adults (Whitney and Underwood, 1952). The pericardial, thoracic, and abdominal cavities of these emaciated raccoons appeared spacious and relatively hollow because of empty digestive tracts, an absence of internal fat depots, and nutritional atrophy of most glandular and muscular organs. The spleen, kidneys, liver, lung, and heart had normal contours but were diminutive because of sustained starvation. The intestines had a bluish opalescent appearance. Even the most tenaciously-retained internal fat depots, and

the firm fat normally present in the coronary groove encircling the heart and also abundant in the perirenal tissues, had been consumed; the process of serious atrophy (mucoid degeneration) converted these depots to a pale watery jelly.

Each of the necropsied specimens harbored parasites. Three individuals (Table 3) contained several *Dracunculus insigne* bilaterally in the subcutis over the femoro-tibial articulations; there was no indication that this nematode was harming its host. Four raccoons had great numbers of small intestinal trematodes, *Fibricola* sp. Seven individuals contained one to many *Physaloptera* sp. in their stomachs and/or duodenums. These large fleshy nematodes were anchored to the digestive mucosa, and their presence in numbers was often accompanied by severe gastritis. Intestinal cestodes, including *Mesocestoides* sp. and *Atriotaenia procyonis*, were found in four raccoons. The lumen of one individual's intestine was filled by adult *Atriotaenia procyonis*, forming an entangled rope-like mass approximately a centimeter in diameter and in excess of a meter in length. One raccoon had several acanthocephalids in the intestine and trematodes, presumably *Paragonimus kellicotti*, in the lung. One raccoon was teeming with unidentified biting lice, and another harbored hundreds of engorged ticks, *Dermacentor variabilis*, arranged in clusters over its entire body and almost hiding the shoulders and neck. For an extensive bibliography concerning parasitism in raccoons see Halloran (1955).

Two juveniles from the same general area, were infected with canine distemper. One of these had bilateral pustular dermatitis affecting the skin of the medial surfaces of the proximal fore limbs, a lesion common in young dogs infected with this common virus. The same individual had low-grade bronchiolitis and bronchopneumonia with numerous eosinophilic virus inclusion bodies in the cytoplasm of the bronchiolar epithelium. The other juvenile had clean lungs but showed distemper encephalitis; there were foci of gliosis and demyelination in the brain, the lesion being pronounced in the white matter of the cerebellar folia. Numerous reacting glial cells contained the eosinophilic inclusions of canine distemper in their nuclei. A third animal with distemper had focal chronic granulomatous pneumonia related to the resident trematodes and severe demyelinating meningoencephalomyelitis. The brain and cord had foci of demyelination, gliosis and perivascular cuffing with conspicuous eosinophilic intranuclear distemper inclusions in many of the astrocytes.

Distemper in raccoons has been studied and recognized only in recent years (Kilham and Herman, 1954; Helmboldt and Jungherr, 1955; Kilham *et al.*, 1956; and Kilham, 1956), but the importance of this disease has already been established. In one study, canine distemper was ascertained to be the cause of death in 24 of 32 raccoons examined in Indiana (Robinson *et al.*, 1957) and it is now regarded as a significant factor in controlling carnivore populations (Gorham, 1966). Undoubtedly the circulation of distemper in

carnivore populations is abetted by the surprising spectrum of species infected by and transmitting this highly contagious and often lethal viral agent.

No enteric bacterial pathogens were isolated, and liver cultures were positive in only three raccoons. The two juveniles known to have distemper did have low-grade bacteremias with coagulase-positive *Staphlococcus aureus*, and one adult male with some histologic features possibly suggesting distemper had a beta-hemolytic *Escherichia coli* bacteremia. Apparently, raccoons, like other carnivores, are not as prone to bacterial infection as are herbivores and birds.

The role of parasitism in the deaths of these raccoons merges so strongly with seasonal inanition that the two are almost inseparable; however, the endoparasites probably were present months before the starvation period. Poor nutrition in the raccoons probably permitted the parasites to accelerate the decline toward cachexia and death. Undoubtedly the loss of subcutaneous fat, and with it efficient insulation, increases the body heat loss at a time when caloric intake is minimal; consequently, sustained subzero weather in late winter and spring may kill many emaciated raccoons that might otherwise have survived. It is easy to believe that heavy parasite burdens destroy much of the host's margin of safety for spring survival.

Such a high rate of natural mortality probably resulted from the study area being closed to hunting and trapping, which often accounts for most raccoon mortality (Sanderson, 1950; Steuwer, 1943), and from being located in the northern part of the species' range, where long winters are common. Whitney and Underwood (1952) reported starving raccoons found in March, and Burroughs (1900, *vide* Steuwer, 1943: 215) in April. Mangold (1951) observed 10 dead or dying raccoons in southern Iowa from October 1949 to March 1950, but did not determine the cause of death.

On our study area, about the only foods available to raccoons in winter and early spring are corn and acorns. Either raccoons must search for these and dig them from under the snow or they must resort to stored corn from cribs. Both methods are used, but it appears that visiting farmyards is the last resort. Four of our starved raccoons perished in or around farmyards, and two other weak and emaciated individuals were captured there.

Population Size and Structure

To obtain an indication of the size of the population of raccoons on the study area, we applied the Lincoln-Peterson Index to data from the standard trapline for each month from April through November 1965. Only animals with transmitters working before and throughout at least half a month were considered marked individuals for that month. Thus the number in the marked cohort was always known. Animals with nonworking transmitters or with none at all were regarded as unmarked. Monthly estimates ranged from 20 in July to 43 in October. However, the 95% confidence limits around

these estimates were so wide during most months that only the July data were considered useful.

The July estimate was 20 individuals, with 95% confidence limits of 5 to 35. Because several of the marked raccoons were trap-shy and none appeared trap-prone during July, the upper limit probably is too large. Therefore we believe (95% confidence) that the July population was not greater than 35 animals.

There were eight marked animals and six newly captured individuals in July. In addition, there were four recently parous females that either stopped transmitting just before July or that were captured after July. Because the movements of females with young less than a few months old are restricted, these individuals were probably present during July. Four adult males that were present in the population both before and after July probably also were present during July. Addition of both these groups to the known individuals gives a minimum figure of 22 raccoons.

The age and sex structure of the population of animals either transmitting or captured in July was four adult females, three adult males, four yearling females, and three yearling males. The composition of the standard trapline catch from June through September 1965 was five adult females, six adult males, five yearling females, and six yearling males. Both samples indicate an even sex ratio and an even ratio of yearlings to adults.

Although the adult sex ratio appeared even, there was a heavy bias toward males in the sample of raccoons born on the study area in 1965. Two of the three litters studied had a ratio of four males to one female, and the other included three males and one female. Three other juveniles captured in the autumn of 1965 and three caught in the spring of 1966 all were males. Pooling of these data gives a sex ratio of 17 males to three females. Such a skewed ratio is unusual compared to those in the literature. Steuwer (1943) found a ratio of 14 males to 19 females in eight litters from Michigan, Sanderson (1951) reported 25 males to 27 females in an undisclosed number of litters from Missouri, and Mech and Turkowski (1966) found seven male and seven female juveniles in a group of 23 raccoons denning together in Minnesota. The uneven sex ratio from our study area could not have been an effect of the radio-tagging of the adult females, because two of the females were not tagged until after the young were born.

All aspects of the present study were facilitated by the radio-tracking technique. This demonstrates that the method can provide data not only on behavior and movement of individuals but also on certain characteristics of entire populations.

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