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THE ECOLOGY OF THE RACCOON (PROCYON LOTOR) IN CADES COVE,

GREAT SMOKY MOUNTAINS NATIONAL PARK

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

Alan Robert Rabinowitz

December 1981

DEDICATION

I wish to dedicate this dissertation to all of those individuals whose ideals and dreams have led them to pursue the field of ecology. It is times such as these that we need dreamers who are willing to fight an uphill battle despite the odds. The field of ecology has become such a battleground, and although we may never be the victor, we can always claim a sense of justice and truth that exists in little else.

"I shall be telling this with a sigh
Somewhere ages and ages hence:
Two roads diverged in a wood, and I--
I took the one less traveled by,
And that has made all the difference."

--Robert Frost
From The Road Not Taken

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ABSTRACT

From September 1979 through September 1980, 288 captures of 153 raccoons were made in Cades Cove, Great Smoky Mountains National Park, Tennessee. Fourteen raccoons were equipped with radio-transmitters to monitor movements, activity patterns, and denning behavior. Measurements, blood samples, and ectoparasites were taken from all animals.

Population density was estimated to be 1 raccoon/17 ha with sex and age ratios indicating a stable population. Parturition occurred in early June with a mean litter size of 2.8 young. Average longevity of raccoons was 30 months with a maximum longevity of approximately 86 months. There were indications of increased male mortality in the older age classes.

Telemetric monitoring indicated an activity peak around 2100 hours. Seasonal and annual home ranges of males were significantly larger than those of females with extensive seasonal home range overlap among both sexes. Extensive reuse of day bed sites was observed for both sexes with rock and tree dens being the favored types. Day bed selection was not based upon the frequency of particular day bed types or tree species occurring with the animals home range. Variability in seasonal temperatures of different day bed types indicated that microclimatic regimes may contribute to differential seasonal use of day beds. Given a choice, raccoons appear to select a variety of day bed types throughout the year.

Plasma protein concentrations were significantly lower in young, nonreproductive raccoons. Red blood cell counts and hemoglobin

concentrations in females, and red blood cell counts and eosinophil levels in males, were elevated during the reproductive period. Of 117 raccoons, 3 had antibody titers to canine hepatitis virus, and 2 had titers to canine parvovirus. Of 148 raccoons, 73% were positive for blood microfilariae with all but one containing *Tetrapetalonema llewellyni*. Seventy-four percent of 385 ticks collected were *Dermacentor variabilis* with the remainder being *Ixodes* sp.

The Cades Cove raccoon population appeared to be healthy and stable and showed characteristics that may be indicative of a relatively natural, undisturbed population.

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CHAPTER I

INTRODUCTION

The raccoon (Procyon lotor) is one of the few mammals that has thrived as a result of human modification of the environment (Johnson, 1970). It has expanded its natural range in the United States (Sutton, 1964) and has been transplanted successfully to different parts of the world (Scheffer, 1947; McKinley, 1959; Aliev and Sanderson, 1966). It is an animal with a wide array of food habits which does well in suburban residential communities (Hoffman and Gottschang, 1977) and in rural and forested areas. The economic importance of raccoons both as furbearing animals, and as potential pests is well known (Johnson, 1970; Urban, 1970; Fritzell, 1978a). Furthermore, their role in the epidemiology of certain diseases such as rabies, distemper, canine parvovirus, St. Louis encephalitis, and others is of considerable importance both to the wildlife and human communities.

For many of the above reasons, raccoons have been the subject of intensive ecological research. Techniques such as trapping, mark-recapture, and radiotelemetry have served to document their movement and activity patterns (Giles, 1943; Johnson, 1970; Schneider et al., 1971; Lehman, 1977), reproduction (McKeever, 1958; Sanderson and Nalbandov, 1973; Fritzell, 1978a), denning habits (Stains, 1961; Mech et al., 1966; Berner and Gysel, 1967; Shirer and Fitch, 1970), food habits (Giles, 1939, 1940; Hamilton, 1936, 1951; Baker et al., 1945), social organization (Fritzell, 1977, 1978b), and other aspects of their behavior (Sharp and Sharp, 1956; Shell and Riopelle, 1957). In addition they have been the subject of a wide array of studies on serology (Robinson et al., 1957; Habermann et al., 1958; Kappus et al., 1970; Bigler, 1971; Hoff et al., 1974; Lotze and Fleishman, 1978; Nettles et al., 1979; Nettles and Gustafson, 1980), heavy metal concentrations (Sanderson and Thomas, 1961; Bigler et al., 1975), and parasitology (Price, 1955, 1962; Clark and Herman, 1959; Jordan and Haynes, 1959; Ash and Little, 1964; Harkema and Miller, 1962; Herman and Price, 1965; Schaeffer et al., 1978).

Although these studies provide considerable knowledge of this animal, there have been no attempts to analyze many of these different aspects over 4 seasons in a single, natural population. Previous work has done much in establishing a good data base but there are still broad ecological questions that need to be addressed. The Cades Cove area of the Great Smoky Mountains National Park provides an ideal setting in which to answer some of these questions. It has been protected from legal hunting for more than 40 years, yet its habitat makes it much like the rest of the rural southeast. The fact that flora and fauna are protected enables one to gain a rare insight into natural population dynamics, physical and physiological parameters, social organization, and ecological interrelationships of the species. Furthermore, comparison of these data with studies of trapped, hunted, or otherwise disturbed populations could give indications of habitat carrying capacity, and natural population control mechanisms. This helps in establishing management criteria for both this species and others like it. With these factors in mind, the objectives of this study were fourfold:

1. To examine basic physical and physiological parameters of the raccoon in a "natural" setting.

2. To utilize trapping and radiotelemetry to investigate the population dynamics of the raccoon in Cades Cove, GSMNP.

3. To examine various aspects of reproduction and social organization involving adult females, yearlings, and juveniles.

4. To investigate the epidemiology of certain key diseases found in the raccoon such as rabies, distemper, canine parvovirus, pseudorabies, and canine hepatitis.

CHAPTER II

STUDY AREA

Cades Cove is a unique historical area located in Blount County, Tennessee within the boundaries of the Great Smoky Mountains National Park (Figure 1). As part of the Cherokee Indian Nation, this area remained essentially undeveloped until settled by white men in 1821. After this time, forested areas were replaced by cropland and orchards. In 1941 Cades Cove was established as a place of living mountain culture and was maintained to "force back the wilderness for a show of history and folk culture" (Frome, 1966). Thus, most of Cades Cove resembles many rural areas of the southeast but devoid of human habitation.

At the present time, Cades Cove is maintained in a pastoral setting of 977.2 ha of which 747.6 ha (76.5 %) are maintained as open fields and the remaining 229.6 ha (23.5%) consist of small wooded areas. Habitat management consists of mowing, periodic plowing, fertilization, and seeding of the pastured areas. Laurel Creek Road is the only paved road into the cove and connects the Cades Cove Loop Road with Route 73 in Townsend. The loop road (17.7 km) encircles the cove and provides visitors with easy access. Two dirt roads, Sparks Lane and Hyatt Lane, cross the cove from North to South but receive limited usage. Geologically, the cove is a low lying dolomite-limestone "window" with its surrounding ridges composed of older metamorphic rock. Elevations within the cove vary from 522 to 600 meters and it is relatively isolated by mountains on virtually all sides.

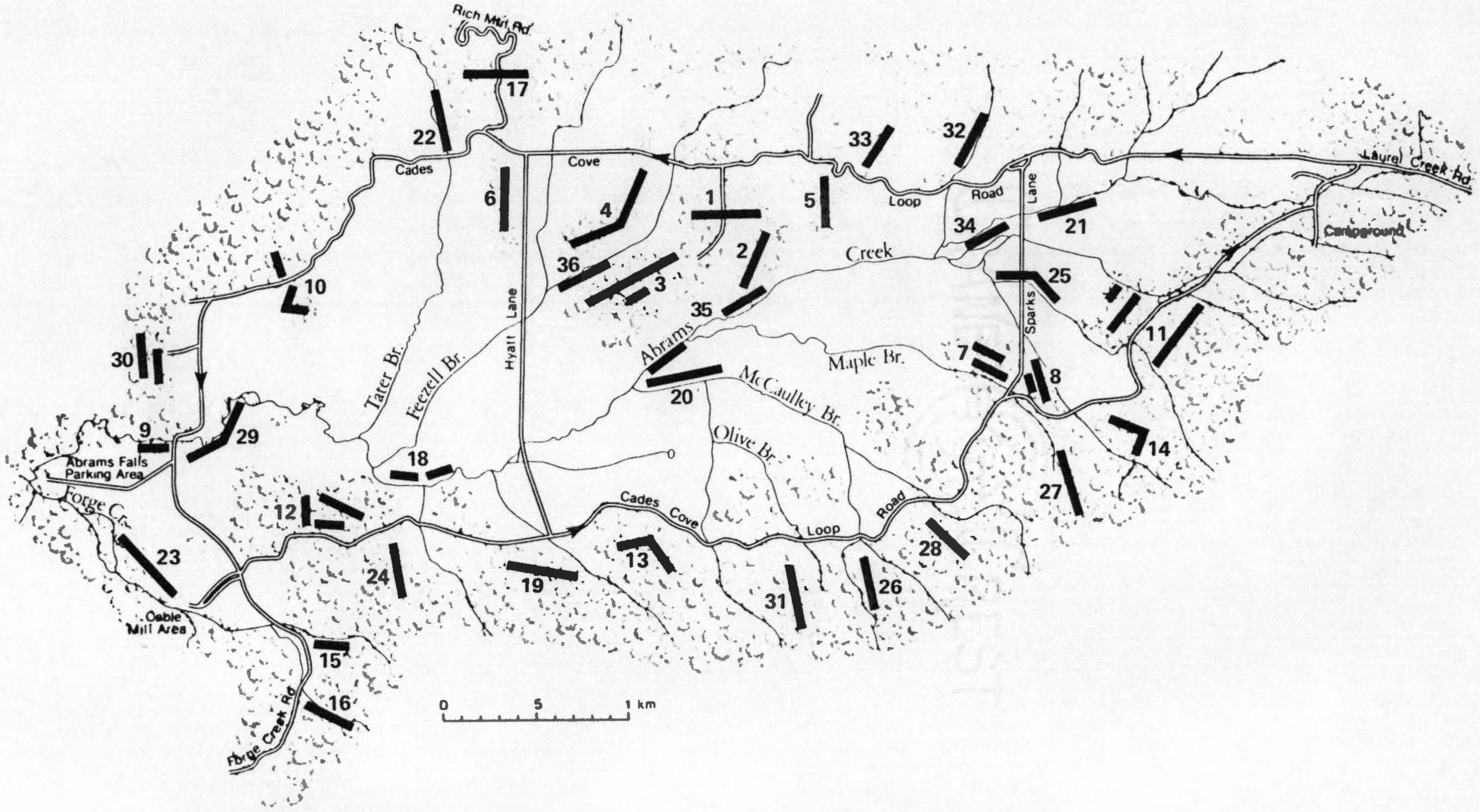

Figure 1. Transects where raccoons were live trapped from 15 September 1979 through 30 September 1980 in Cades Cove, Great Smoky Mountains National Park.

A diversity of flora and fauna are found within Cades Cove. The open fields consist primarily of fescue (Festuca sp.), orchard grass (Dactylis sp.), timothy (Phleum sp.), red top grasses (Agrostris sp.), and red and ladino clovers (Trifolium sp.) (National Park Service, 1969). Some of the old farmsteads that are being reclaimed through natural succession consist of pure stands of white pine (Pinus strobus) or short leaf pine (P. echinata) with an understory of hemlock (Tsuga canadensis). The wooded areas of the cove consist primarily of mixed hardwoods, including several species of oak (Quercus sp.), maple (Acer sp.), hickory (Carya sp.), and yellow poplar (Liriodendron tulipifera). Some of the more common understory species consist of serviceberry (Amelanchier laevis), mountain laurel (Kalmia latifolia), rhododendron (Rhododendron sp.), blueberries (Vaccinium sp.), and huckleberries (Gaylussccia sp.). Fifty-nine mammalian species have been found within the park (Linzey and Linzey, 1971). Those in Cades Cove include black bears (Ursus americanus), white-tailed deer (Odocoileus virginianus), European wild hogs (Sus scrofa), bobcats (Lynx rufus), raccoons, striped skunks (Mephitis mephitis), spotted skunks (Spilogale putorius), gray fox (Urocyon cinereoargenteus), red foxes (Vulpes vulpes), muskrats (Ondatra zibethicus), mink (Mustela vison), cottontail rabbits (Sylvilagus floridanus), oppossums (Didelphis marsupialis), woodchucks (Marmota monax), gray squirrels (Sciuris carolinensis), red squirrels (Tamiasciurus hudsonicus) and many others (Linzey and Linzey, 1971). In addition to the mammalian fauna, a wide array of snakes, fish, frogs, reptiles, and salamanders inhabit Cades Cove (Huheey and Stupka, 1972).

Seasonal temperatures fluctuate widely within Cades Cove. During this study temperatures ranged from -12^{o}C in February to 33^{o}C in August with a mean annual temperature of 17^{o}C. The study area of this project included the low-lying areas both within and outside the Cades Cove loop road (Figure 1). This area encompassed approximately 2000 ha.

CHAPTER III

MATERIALS AND METHODS

I. Trapping and Handling

From 15 September 1979 to 30 September 1980, 36 traplines were established within and around the periphery of the Cades Cove loop road (Figure 1). Since the major objective was to trap raccoons over the entire study area, traps were set in most of the wooded areas, swamps, ponds, and creeks. However, several areas of good raccoon habitat were not trapped due to heavy visitor traffic. An average of 2 traplines were established 2 to 3 times per week for the length of the study period. Traplines were usually maintained for 1 to 2 weeks before new lines were established. The number of traps per line and the length of time that a trapline was maintained depended upon the number of new animals being captured, human visitation, and vandalism. Trapping was suspended during a 2 to 3 week period in the winter when radiotelemetry data indicated virtually no movement of raccoons.

Raccoons were captured using 12 gauge collapsible wire live-traps (Tomahawk Live Trap Co., Tomahawk, WI) baited with sardines. Upon capture, animals were injected with 0.2 cc/kg Ketamine hydrochloride (Parke, Davis & Co., Detroit, MI) (Bigler and Hoff, 1973; Gregg and Olson, 1975) using a syringe on the end of a jab stick. Since the eyes of the drugged animals remained open and their pupils dilated with some nystagmus, an ophthalmic ointment, Lacri-lube (Allergan Pharmaceuticals Inc., Irvine, CA) was given to prevent corneal injury. Initially, all raccoons were given 2 numbered ear tags; 1 plastic tag (rototag, NASCO, Ft. Atkinson, WI) and 1 metal tag (Monel, No. 4, National Band and Tag Co., Newport, KY). After 3 to 4 months, the metal tags were discontinued because they often resulted in ear infection and were easily lost. The rototags, however, made a clear hole through the ear and there appeared to be no tag loss. After tagging, animals were sexed, weighed, measured, and aged. Measurements included front and rear foot lengths, ear lengths, tail length, and total length. Aging was based primarily upon tooth wear, particularly of the molars. Animals were then placed into 1 of 5 wear classes which corresponded to different age ranges. Class 1 animals were approximately 0-14 months, class 2 were 15-38 months, class 3 were 39-57 months, class 4 were 58-86 months, and class 5 were >86 months old (Grau et al., 1970). Preweaned raccoons were more precisely aged according to the presence or absence of deciduous or permanent teeth (Montgomery, 1964). Rectal temperatures were taken using a digital thermometer (Markson Scientific Co., Del Mar, CA). Reproductive condition, general body condition, and color were noted for every animal. The presence of any ectoparasites were noted and samples collected. Approximately 2.2 cc/kg of blood was drawn from the femoral vein of each animal. One cc of this blood was placed in an EDTA tube to prevent clotting while the remaining blood was put into an untreated blood tube.

II. Radiotelemetry

During this study, 14 raccoons, 8 females and 6 males, of various ages were fitted with radiotransmitter collars operating in the 150.850 to 151.450 MHz range (Wildlife Materials Inc., Canbondale, IL) (Table 1). Each transmitter had an individual frequency, weighed approximately 120 grams, and had an expected life of 370 ± 74 days. The transmitters were attached to nylon webbing which allowed for individual adjustment. Once a collar was properly fitted around an animal's neck, holes were burnt into the webbing and bolts were used to secure the collar in place. Proper fitting allowed for free movement of the collar around an animal's neck. Radiocollared animals were kept in the traps until they fully recovered from the anesthetic. The radio-receiving equipment consisted of a portable Falcon-5 receiver (Wildlife Materials, Inc.) and a portable, directional, 2-element "H" antennae (Telonics, Inc., Mesa, AZ).

During the initial 2 months of the study, 10 raccoons were captured and radiocollared within the central area of Cades Cove (transects 1 - 4) (Figure 1). This was done to obtain animals whose home ranges, movement patterns, and den utilization overlapped. After 6 months, transects 2 and 3 were reopened to recapture and change radiocollars on these initial animals. Nine of the original raccoons were successfully recollared.

In addition to individual frequencies, all radiocollars were equipped with a mercury switch activity monitor which, when activated by head and neck movement, triggered a noticeable change in the signal rate and signal strength. A raccoon was considered active when the

TABLE 1. Background history of all radiocollared raccoons captured in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

Animal	Sex[a]	Age[b]	Reproductive Status	Weight at Capture (kg)	No. of Radiolocations	Period of Time Radiotracked
R01	F	3	Had cubs in 1979 & 1980	5.2	258	19 Sept. 79-26 Sept. 80
R02	F	3	Had cubs in 1979 No cubs in 1980	4.0	263	19 Sept. 79-26 Sept. 80
R04	F	2	Had cubs in 1980	3.6	263	19 Sept. 79-26 Sept. 80
R06	F	2	No cubs in 1980	4.0	215	20 Sept. 79-26 Sept. 80
R09	F	2	No cubs in 1980	5.0	241	7 Oct. 79-26 Sept. 80
R15	F	1	Had at least 2 cubs in 1980	4.0	291	4 Oct. 79-26 Sept. 80
R20	F	1	No cubs in 1980	4.5	291	4 Oct. 79-26 Sept. 80
R55	F	3	Had cubs in 1980	4.0	109	10 May 80-26 Sept. 80
Y54	M	1	--	2.7	81	27 March 80-15 Sept. 80
Y55	M	3	--	5.4	86	28 Sept. 79-27 March 80[c]
Y58	M	3	--	6.3	270	29 Sept. 79-26 Sept. 80
Y61	M	3	--	6.8	266	19 Sept. 79-29 Sept. 80
Y65	M	2	--	4.0	149	22 March 80-26 Sept. 80
Y66	M	2	--	5.8	24	28 Feb. 80-7 April 80[d]

[a]F = Female, M = Male

[b]1 = 0-14 months; 2 = 15-38 months; 3 = 39-57 months; 4 = 58-86 months; 5 = > 86 months.

[c]Radiocollar was removed from raccoon.

[d]Radiocollar failed prematurely.

signal rate changed at least 4 times during a 2-minute time period. This was determined through visual observations of radiocollared animals.

During radiotracking, peaks in signal strength were used to locate directional azimuths which were determined using either a hand-held compass or a compass board mounted at the base of a mast antenna. The loudest signal method was used instead of the null average method to determine azimuths because it showed less bias and error (Springer, 1979). Azimuths were triangulated on a 1:24000 scale U.S.G.S. topographical map of Cades Cove. Time of the radiolocation and the activity of the raccoon were recorded for each radio fix. At least 3 times weekly, the day beds of all radiocollared animals were located during daylight hours. Any change in activity pattern due to disturbance at the day bed site was noted so that data regarding movements between consecutive day beds would not be biased. Once a month, all night radiotracking sessions were undertaken using 9 meter tall, 8-element mast antennas that were permanently erected on the north and south sides of the cove. Data collection began about 1 hour before sunset and continued until approximately 1 hour after sunrise. Simultaneous radiolocations were recorded hourly to assess movement patterns, rates of travel, and for home range analysis.

III. Use of Day Beds

Day bed sites were classified into 7 categories: Tree dens, tree roosts, tree nests, rock dens, barn dens, ground dens, and miscellaneous sites. Tree dens consisted of tree cavities where raccoons were totally sheltered from the external environment. Tree nests were usually abandoned bird or squirrel nests while tree roosting was when an animal was observed lying up in the branches or limb of a tree. Rock dens consisted either of a cave or rock cavity. Ground dens were abandoned woodchuck holes and barn dens were burrows dug into hay that was located within a barn. The miscellaneous category was for infrequently used day bed sites such as brushpiles and weeds. Throughout this report the term den is used only in reference to barn, tree, rock, and ground dens. Upon location of a day bed site, a numbered metal tag was permanently affixed to the site. This was done in order to document day bed reuse and use of the same site by different radiocollared animals. If the day bed was a tree, the diameter and species of the tree, as well as the height of the day bed were noted. To document day bed availability, 7 transects were walked within the areas of greatest day bed concentration. The transects were 3 m wide but the length varied with the size of the wooded area. The species and diameter of every tree greater than 5 m in height, as well as the presence of rock, ground, and barn dens were recorded.

Continuous 7-day and 30-day thermograph probes were inserted into one of each of the 4 den types. Ambient temperature probes were also set up in wooded areas about 1.5 m high, away from wind and direct sunlight. Temperature data allowed for comparisons between seasonal den utilization, den temperature, and ambient temperatures.

IV. Blood and Parasite Collection and Analysis

Blood samples were taken from the femoral veins of most of the captured animals. Part of the blood sample was collected into EDTA vacutubes and immediately placed on ice. Blood smears were made from the EDTA blood within several hours after collection. The remaining blood was allowed to clot at room temperature for several hours after which it was centrifuged at 1500 rpm for approximately 15 minutes. The clot was then discarded and the remaining serum was frozen. The whole blood samples, as well as the smears, were brought into the Clinical Pathobiology Laboratory of The University of Tennessee Veterinary Hospital, where they were analyzed for 11 hematological parameters. In addition, the whole blood was analyzed for microfilaria. Filariasis determination was based upon microscopic examination of the blood by the Knotts technique (Gubler, 1966). Morphology of randomly selected microfilaria was examined and measurements taken with an ocular micrometer of X20 for length and X40 for diameter.

The serum samples were assayed for antibodies to several viruses using the indirect fluorescent antibody test (Hsiung, 1973). The viruses of interest included those for canine distemper, rabies, pseudorabies, canine parvovirus, and canine hepatitis.

In addition to blood, 386 ectoparasites were collected from 77 raccoons in Cades Cove. These ectoparasites consisted of 385 ticks and 1 bot fly larvae. Most of the ticks were removed from the facial areas and ears with forceps and placed in glass vials containing 70% ethanol (Braum, 1978). Identification was determined by microscopic examination.

Ticks were identified to genus and when possible to species.

V. Data Analysis

Mark-recapture data was used to obtain a population estimate using the POPAN-2 computer program (Arnason and Baniuk, 1980). This program edits and displays the data, provides general statistics-gathering capabilities, and provides a comprehensive set of analyses based on the Jolly-Seber model (Jolly, 1965; Seber, 1965), an open population model taking into account losses and additions to the population. Due to the methods of sampling during the course of the study, and the inherent assumption of equal catchability in the model, the Cades Cove raccoon population was treated as several subpopulations.

Home range and activity center calculations were based upon the elliptical or bivariate home range model (Koeppel et al., 1975). All radiotelemetry locations were initially used in the analysis. However, based upon values for skewness and kurtosis and the T values given by the program, outlying or unusual locations were deleted for the final estimations of home range. Home range values were adjusted until they approximated acceptable T values for skewness and kurtosis ($\alpha = .05$). For every animal, calculations were made for both seasonal and annual home ranges. Seasonal data were based upon classifying September through November as fall, December through February as winter, March through May as spring, and June through August as summer.

In addition to the above models, the Statistical Analysis System (SAS) (Barr et al., 1976) was used for most parametric statistical work and the Statistical Package for the Social Sciences (SPSS) (Nie et al.,

1970) for discriminant function analysis and for nonparametric statistics. In SAS, statistical tests included analysis of variance, Duncan's multiple range test, T-tests, and basic univariate descriptive statistics. The latter was used for tests of normality, means, ranges, and frequencies. In SPSS, the Kruskall-Wallis test and Mann-Whitney U-Test were used when dealing with small sample sizes. Unless otherwise specified in the text, statistical significance was set at $P \leq .05$.

CHAPTER IV

RESULTS AND DISCUSSION

I. Trapping

During the period 15 September 1979 through 30 September 1980, 858 trap nights in Cades Cove resulted in the capture of 153 different raccoons, 288 times. Adjusting for traps sprung by animals other than raccoons (Nelson and Clark, 1973), a 45% success rate was calculated. This compares to the unadjusted figure of a 33% success rate. Both of these figures are much higher than those reported by Keeler (1978) in Cades Cove, by Woods (1978) on the Chuck Swan Wildlife Management Area, Union Co., Tennessee, or by Lehman (1977) on a wildlife study area in Indiana. In fact, the trap success obtained in this study appears to be the highest reported in the literature to date. Trap success did not differ appreciably during different seasons. The highest was observed in spring (47%), followed by winter (46%), fall (42%), and summer (41%).

II. Physical Parameters

Weights and Measurements

Table 2 indicates the average weights and measurements for the different raccoons captured of each sex. There were no significant differences (analysis of variance, $P > .05$) for either sex in terms of ear length, front foot length, tail length, and total length. However,

TABLE 2. Body weights and measurements of male and female raccoons from Cades Cove, Great Smoky Mountains National Park, 1979-1980.

Variable	N	Mean	Standard Error	Range
MALES				
Weight (kg)	85	4.2	0.17	1.4 - 7.7
Ear length (cm)	57	5.4	0.076	4.0 - 7.0
Front foot length (cm)	58	6.8	0.077	5.3 - 8.0
Rear foot length (cm)	58	9.9	0.083	8.0 - 11.0
Tail length (cm)	57	22.8	0.47	19.0 - 27.0
Total length (cm)	57	76.8	1.7	64.0 - 99.0
FEMALES				
Weight (kg)	111	3.5	0.091	0.68- 5.9
Ear length (cm)	77	5.4	0.050	4.0 - 6.4
Front foot length (cm)	78	6.7	0.066	5.0 - 8.3
Rear foot length (cm)	77	9.6	0.078	6.5 - 10.7
Tail length (cm)	77	23.8	0.36	11.0 - 32.0
Total length (cm)	77	76.0	0.94	44.0 - 90.0

males were significantly heavier and had significantly larger rear paw lengths than females (ANOVA, $P < .05$). Males averaged 4.2 ± .17 kg with a rear paw length of 9.9 ± .083 cm while females averaged 3.5 ± .091 kg with a rear paw length of 9.6 ± .078 cm. All measurements are similar to those found previously for raccoons in Cades Cove (Keeler, 1974) as well as for raccoons in Alabama (Johnson, 1970), and Florida (Bigler et al., 1977).

Additional patterns emerge when the data are broken down into the mean seasonal weights for the different age class raccoons (Table 3). Although the uneven and small sample sizes did not allow for statistical analysis for all age classes, in all seasons, the class 1 raccoons of both sexes generally weighed less than all other age classes. Furthermore, all raccoons of all ages except class 1 males were heaviest during the fall and winter months. It is during this time that raccoons build up fat reserves for the cold periods. Weight differences between class 1 and older animals may be partly attributed to the fact that during the fall, most of the food consumed by older raccoons is stored as fat reserve, while juveniles must still use much of their food for growth (Stuewer, 1943b).

Comparison of seasonal weight changes within different raccoon populations indicates a general tendency for both the weights and the degree of seasonal fluctuation to increase with increasing latitude (Johnson, 1970). In this study, comparison of the weights of recaptured raccoons of both sexes indicated the greatest fluctuations between the fall and winter months and the spring and summer months (Table 4). Between the beginning of fall and the end of winter there was a 32% and

TABLE 3. Mean seasonal weights (kg) for different age class raccoons of both sexes from Cades Cove, Great Smoky Mountains National Park, 1979-1980.

	Season			
Age Class	Winter (n)[a]	Spring (n)	Summer (n)	Fall (n)
Males				
1	2.8 + .17 (11)	2.8 + .32 (5)	3.4 + .26 (7)	2.1 + .10 (10)
2	5.0 (1)	4.2 + .14 (4)	3.4 + .43 (4)	5.4 + .30 (9)
3	6.7 + .21 (5)	4.7 + .11 (5)	4.3 + .31 (8)	5.8 + .33 (5)
4	7.7 (1)	5.0 (1)	5.3 + .08 (3)	6.8 (1)
5	-	4.8 (2)	-	7.0 (2)
Females				
1	3.3 + .19 (6)	2.7 + .09 (8)	2.5 + .34 (11)	3.0 + .26 (16)
2	4.0 + .18 (7)	3.8 + .18 (9)	3.7 + .23 (8)	4.5 + .25 (9)
3	4.4 + .27 (5)	4.1 + .23 (5)	3.5 + .18 (6)	4.4 + .16 (9)
4	4.5 (1)	3.6 (2)	-	-
5	4.5 (2)	3.2 (1)	3.5 (2)	4.5 (1)

[a]Numbers in parentheses denote sample size.

TABLE 4. Seasonal recapture weights (kg) of adult raccoons (> Class 1) from Cades Cove, Great Smoky Mountains National Park, 1979-1980.

Sex		Season			
		Fall (n)[a]	Winter (n)	Spring (n)	Summer (n)
Males	Mean	6.9 (7)	4.7 (8)	3.7 (4)	6.1 (5)
	Std. dev.	0.5	0.4	2.0	0.5
	Range	6.1 - 7.7	4.1 - 5.0	4.3 - 5.2	5.4 - 6.8
Females	Mean	4.4 (9)	3.6 (5)	2.5 (4)	3.7 (6)
	Std. dev.	0.6	0.5	1.6	1.8
	Range	3.6 - 5.4	3.2 - 4.5	3.2 - 4.1	3.6 - 5.4

[a]Numbers in parentheses denote sample size.

18% weight reduction in recaptured males and females respectively. From the beginning of spring to the end of summer there was a 65% and 48% weight gain in recaptured males and females respectively. This is similar to what was found in Alabama by Johnson (1970). However, Mech et al. (1968) and Stuewer (1943a) found weight losses of over 50% to be common in Minnesota and Michigan due to severe winters and prolonged winter lethargy.

Pelage

Although the majority of captured animals were typically gray, 1 black and 3 blond raccoons were captured. These 3 colors are all variations of the gray raccoon line (Whitney and Underwood, 1952). Other color phases exist but they are rare and usually seen only when raccoons are bred in captivity (Whitney and Underwood, 1952).

III. Population Size and Structure

Density

An estimate of 118 ± 59 raccoons was made for the Cades Cove study area. Given a study area of 2000 ha, this indicates a population density of 1/17 ha. This is not a high density compared to some other raccoon populations (Table 5). The highest densities, such as those observed by Lehman (1977) are found in swamp and marshy areas and the lowest, such as those observed by Fritzell (1977) are in residential areas. The density in this study compares favorably to Keeler's (1978) estimate of 1/17.8 ha in Cades Cove and to Wood's (1978) estimate of 1/23.1 ha in a similar habitat type in East Tennessee. Furthermore, this estimate indicates the resiliency of the population from a 1974

TABLE 5. Raccoon densities reported from different regions of the United States (only those obtained by mark-recapture data).

State	Density	Source
Alabama	1/8.5 ha	Johnson (1970)
Illinois	1/5.7 ha	Urban (1970)
Indiana	1/2.8 - 1/.45 ha	Lehman (1977)
Michigan	1/6.6 - 1/12.5 ha	Stuewer (1943a)
N. Dakota	1/170 - 1/85 ha	Fritzell (1978a)
Ohio	1/2.4 ha	Williams (1936)
	1/5.7 ha	Urban (1970)
	1/10.9 - 1.42.9 ha	Butterfield (1954)
	1/1.5 ha	Hoffman and Gottschang (1977)
S. Carolina	1/4.0 ha	Cunningham (1962)
Tennessee	1/23.1 ha	Woods (1978)
	1/17.8 ha	Keeler (1978)
	1/17 ha	This study
Virginia	1/5.7 ha	Soneshine and Winslow (1972)
Wisconsin	1/44.0 ha	Dorney (1954)

epizootic of canine distemper that reduced the population to 1/52.5 ha (Keeler, 1978).

Although the fields in Cades Cove were utilized by the raccoons for travel and foraging, they were not true living space because of a lack of suitable day bed sites. A more accurate representation of density may be expressed by ecological density (Smith, 1974). Since there are approximately 1200 ha of woodland within the study area, the ecological density of raccoons was estimated at 1/10 ha.

Sex Ratio

Among mammals, the sex ratio at birth is often slightly in favor of males (Smith, 1974). By adulthood it may favor either males or females depending upon species, mortality, and habitat (Smith, 1974). Although the sex ratio at birth could not be determined in this study, the sex ratio of 22 pre-weaned juveniles captured during the summer months was 1:1. The sex ratio of all of the raccoons captured during the study period was 1.3:1 females to males (Figure 2). This ratio is similar to that observed in some studies (Stuewer, 1942a; Lehman, 1977; Dew, 1978) but contrasts with others that demonstrate a live trap bias toward males (Urban, 1970; Sonershine and Winslow, 1972).

Examination of the seasonal variation in sex ratios of captured raccoons indicated no significant variation between the seasons (Kruskall-Wallis Test, $P > .05$) but interesting monthly variations (Figure 3). The atypical 3:1 ratios of females to males during the month of June may be related to the dispersal of yearling males from the study area during this time. Age and sex ratio data must be interpreted carefully with the premise that observed ratios may not

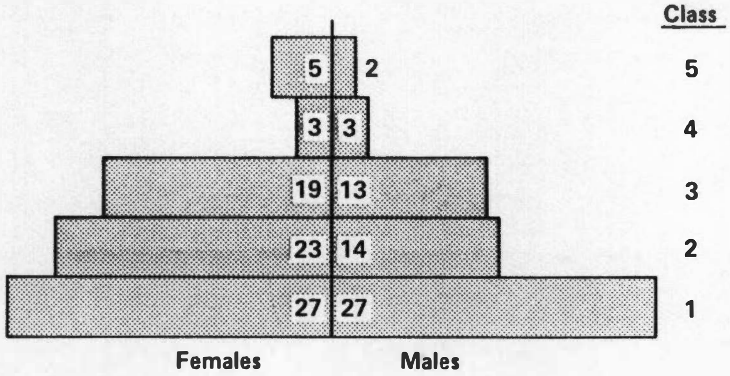

Figure 2. Age pyramid of raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980. Numbers in pyramid represent sample size.

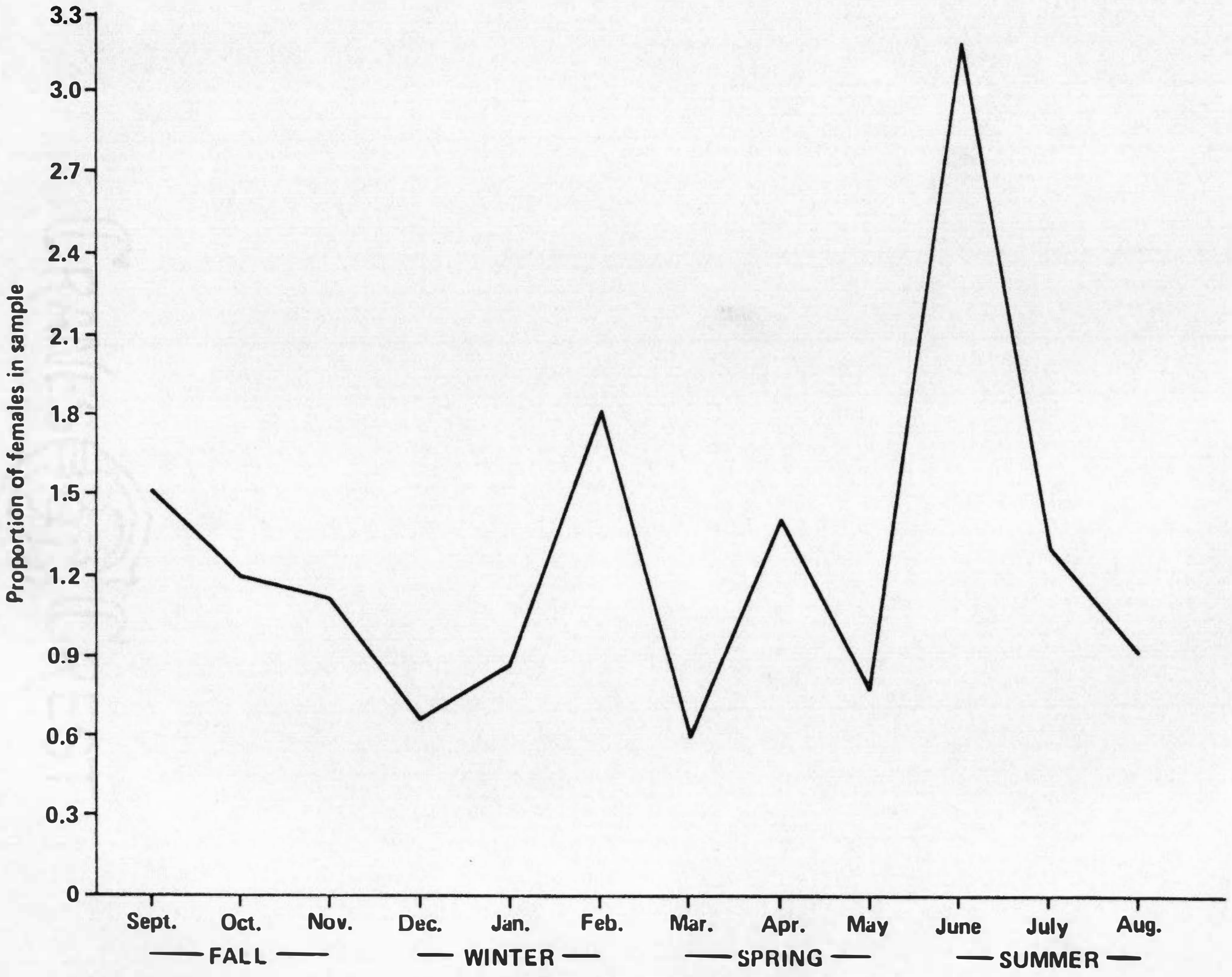

Figure 3. Monthly variation in sex ratios of captured raccoons from Cades Cove, Great Smoky Mountains National Park, 1979-1980.

necessarily be true ratios (Petrides, 1949).

Age Ratios

The technique used in this study for age determinations (Grau et al., 1970) had limited accuracy but is one of the better techniques available for use with live animals. The least accuracy was obtained with middle-aged animals (age classes 2-4). If we classified age classes 1 and 2 as young animals, and age classes 3, 4, and 5 as older animals, an age ratio of 2:1 young to older animals was obtained. Smith (1974) states that an age ratio of young to adults in a stable population should be approximately 2:1.

Changes in seasonal age and sex ratios (Figure 4) also can be used to obtain additional information about a population (Paulik and Robson, 1969; Tanner, 1978). However, the extent to which these ratios can be used to reflect the dynamics of a population is questionable. They can often provide ambiguous information and their misinterpretation can lead to serious management blunders (Caughley, 1974).

IV. Population Dynamics

Breeding and Reproduction

Several key sexual characteristics were noted on randomly selected raccoons of both sexes. In males, the absence of testes were noted. Of 55 individual males that were examined, 56% had descended testes. Seasonally, the highest frequencies of descended testes were observed in spring (5/7) and summer (9/13), and the lowest during winter (6/13). In all but 3 of the instances in which testes were withdrawn (N=21), the animals were juveniles. Due to the lack of

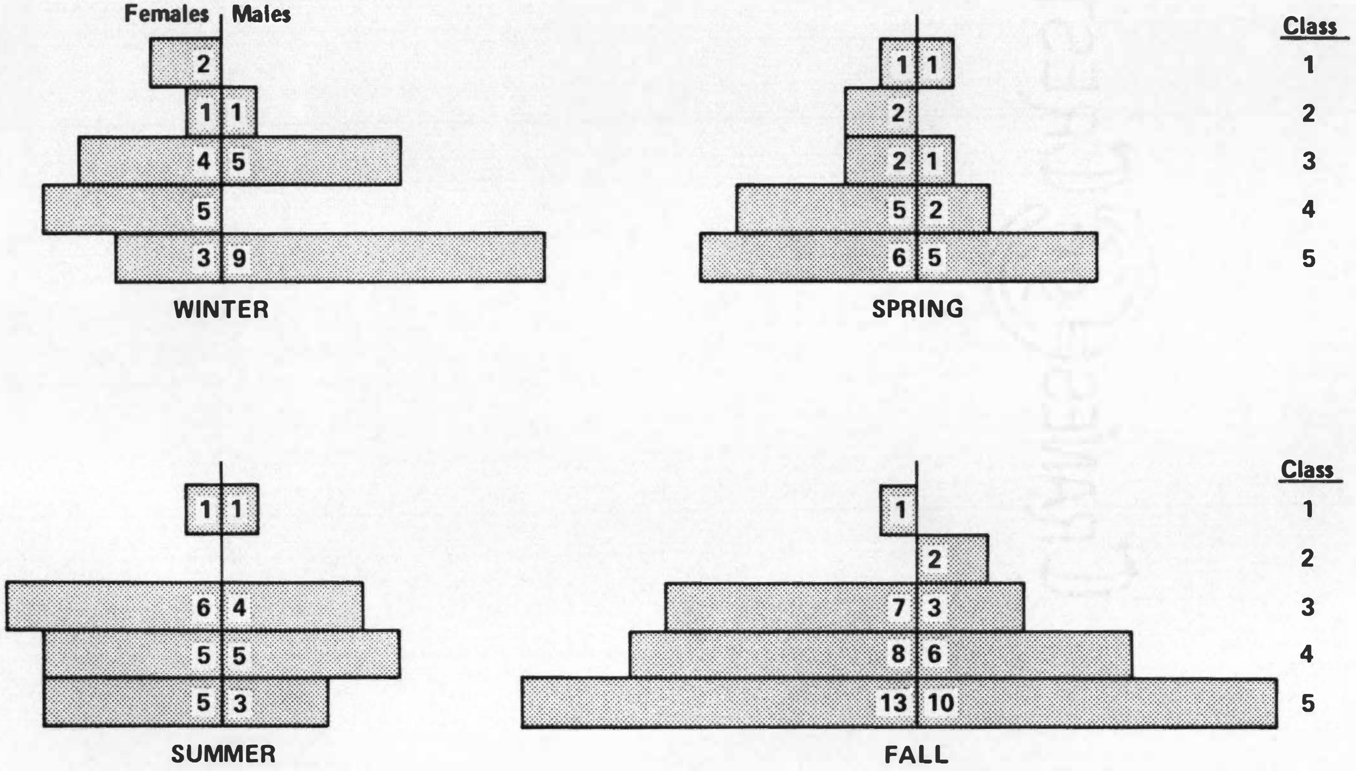

Figure 4. Seasonal age pyramids for raccoons from Cades Cove, Great Smoky Mountains National Park, 1979-1980. Numbers in pyramid represent sample size.

additional data concerning testicular weights and sizes, no inferences can be made from these data regarding male seasonal cycles. Stuewer (1943b) reported that the testes of juveniles and yearlings are abdominal while those of adults remain in the coelom only to descend during the breeding season. Sanderson and Nalbandov (1973) however, found that raccoon testes were nearly always descended, even at birth, and Nalbandov (1958) cites the male raccoon as a species in which spermatogenesis is continuous throughout the year.

In female raccoons, teat length and pigmentation were recorded and individuals that were obviously pregnant or lactating were noted. Teat lengths were used as indicators of breeding condition and lactation (Stuewer, 1943b; Sanderson, 1950). Although pigmentation of nipples were noted, it was not used as an indication of reproductive activity. Although this characteristic has been used by previous studies to assess reproductive condition (Stuewer, 1943b), more recent evidence indicates that pseudopregnant yearling females may develop heavily pigmented nipples, and some parous adults have nonpigmented teats (Sanderson, 1950). Generally, pigmentation has not been correlated with any physiological factor (Sanderson and Nalbandov, 1973). Teat length categories of 0-1.0 cm and > 1.0 cm were used to represent nonlactating and lactating females respectively (Stuewer, 1943b). Ten of 11 female raccoons sampled were lactating during the summer months but only 11 of 41 were lactating during the winter months. During spring and fall, 11 of 24 and 5 of 12 females examined were lactating. These data support the hypothesis of single annual litters in raccoons but also suggests that early or late litters may occur (Stuewer, 1943b; Whitney and Underwood, 1952; Lehman, 1968). Females that fail to breed during their first estrus, or who lose their first litter shortly after birth, are capable of having a second litter 2 to 3 months later (Stuewer, 1943b; Whitney and Underwood, 1952; Johnson, 1970; Sanderson and Nalbandov, 1973).

Several methods were used to assess dates of breeding and parturition. Three radiocollared females were known to have given birth during the study and parturition was strongly suspected in 1 other radiocollared animal. Since pregnant females will enter a litter den 3 to 7 days before birth and remain in the den with the young for 50 to 60 days after birth (Schneider et al., 1971), continuous radiotracking data could be used to locate maternity dens and estimate birth dates (Table 6). This method indicated a birth date of early June with an average of 60 ± 14 days spent within the litter den. A second method of establishing average birth dates involved the capture of 22 pre-weaned juveniles during summer and fall. The presence or absence of particular deciduous and permanent teeth were used to age these animals to within a few days (Table 7) (Montgomery, 1974). These ages could then be extrapolated back to the birth date. Using this method, the earliest birth date was estimated at 12 May and the latest 2 August, with a mean birth date of 23 June. The dates of capture of pregnant and lactating females (Table 8) also indicate that parturition usually occurs in June. If an average gestation period of 63 days is assumed (Hamilton, 1936; Stuewer, 1943b; Whitney and Underwood, 1952), breeding in the Cades Cove raccoon population should have occurred in late March or early April.

In the northern United States, raccoons breed from January through March, with a peak in February (Hamilton, 1936; Sanderson,

TABLE 6. Maternity den data for raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

Animal	Den Entry-Exit Dates	Time in Den	Den Type	Number of Radiolocations
R01	4 June 80 - 14 July 80	40 days	Tree	20
R15	21 May 80 - 31 July 81	71 days	Tree	34
R20	29 May 80 - 28 July 80	60 days	Tree	27
R55	21 May 80 - 30 July 80	70 days	Tree	34
Mean	26 May 80 - 26 July 80	60 days		

TABLE 7. Ages and estimated birth dates of captured preweaned raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

Animal	Age (days)	Capture Date	Estimated Birth Date
R03	86 - 97	19 Sept 79	21 June 79
R05	86 - 97	20 Sept 79	22 June 79
R12	106 - 112	20 Oct 80	4 July 80
R78	86 - 97	19 Sept 80	21 June 80
R82	86 - 97	19 Sept 80	21 June 80
R87	86 - 97	19 Sept 80	21 June 80
R201	73	21 Aug 80	10 June 80
R203	73	21 Aug 80	10 June 80
R202	106 - 112	4 Oct 80	18 June 80
R204	106 - 112	12 Oct 80	26 June 80
R205	106 - 112	12 Oct 80	26 June 80
Y52	86 - 97	4 Oct 80	5 July 80
Y53	86 - 97	20 Sept 80	22 June 80
Y54	86 - 97	20 Sept 80	22 June 80
Y60	86 - 97	4 Oct 80	5 July 80
Y62	86 - 97	29 Sept 80	30 June 80
Y67	106 - 112	7 Oct 80	21 June 80
Y70	106 - 112	7 Oct 80	21 June 80
Y71	86 - 97	25 Oct 79	2 Aug 79
Y105	86 - 97	19 Sept 80	21 June 80
Y201	66	16 July 80	12 May 80
Y202	73	19 Sept 80	8 July 80
N = 22		Mean birth date - 23 June 80	
		Range 12 May - 2 Aug	

TABLE 8. Dates of capture of pregnant and lactating female raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

Animal	Date Captured	Reproductive Condition	
R01	10 May 80	Pregnant	Stomach distended
R08	24 May 80	Pregnant	Stomach distended Nipples swollen
R55	18 May 80	Pregnant	Stomach distended Nipples swollen
R57	24 May 80	Pregnant	Stomach distended
R60	18 May 80	Pregnant	Stomach distended
R61	11 May 80	Pregnant	Stomach distended
R75	21 June 80	Lactating	Teats swollen, large
R41	18 July 80	Lactating	Teats swollen Teat size 1.8 cm
R43	1 Aug 80	Lactating	Teats swollen, 2.0 cm
R46	25 July 80	Lactating	Teats swollen
R151	18 Sept 80	Lactating	Teats swollen Caught with 2 cubs
R15	19 Sept 80	Lactating	Teats swollen Caught with 2 cubs

1961; Stuewer, 1943a) and parturition in late April (Sanderson, 1961a). In the south, the breeding peaks in March and April (McKeever, 1958; Cunningham, 1962; Johnson, 1970) with parturition in May (McKeever, 1958). In Cades Cove, breeding peaked in April with parturition in June. These periods are about the same as recorded from Alabama (Johnson, 1970) and compare with the data from the more southern latitudes. Variations in the breeding season are not unusual since breeding ages, parturition dates, litter sizes, and frequency of late litters have been shown to vary with latitude, habitat, and population density (Fritzell, 1978a). Furthermore, the length of the breeding season can be affected by diet (Bissonnette and Csech, 1938, 1939). Despite these factors, there does appear to be a general trend of earlier breeding and parturition dates in more northerly latitudes. This may be related to the harsher and more prolonged winter conditions at these latitudes. Since the female-young relationship in raccoons is lengthy and energetically expensive (Schneider et al., 1971), it is much more crucial in northern areas for the females to undergo parturition and lactation as early as possible so that they may quickly and efficiently store needed energy reserves for the upcoming winter months.

Three radiocollared animals, R1, R2, and R15, and 1 tagged animal, R151, were observed in the field with 4, 4, 2, and 1 young respectively. This small sample indicates a mean litter size of 2.8 ± 1.5 young which compares favorably to the findings of Woods (1978) in Tennessee but differs from those of other studies (Table 9). There is a general trend toward larger litter sizes in more northern latitudes (Johnson, 1970). This is a possible mechanism to compensate

TABLE 9. Variation in mean litter size of raccoons throughout the United States.

State	N	Mean Litter Size	Source
North Carolina	10	1.9	Llewellyn (1952)
Washington	7	2.0	Scheffer (1950)
Maryland	12	2.3	Llewellyn (1952)
Alabama	101	2.5	Johnson (1970)
South Carolina	13	2.8	Cunningham (1962)
Tennessee	20	2.8	Woods (1978)
	4	2.8	This study
Georgia, Florida	17	3.2	McKeever (1958)
Texas	26	3.4	Wood (1955)
Illinois	?	3.5	Sanderson (1960)
Louisiana	6	3.8	Cagle (1949)
Missouri	22	3.8	Sanderson (1950)
Michigan	11	4.0	Stuewer (1943b)
Virginia	5	4.4	Kellner (1954)
Kansas	8	4.6	Stains (1956)
North Dakota	?	4.8	Fritzell (1977)
New York	4	5.0	Llewellyn (1952
	MEAN -	3.4	

for higher winter mortality at these latitudes (Mech et al., 1968).

Of the maternity dens that were located, only 1 was examined. This den consisted of a 0.3 m deep, 32 cm diameter cavity, 5.4 m high in a white oak tree. Although the cavity opened from the top, there appeared to be excellent canopy protection against rain. There was no indication of any nest building within the den although this behavior has been observed in other studies (Schneider et al., 1971; Stuewer, 1948; Whitney and Underwood, 1952).

Activity

Throughout the study, 5,434 activity readings were obtained from 14 radiocollared raccoons. Activity was documented while searching for dens during the daylight hours and during the all night radiotracking sessions. Any activity readings considered to be a result of disturbance at the day bed were discounted. The use of motion sensitive transducers to document activity in wildlife is a relatively new technique in radiotelemetry. Previous studies to document activity have considered distances between sequential radiolocations (Alt et al., 1976; Kammermeyer and Marchinton, 1977) and audible changes in signal frequency and strength (Gilmer et al., 1971; Poelker and Hartwell, 1973). However, both of these have been shown to be less accurate than the use of motion sensitive devices (Quigley et al., 1979). The tip-switch motion sensor, used during this study, was considered superior to the reset motion sensor to measure activity, although it was less accurate for locating animals (Quigley et al., 1979). Only 2 previous studies (Hardy, 1979; Taylor C.I., 1979) have employed tip-switch monitors for obtaining activity information from raccoons.

Since a high correlation was shown between movement patterns and activity as determined by motion sensitive devices in black bears (Garshielis and Pelton, 1978), this was assumed true for the raccoons as well. The seasonal trends in activity (Figure 5) generally showed a sharp increase in activity from 1800 to 2100 hours, a gradual decline until 0300 hours, followed by sharp declines until sunrise. Similar activity patterns were observed by Sharp and Sharp (1956), Hardy (1979), and Taylor C.I. (1979). The daily transitions from inactivity to activity and back to inactivity took place most frequently at 1900 hours and 0700 hours respectively. These times closely corresponded to sunset and sunrise. The winter activity pattern showed the greatest differences relative to the other seasons. During the winter months, only 50% of the raccoons were active during peak activity hours. Furthermore, the leveling off in activity occurred earlier at 1800 hours, and the decline after 2400 hours was more rapid than during other seasons. Of all the environmental variables known to influence activity in raccoons, air temperature is believed to play the greatest role, with lower temperatures causing decreased movement and activity (Stuewer, 1943b; Whitney and Underwood, 1952). The presence of snow cover has also been shown to inhibit movement (Stuewer, 1943b; Stains, 1956; Cabalka, 1952). During the fall months, a greater proportion of animals were active over all time periods than during any other season. Most of the raccoons remained active until 0300 hours instead of showing the typical pattern of decline after 2400 hours. At 0700 hours, approximately 40% of the raccoons were still active. This increase in activity over longer periods of time may be expected during

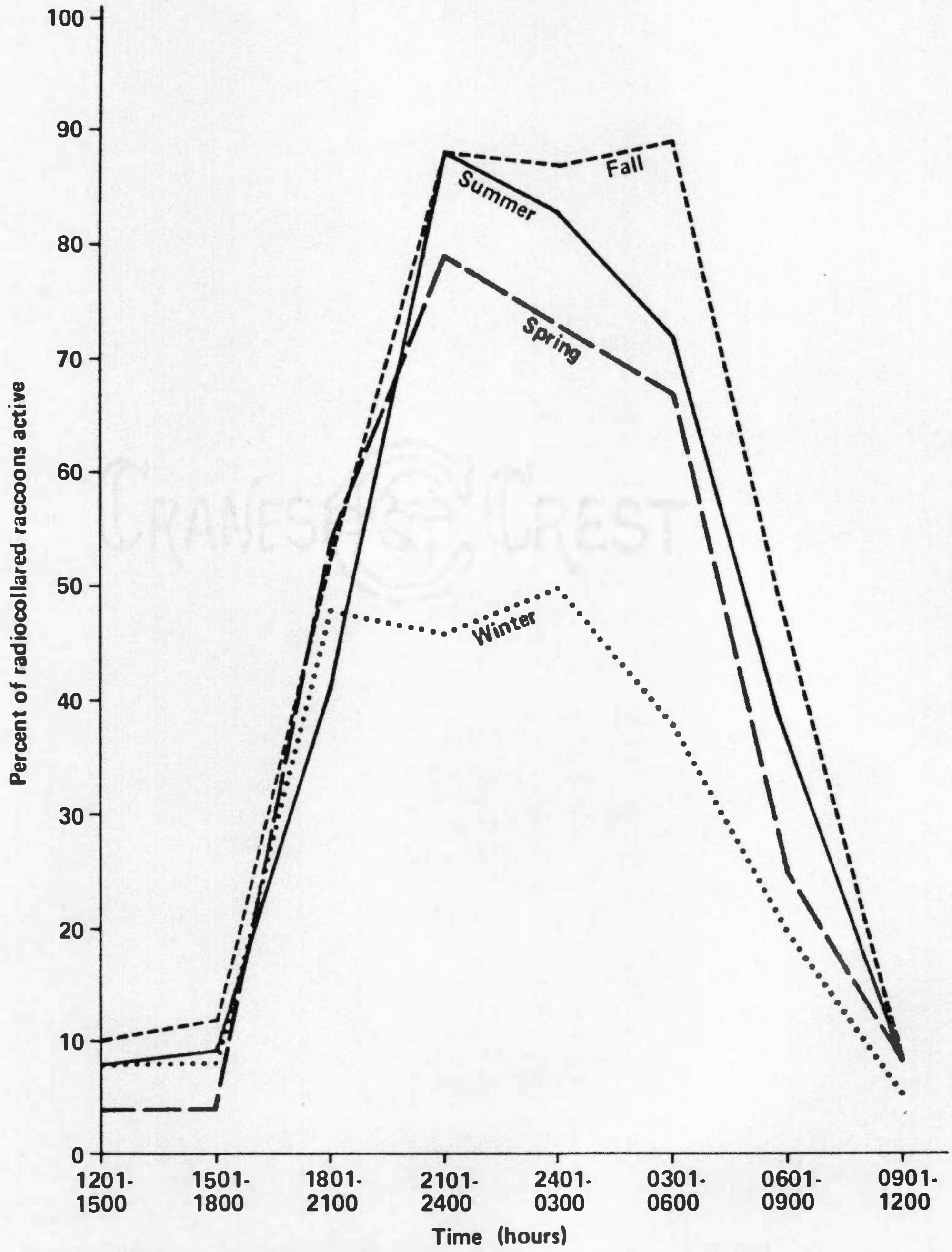

Figure 5. Seasonal hourly activity patterns for radiocollared raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

the fall. During spring and summer there are high energy demands on females due to pregnancy, parturition, and lactation, and higher than normal demands on males due to conception and dispersal. Fall is the time for the raccoons to replenish needed reserves and begin to build up additional reserves for the winter.

Social Interactions

Since raccoons could not be directly observed in the field social interactions could be inferred from such things as home range overlap, distance between activity centers, and distance between day bed sites. Convex polygons were used to graphically represent seasonal home range overlap among representative male and female raccoons (Figures 6-9). Although polygon methods have subjective biases (Sanderson, 1966) and are dependent upon sample sizes (Madden and Marcus, 1978), the advantages of the convex polygon in examining habitat utilization can outweigh the disadvantages (Lindzey and Meslow, 1977). Seasonal home ranges indicated extensive overlap among both male and female raccoons of all ages. Female raccoons appeared to have a greater degree of home range overlap than males, with both sexes showing their largest home ranges and overlap during the spring months. Other studies have also shown extensive home range overlap in raccoons (Stuewer, 1943a; Geis, 1966; Hardy, 1979; Taylor, 1979), and the degree of overlap has even been used to assess agonistic interactions and territoriality (Jorgensen, 1968). These studies have generally led to the belief that raccoons are not territorial. However, Mech et al. (1966) postulated that raccoons do maintain minimum spacing distances between resting sites and Tevis (1947) and Sharp and Sharp (1956)

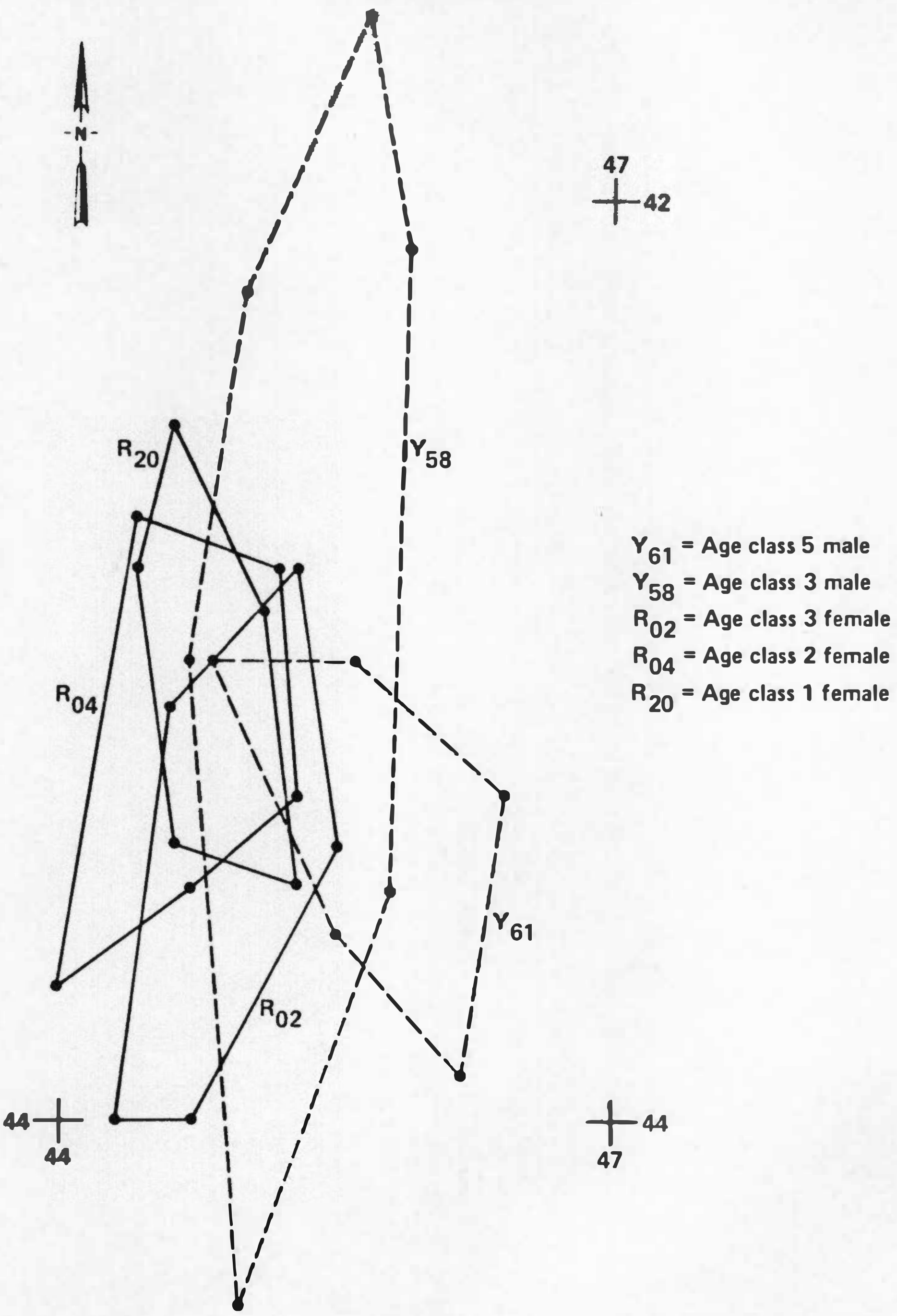

Figure 6. Winter home range overlap among various age male and female radiocollared raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980. Each UTM grid tic = 1 km.

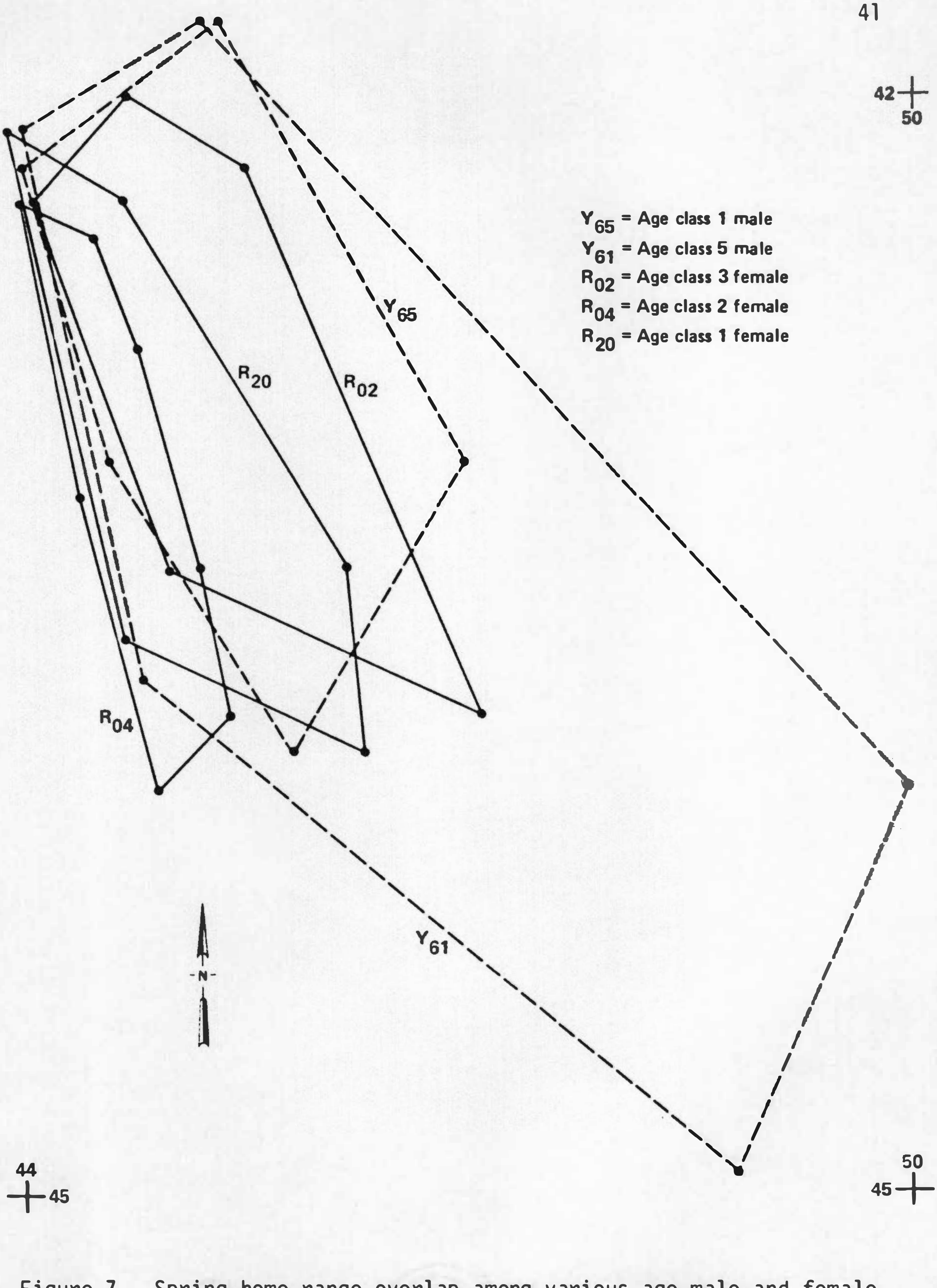

Figure 7. Spring home range overlap among various age male and female radiocollared raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980. Each UTM grid tic = 1 km.

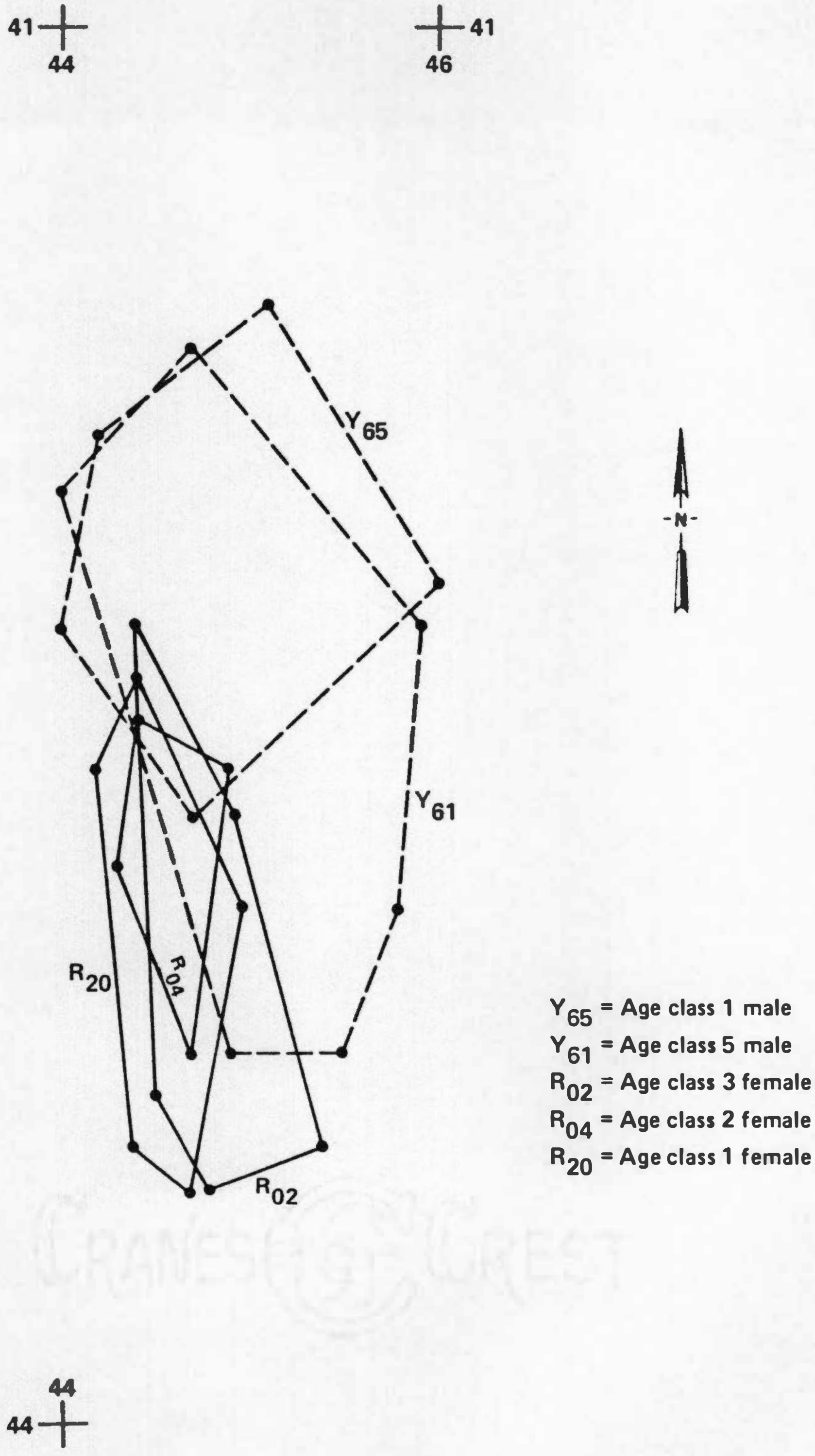

Figure 8. Summer home range overlap among various age male and female radiocollared raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980. Each UTM grid tic = 1 km.

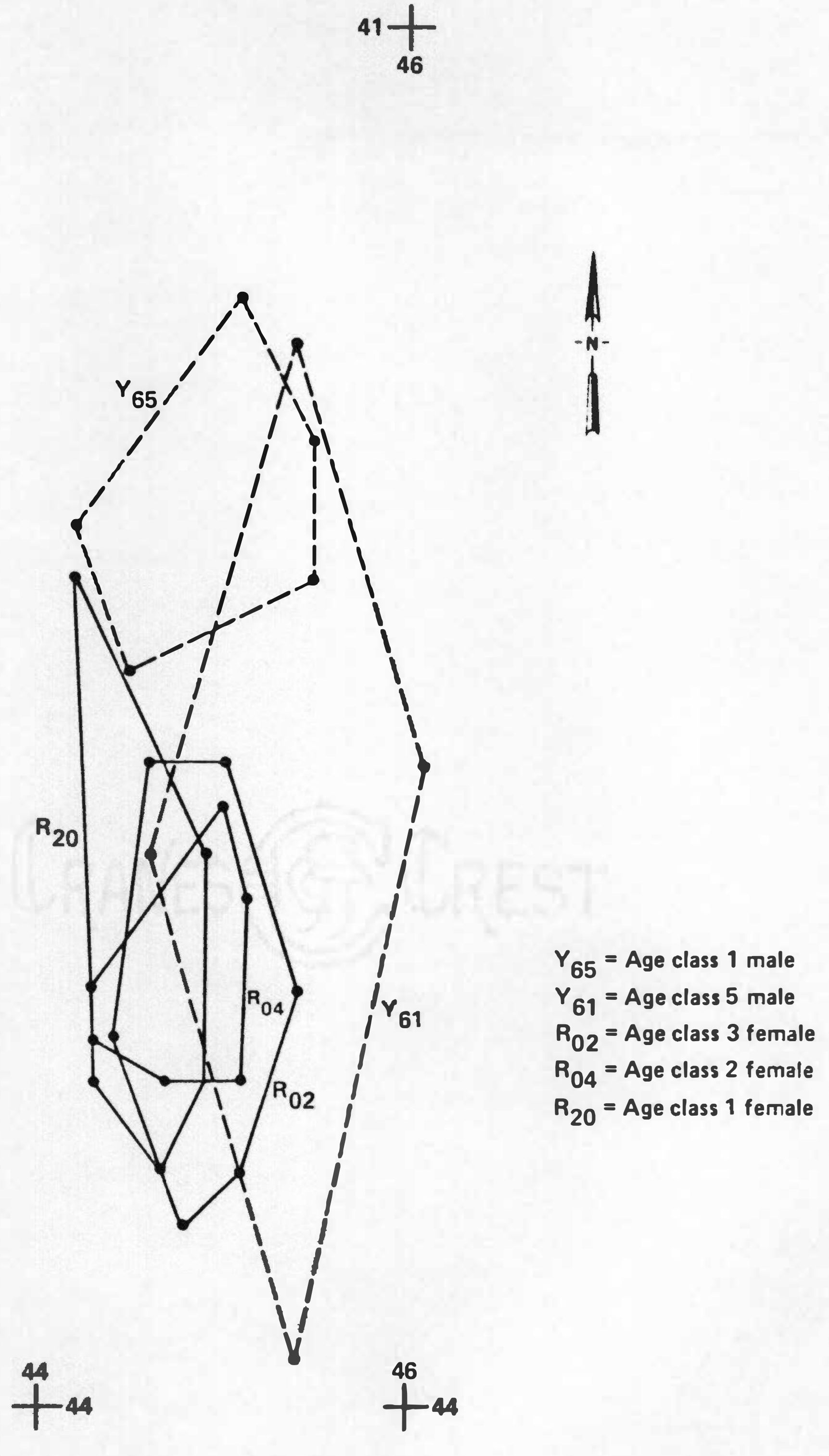

Figure 9. Fall home range overlap among various age male and female radiocollared raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980. Each UTM grid tic = 1 km.

showed that feeding areas may be actively defended by adult males. As a result of a recent study, Fritzell (1978b) has even speculated that a form of territoriality is exhibited by adult male raccoons in response to competition for access to females.

Although data concerning simultaneous locations of adult males was not available from this study, comparisons of seasonal and annual activity centers can be examined (Appendix 1). The 2 oldest radio-collared male raccoons from this study, Y58 and Y61, showed variability in degree of seasonal overlap (Figure 10). During most of the year they maintained relatively close contact with activity centers only 0.5 km apart during fall, 0.4 km apart during spring, and 0.3 km apart during winter. However, during the month of April, when breeding occurred, they remained relatively distant from each other with activity centers 1.3 km apart. During the summer months, when young were being weaned and family units began to leave their maternity dens and travel together, these 2 males maintained activity centers 1.5 km apart. These data indicate the possibility that adult males may maintain some degree of distance from each other during breeding and parturition, but not at other times of the year. During late fall and winter both males were known to share the same den on at least 10 occasions. It is unlikely that these 2 raccoons were siblimgs since male siblings usually separate early in life (Fritzell, 1977).

Another possible explanation for extensive home range overlap, particularly during the winter months, is the behavior involving favored rock den sites. Tory Shields Cave, the only cave within the study area, was within the home ranges of every radiocollared raccoon

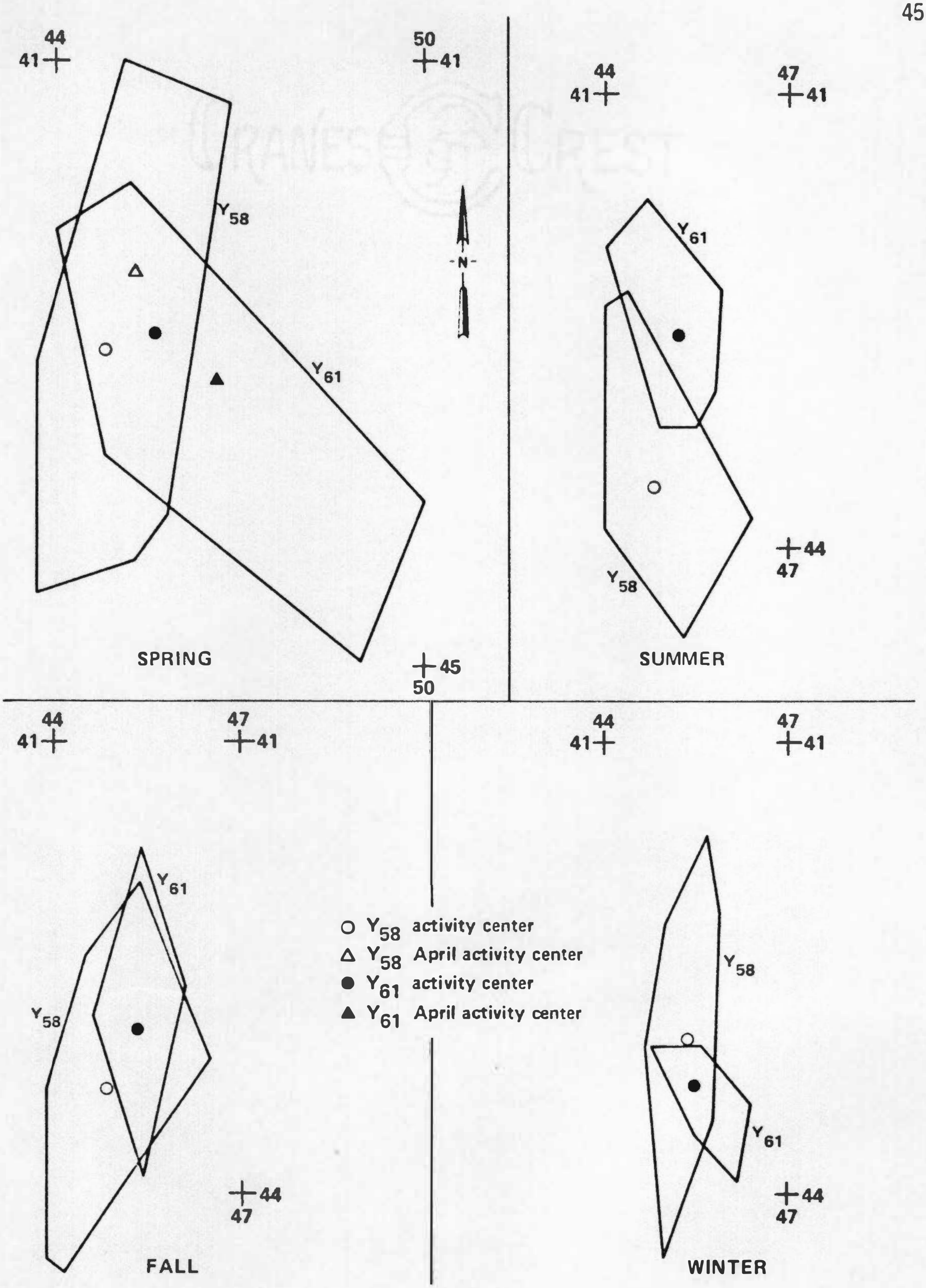

Figure 10. Seasonal home range overlap and distance between activity centers for two adult male raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980. Each UTM grid tic = 1 km.

except 1 older male (Y55). This cave was occupied by 7 different radio-collared raccoons during the winter, 112 times. Numerous instances of communal denning occurred within this and other favored rock dens.

Home Range

The most generally accepted definition of home range is the area that an animal occupies during its normal daily activities (Burt, 1943). In recent years, this definition has included various probabilistic distributions of animals within their environment. One such model used in this study is that of the bivariate home range (Mazurkiewicz, 1969; Jennrich and Turner, 1969). This was used instead of the more common circular home range models (Burge and Jorgensen, 1973; Metzgar, 1973) or the nonstatistical polygon methods, to generate home range sizes. For circular home range models, the home range size depends upon circular distribution of locational data and is not applicable to other home range shapes (Koeppl et al., 1975). Although it has been suggested that statistical methods may yield home range estimates that are significantly larger and sometimes more inaccurate than nonstatistical methods (Waldschmidt, 1979), the bivariate home range model was well suited for the data in this study because of large sample size and the fact that the model is affected by frequency of habitat use within the home range.

Utilizing the bivariate home range model put forth by Koeppl et al. (1975), annual and seasonal home range sizes (Table 10) and activity centers (Appendix 1) were obtained using 2,753 radiolocations from 14 animals. Examination of the data indicated no significant interaction effects of sex and season on home range size (ANOVA, $P > .05$).

TABLE 10. Annual and seasonal home range sizes (km)^2 for raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980. Range size is defined as the area of the 95 percent confidence ellipse.

Raccoon No.	Winter Area (n)[1]	Spring Area (n)	Summer Area (n)	Fall Area (n)	Annual Area (n)
Males					
Y58	3.5 (95)	21.0 (62)	4.8 (58)	9.2 (55)	10.4 (270)
Y66	---	3.1 (21)	---	---	---
Y65	---	8.2 (50)	2.6 (70)	2.1 (20)	6.0 (149)
Y55	4.5 (46)	11.2 (16)	---	12.1 (24)	7.6 (86)
Y61	0.5 (65)	11.6 (63)	3.7 (77)	3.5 (52)	6.1 (266)
Y54	---	3.0 (54)	0.7 (20)	---	---
subaverage	2.8	9.7	3.0	6.7	7.5
std. deviation	2.1	6.7	1.7	4.7	2.0
Females					
R01	1.2 (62)	7.5 (74)	4.8 (69)	4.9 (37)	5.8 (258)
R02	1.3 (71)	4.2 (72)	0.6 (46)	0.9 (57)	3.3 (263)
R04	0.5 (78)	1.6 (80)	0.5 (44)	0.2 (46)	1.4 (263)
R06	0.1 (60)	5.7 (64)	1.5 (32)	1.1 (53)	3.2 (215)
R09	1.6 (75)	5.9 (54)	2.5 (64)	2.7 (48)	3.4 (241)
R15	0.6 (69)	3.8 (80)	1.0 (76)	2.6 (59)	2.7 (291)
R20	0.2 (80)	2.4 (77)	1.1 (68)	0.9 (60)	1.5 (291)
R55	---	---	1.7 (65)	1.3 (27)	---
subaverage	0.78	4.4	1.7	1.8	3.0
std. deviation	0.58	2.1	1.4	1.3	1.5
total average	1.4	6.9	2.1	3.4	4.7

[1]The number of radiolocations used in the home range analysis.

Therefore, considering each effect separately, male raccoons had significantly (ANOVA, $P < .05$) larger home range sizes both seasonally and annually than females. This was particularly exemplified during the month of April when male home ranges were almost 5 times that of females. Home range sizes of male raccoons were significantly larger (ANOVA, $P < .05$, Duncans Multiple Range Test $\alpha = .05$) during spring than all other seasons with no significant differences between fall, winter, and summer (Duncans Multiple Range Test, $\alpha = .05$). Home ranges of female raccoons were significantly largest during spring, and smallest in winter with no significant differences between fall and summer (ANOVA, $P < .05$, Duncans Multiple Range Test, $\alpha = .05$). The fact that both sexes maintained relatively large spring home ranges appeared to be due to movement patterns during the month of April. During April, raccoons were found in areas almost entirely outside their normal home ranges. This shift greatly affected both spring and annual home range sizes, particularly in males. Reproductive data collected during this study indicated that breeding took place during late March, early April. During this time male raccoons travelled widely seeking out different females with which to breed.

Since the reproductive success of males depends upon their ability to breed with many females (Orians, 1969), it would be advantageous for males to be mobile and occupy large areas that overlap the ranges of many females. On the other hand, females cannot improve their reproductive success by breeding with many males so females should be less mobile than males and occupy areas no larger than necessary to assure adequate nutrition for self-maintenance and development of young (Amstrup and Beecham, 1976). This might explain the significantly larger male home range sizes and the degree to which they overlap female home ranges.

The overall mean home range sizes for Cades Cove raccoons are different from those obtained in other populations. They are considered larger than those obtained by Urban (1970), Ellis (1964), Lehman (1977), and Hoffman and Gottschang (1977) but considerably smaller than that obtained by Fritzell (1978b). Some of these differences may be attributed to different methods of home range calculation or may be related to different population densities as suggested by Ellis (1964). Sanderson (1966) believed that the average home range size decreased as the population increased but Blair (1953) did not consider this a valid concept. Other factors that could affect home range sizes include social structure of the population, seasonal food availability, and habitat differences within the study area. Hardy (1979) found that food availability and habitat differences had the greatest influence on raccoon home range size in East Tennessee.

In order to evaluate seasonal shifts in home range, one can examine shifts in activity centers (Mazurkiewicz, 1969). Activity centers do not necessarily have any biological meaning apart from being an average of points of capture (Hayne, 1949). In this study, however, day bed locations as well as night locations were used in cal-calculating activity centers. This procedure biased the location of the activity centers due to high day bed reuse patterns. It was felt that this bias made the activity centers more representative of true activity centers since they were the areas of greatest familiarity.

When examined by sex, male raccoons showed a significantly larger shift in activity centers than females (Mann-Whitney-Wilcoxen Test, $P < .05$) during the fall to winter transition but no significant differences (Mann-Whitney-Wilcoxen Test, $P > .05$) between any of the other seasons (Table 11). Overall, males averaged shifts in activity centers of .21 km and females, of .14 km with no significant differences (ANOVA, $P > .05$) between the seasons. However, atypical movement patterns occurred during the spring months. Virtually all of the raccoons established different home ranges in April relative to those which were originally established and which were returned to in May. This was indicated in the shift of activity centers which was significantly larger (ANOVA, $P < .05$) during spring than between any of the seasons. Johnson (1970) reported that shifting activity centers may be related to food supply. The lack of large differences either in seasonal home range sizes or seasonal shifts in activity centers indicates that changes in seasonal food availability may not be a crucial factor in Cades Cove influencing the dynamics of the raccoon population. The significant shifts in home range sizes and activity centers that do occur appear to be well correlated with peak breeding activity in the population.

Nocturnal Movements

Locational data taken between 2000 and 0500 hours were analyzed for rates of travel (Table 12). There were no significant seasonal or annual differences in travel rates (ANOVA, $P > .05$) between the sexes. Males, however, showed significantly greater rates of travel (ANOVA, $P < .05$, Duncans Multiple Range Test, $\alpha = .05$) during spring than

TABLE 11. Mean seasonal shifts (km) in home range activity centers for raccoons from Cades Cove, Great Smoky Mountains National Park, 1979-1980.

	Fall(79)/ Winter(79) (n)[1]	Winter(79)/ Spring(80) (n)	Spring(80)/ Summer(80) (n)	Spring(80)[2] March,May/April (n)
Males				
Mean	0.23 (3)	0.21 (3)	0.19 (4)	0.38 (4)
Std. Deviation	0.021	0.030	0.062	0.14
Range	0.21 - 0.25	0.18 - 0.24	0.10 - 0.14	0.25 - 0.58
Females				
Mean	0.10 (7)	0.17 (7)	0.15 (7)	0.27 (7)
Std. Deviation	0.075	0.13	0.086	0.093
Range	0.0 - 0.22	0.06 - 0.42	0.06 - 0.31	0.12 - 0.40

[1]Number in parentheses denotes sample size.

[2]Due to atypical movements during April, a separate category was made to portray the shift in activity centers during this month.

TABLE 12. Mean nocturnal travel rates (km/hr) during 2000 - 0500 hours by raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

	Winter Rates[a] (n)[b]	Spring Rates (n)	Summer Rates (n)	Fall Rates (n)[c]
Males				
Mean	0.34 (33)	0.57 (69)	0.34 (58)	0.31 (28)
Std. Deviation	0.32	0.31	0.12	0.18
Range	0.11 - 0.87	0.23 - 1.0	0.20 - 0.61	0.08 - 0.50
Females				
Mean	0.21 (72)	0.40 (119)	0.28 (99)	0.36 (58)
Std. Deviation	0.15	0.21	0.17	0.15
Range	0.0 - 0.44	0.19 - 1.1	0.05 - 0.78	0.15 - 0.64

[a]No data obtained during February due to near zero activity by the raccoons. Thus, winter figures may be overestimated.

[b]Numbers in parentheses represent sample size.

[c]No data was obtained for November.

during all other seasons. Females showed significantly lower rates of travel (ANOVA, $P < .05$, Duncans Multiple Range Test, $\alpha = .05$) during winter but no significant differences (ANOVA, $P > .05$) between other seasons. Further breakdown of the seasonal data into its component months (Figure 11) indicated that males travelled faster during March and April, and slowest during January. The unavailability of sufficient locational data during February was due to near zero activity during radiotracking sessions. Therefore, it was possible that travel rates were even lower during this month than January. Females appeared to travel fastest during April and slowest during January. The fast travel rates in both sexes again appeared to be related to breeding periods. Stuewer (1943a) reported that during breeding, males travel extensively from one den to another seeking females. The slow travel rates exhibited during January is temperature and snow related (Stuewer, 1943b; Whitney and Underwood, 1952). The overall mean travel rate for all radiocollared Cades Cove raccoons was 0.38 km/hr. This is over twice the rate of 0.15 km/hr. reported by Urban (1970) or the 0.12 km/hr. reported by Ellis (1964) in other populations. These differences may be due to the comparatively low population density and large home ranges found in this study compared to that of both Ellis (1964) and Urban (1970). Animals with faster travel rates can move over larger distances to obtain food, day bed sites, and other resources.

Dispersal

Dissolution of parent-offspring bonds and subsequent dispersal is well documented for raccoons (Urban, 1970; Fritzell, 1977, 1978). Of the 14 raccoons radiocollared during this study, 2 class 1 females

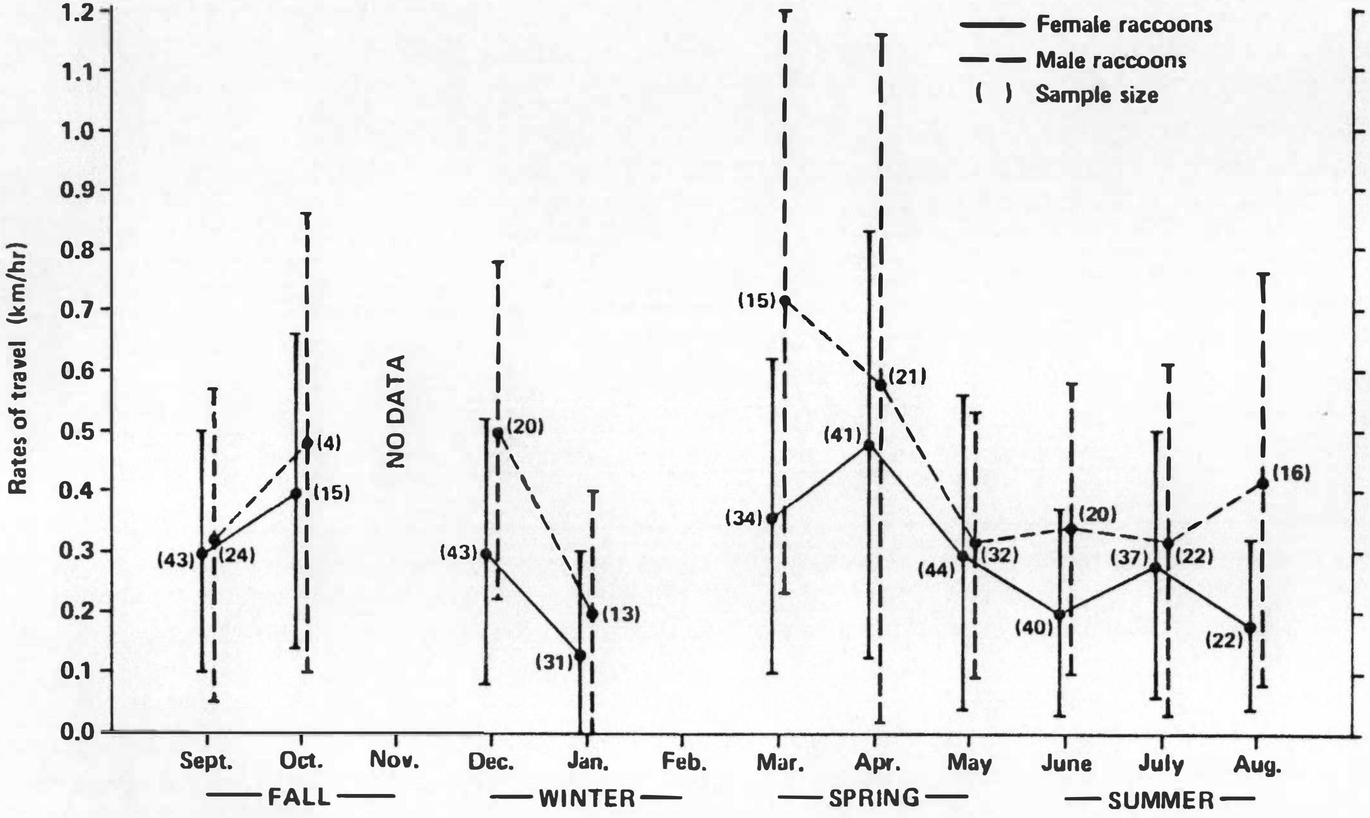

Figure 11. Monthly nocturnal travel rates (km/hr) during 2000-0500 hours by radiocollared raccoons from Cades Cove, Great Smoky Mountains National Park, 1979-1980.

were collared in October, 1979 and 1 class 1 male was collared in March, 1980. The yearling females never left the area in which they were collared, and 1 of them (R15) subsequently had young. The yearling male was last located within the study area on 19 June 1980. Subsequent aerial radiotracking located this raccoon 2 weeks later in the vicinity of Laurel Lake, Townsend, Tennessee, an air distance of approximately 9.6 km. The last radiolocation of this male within the Cades Cove study area coincided with estimated female parturition dates. It is also similar to the dispersal date of June 6 found by Fritzell (1978b) in North Dakota. Live trapping data provided additional examples of dispersal. A 3 month old male captured on 20 September 1979 in the middle of Cades Cove was subsequently recaptured 18 June 1980 on the western extremity of the study area, a 4 km straight line distance. In addition, a yearling female first captured 23 May 1980 along Mill Creek in Cades Cove was subsequently recaptured 16 October 1980 at the Tipton Oliver house, a straight line distance of 3 km. Dispersal distances, however, appear to vary greatly between different raccoon populations. Dispersal distances obtained by Fritzell (1978b) averaged 15.5 km (N = 3) while those obtained by Urban (1970) averaged only 2.3 km (N = 3). Occasionally, unusually large dispersal distances such as 263 km (Lynch, 1967) and 275 km (Priewert, 1961) have been reported for raccoons. Reasons for such variation in dispersal distances are largely unknown but may be related to population densities, habitat type, food availability, and differences in research methodology.

Dispersal in yearling females appeared to occur much more infrequently than with yearling males. Although Stuewer (1943a) reported a fall dispersal of both juvenile males and females from natal areas, Fritzell (1978b) felt that yearling females do not undergo dispersal but usually stay in the same general area of birth. Additional evidence in this study for yearling males dispersing to a greater extent than yearling females came from mark-recapture data. Considering only those raccoons that were captured and marked in areas where they could have been recaptured after spring and summer 1980, 16 of 21 female yearlings in this category were recaptured while only 22 of 61 male yearlings were recaptured. These data are supported by those of Butterfield (1944) who reported a sex ratio of recaptured raccoon young of 14% males and 86% females again suggesting that the male young left the area.

Dispersal of male and female yearlings is a relatively well studied phenomenon among carnivores. It has been documented in foxes (Errington and Berry, 1937; Longley, 1962; Ables, 1965), coyotes (Gier, 1975), mink (Gerrell, 1967), martens (Hawley and Newby, 1957), bobcats (Bailey, 1974), and black bears (Lindzey, 1976; Rogers, 1977). However, the reasons behind such movements are not totally understood. It is logical that dispersal should be advantageous when the local environment is deteriorating, but Hamilton and May (1977) argue that it is adaptive for parents to enforce dispersal of some of their young even in an environment that is crowded but healthy. Offspring which do not disperse compete with both siblings and the dispersive offspring of other families. Dispersal of at least some offspring lowers the probability of total reproductive failure and it gives a parent a more even chance in competition with other parents of dispersive young, for placement of young in new vacancies. In addition, dispersal may be a mechanism to prevent inbreeding (Rogers, 1977), since there is no evidence to suggest that an animal can simply recognize its relatives by their phenotype and refrain from mating with them (Smith, 1978). If these are the reasons for dispersal, a question might arise as to why raccoons disperse post-estrus, and pre-parturition while animals such as bears disperse pre-estrus. Data from juvenile and adult male raccoons (Sanderson and Nalbandov, 1973) indicate that juveniles become sexually mature 3 to 4 months later in the year than adults. In fact, juvenile males appear to lack any sperm in their epididymides during the peak of the breeding season but became sexually mature after most of the breeding had been accomplished (Sanderson and Nalbandov, 1973). If this is typical in the raccoon, then juvenile males might not present any threat to their parent in terms of fitness nor are they competing with adult males for other females.

Longevity and Mortality

Of the 135 raccoons that were captured and aged during the study period, only 12 animals were older than 58 months, and of these only 6 were older than 86 months (age class 5). Seven years appeared to be near the upper extreme for longevity of raccoons in Cades Cove. Animals which had reached this age were in poor physical condition (Table 13). The mean age for the entire sample was 29 months (age class 2). Petrides (1949) stated that the relationship between average longevity (l) of a stable population and its percentage of grown first year animals (j) is: $L = \frac{1}{j}$. Using the annual percentage of first year animals in late winter, the average longevity for this population was

TABLE 13. Physical conditions of age class 5 raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

Animal	Sex	Capture Date	Weight (kg)	Physical Condition	Fate
R13	F	18 Jan. 80	3.6	Cataracts, missing teeth, molars worn to gums.	Unknown
R23	F	7 Oct. 79	4.5	Shabby body condition, teeth worn to gums.	Died under drug.
R46	F	12 Dec. 79	5.4	Molars worn to gums.	Recaptured 25 July 80 at 3.4 kg.
R50	F	23 Mar. 80	2.7	Shabby coat, teeth worn to gums.	Unknown
R67	F	24 July 80	3.6	Covered with ticks, appeared healthy.	Unknown
Y50	M	3 May 80	4.5	Ears and nose ripped, appeared healthy.	Unknown
Y61	M	19 Sept. 79	6.8	Appeared healthy.	Killed by ranger (2/80) due to unusual behavior at 1.4 kg.

calculated by Petrides formula to be 30 months. This number represents the average longevity only of animals that have survived to the end of their first year and is comparable to the average longevity of 22 months in Missouri (Sanderson, 1951) and 36 months in Alabama (Johnson, 1970). The maximum known longevity in the wild is 17 years (Garrett and Goertz, 1975).

Throughout the study, only 5 raccoons (1 age class 3, 4 age class 1) were known to have died of apparent natural causes. This points to low natural mortality rates among these raccoons. Hunting, which is the major cause of raccoon mortality (Sanderson, 1950), is forbidden within the park and there are not many natural predators of the raccoon within Cades Cove. The major predators were wild dogs from surrounding residential areas. Other predators included bobcats, red foxes, and owls (Whitney and Underwood, 1952; Stains, 1956). Younger raccoons are much more prone to such predator pressure than older animals.

As shown in the age pyramid of captured animals (Figures 2, page 25, Figure 4, page 28) after age class 1, the ratio of females to males appeared to increase. This could be related to females becoming increasingly trap shy with age, but additional data suggested the possibility of differential male mortality in the older age classes. Of the 32 captured males older than age class 1, 13 (40%) showed loss of hair and abrasions in the facial region, particularly on the nose and ears. Of the 52 captured females older than age class 1, only 8 (15%) showed these same characteristics. Since males exhibited much larger movements and home ranges than females, they might be more prone to predatory pressures. Furthermore, their extensive movements would increase their chances of exposure to disease and to aggressive encounters with other raccoons. Agonistic behavior among raccoons is well documented in the literature (Whitney and Underwood, 1952; Sharp and Sharp, 1956; Barash, 1974; Fritzell, 1978b) and may be involved in neighbor recognition (Barash, 1974). Hostile interactions among carnivores are not uncommon and have been documented in such species as African hunting dogs (van Lawick-Goodall and Lawick, 1970) and lions (Schaller, 1969).

Day Bed Selection

Day beds have 3 main functions for raccoons: (1) protection against adverse weather conditions, (2) providing a secure environment to bear and raise young (Preble, 1940), and (3) protection against predators. To assess the relative importance of these factors, one must look at the types of day beds selected, seasonal, sexual, and age related factors, microclimatic conditions of the day beds, proximity to food and water, and possible competitive interactions for the day bed sites.

During the study, 330 individual occupied day bed sites were located 1,492 times. Of these sites, 54% were utilized on a single occasion, while 46% were used by raccoons more than once. Although only 5% of the day bed sites were used by animals greater than 15 times, these 15 sites accounted for 50% of all day bed use observed (Table 14). All but 3 of the sites in this category were used by more than 1 radiocollared animal. The most frequently occupied day beds were 4 rock dens and 2 barn dens. These 6 dens were used by 5 to 7

TABLE 14. Day beds used most frequently by raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

Den No.	Den Type	No. of Times Used by Raccoons	Percentage of Total Usage	No. of Radiocollared Animals Using Den
1	Rock Den	112	7.5	7
23	Tree Den	32	2.1	1*
509	Tree Den	29	1.9	4
530	Barn Den	42	2.8	5
538	Rock Den	31	2.1	6
560	Tree Den	57	3.8	3
569	Tree Roost	28	1.9	2
581	Rock Den	114	7.6	6
594	Rock Den	24	1.6	4
597	Ground Den	36	2.4	2
623	Tree Roost	22	1.5	1
647	Tree Den	28	1.9	1*
695	Rock Den	75	5.0	7
800	Barn Den	116	7.8	6
			50%	

*Maternity dens

different radiocollared raccoons throughout the study and accounted for 37% of all den usage observed. It was not unusual in this study for raccoons to utilize particular sites repeatedly. This was also observed by Berner and Gysel (1967) who found 1 tree cavity that accounted for 36% of all den occupancies and also served as a maternity den.

Due to seasonal differences in movements and home range sizes, it was important to look at differential den usage by season, for males and females separately. Males showed no significant difference (Kruskall-Wallis Test, $P > .20$) in the use of any particular day bed type for any season. This can be at least partly attributed to small sample size and large standard errors (Table 15). Female raccoons, on the other hand, showed significant differences (Kruskall-Wallis Test, $P > .05$) for fall. During spring and summer, tree dens played a crucial role and during the winter months, both tree and rock dens were important (Table 16). Although other day bed types played less important roles than tree and rock dens, they showed marked seasonal trends. Tree roosts were used most frequently during spring while tree nests and ground dens had their greatest use during summer. Barn dens were used most frequently during the winter months (Figure 12).

The extensive use of rock and ground dens by raccoons is well documented in the literature (Grinnel et al., 1937; Giles, 1940, 1942; Stuewer, 1943a). Giles (1940) even reported a preference for rock dens in a hunted area and Shirer and Fitch (1970) found that more than 50% of the den sites for a raccoon population in Iowa consisted of rock outcrops. Taylor, C. I. (1979) found in East Tennessee that, although

TABLE 15. Mean number of locations for male raccoons found in different day bed types during different seasons in Cades Cove, Great Smoky Mountains National Park, 1979-1980

Den Type	Season			
	Winter (3)[a]	Spring (6)	Summer (4)	Fall (3)
Tree Den				
Mean	5.3	5.5	3.5	1.0
Std. Error	4.8	2.1	2.2	0.6
Tree Nest				
Mean	0.0	1.5	5.2	0.33
Std. Error	--	1.1	2.5	0.33
Tree Roost				
Mean	0.67	4.2	4.5	0.67
Std. Error	0.67	3.0	3.9	0.67
Ground Den				
Mean	0.0	0.5	3.2	3.0
Std. Error	--	0.22	1.2	2.1
Rock Den				
Mean	24.0	4.0	5.8	8.3
Std. Error	13.0	2.9	5.4	5.6
Barn Den				
Mean	8.0	2.3	5.0	6.0
Std. Error	5.7	1.1	3.1	3.8

[a]Numbers in parentheses denote sample size for each day bed type.

TABLE 16. Mean number of locations for female raccoons found in different day bed types during different seasons in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

Den Type	Season: Winter (7)[a]	Spring (8)	Summer (8)	Fall (78)
Tree Den				
Mean	14.4	13.3	16.2	4.4
Std. Error	5.6	2.1	4.2	1.4
Tree Nest				
Mean	2.0	1.8	1.4	1.8
Std. Error	0.80	1.2	0.40	0.98
Tree Roost				
Mean	1.0	6.6	4.6	3.5
Std. Error	0.60	2.2	2.1	1.2
Ground Den				
Mean	5.1	1.5	6.1	5.2
Std. Error	3.2	0.60	1.6	1.8
Rock Den				
Mean	19.7	8.6	2.9	8.2
Std. Error	7.0	3.6	2.1	4.1
Barn Den				
Mean	5.0	0.75	2.2	2.5
Std. Error	4.5	0.53	1.7	2.4

[a]Numbers in parentheses denote sample size for each day bed type.

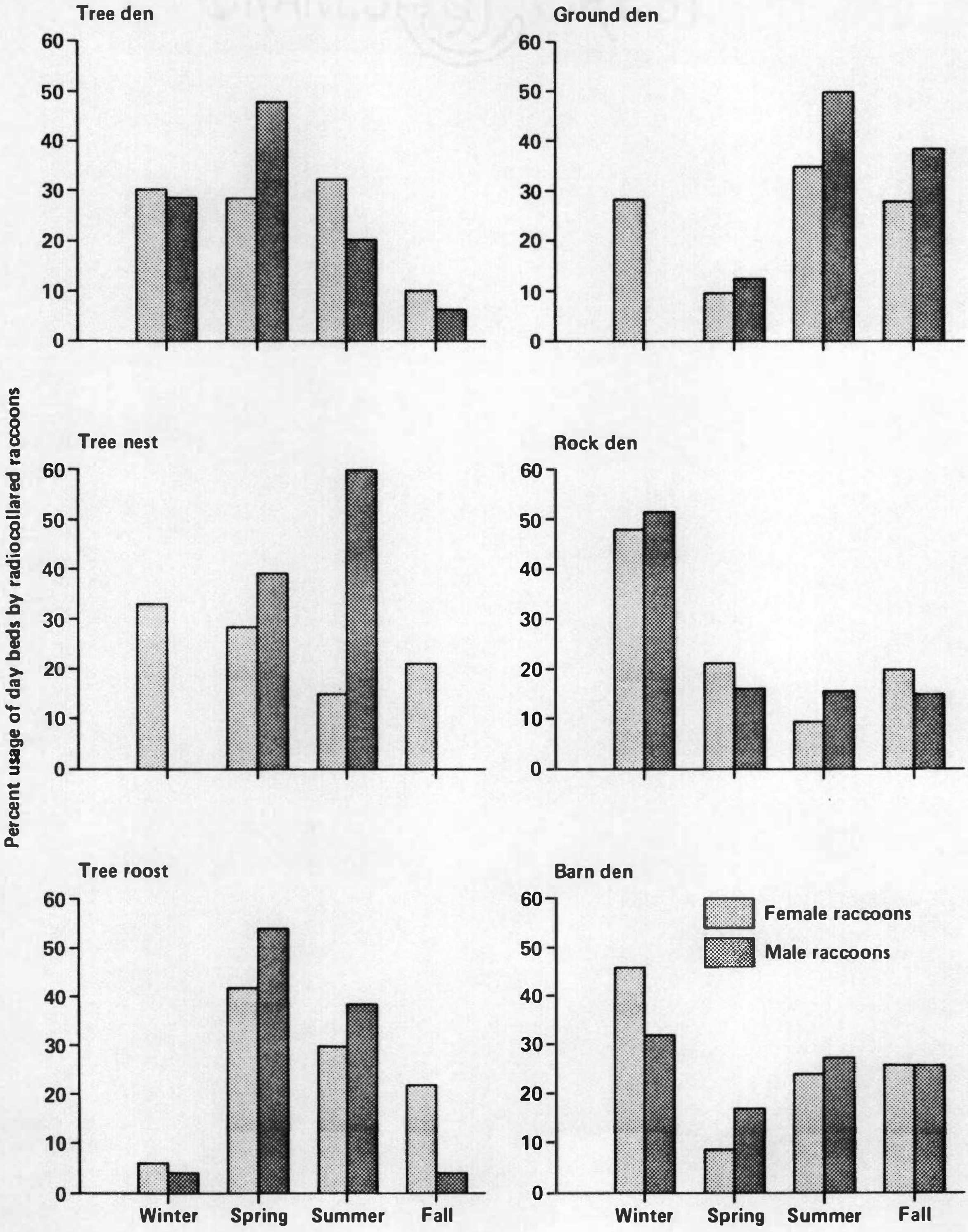

Figure 12. Seasonal use of different day bed types of male (N=5) and female (N=7) radiocollared raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

tree dens were the most frequently recorded day bed site, rock dens were the preferred den type when they were available, particularly during monitored hunts. However, since most studies have located raccoons in tree dens, it has been speculated that these were the optimal den type for raccoons (Stuewer, 1943a; Cabalka, 1952; Whitney and Underwood, 1952). It has even been speculated that lack of tree dens may limit raccoon populations (Bennitt and Nagel, 1937; Stuewer, 1943a; Whitney and Underwood, 1952; Butterfield, 1954). The use of other day bed sites was thought to be a result of the inavailability of adequate trees (Stuewer, 1948; Stains, 1956; Dorney, 1954). However, Mech et al. (1966) found ground beds to be highly utilized day bed sites even with adequate numbers of hollow trees available. In the Cades Cove population, it appeared that given a choice of a variety of day bed types, raccoons, particularly females, will vary their selection according to seasonal climatic trends, and the onset of parturition. Thus, since most studies discuss the overall usage of particular day bed types, the important seasonal differences may be obscured. Another important factor is the ability to locate animals that are denning underground through the use of radiotelemetry. During this study, when raccoons used rock or ground dens their radio-signals were lost from most radiotracking stations. The only way to locate the animal was to walk into the general area where it had been located previously until one was close enough to the den to pick up a signal. Only after each individual animal and its home range became fully known was this an efficient procedure; this could definitely bias results regarding frequency of use of ground and rock dens.

Data from this study suggests the idea that suitable trees for tree dens can be of major importance in maintaining raccoon populations. Not only do females appear to prefer tree dens as maternity sites, but trees can be used for nest and roosting sites as well. The selection of leaf nests as resting sites has been well documented in the literature (Twitchell and Dill, 1949; Mech et al., 1966; Johnson, 1970; Shirer and Fitch, 1970; Schneider et al., 1971; Hardy, 1979; Taylor, C. I. 1979). During summer, these nests are cooler and contain fewer insect pests than tree, rock, or ground dens (Madson, 1964). There were 230 different trees of 12 genera used 698 times as day bed sites throughout the study (Table 17). Tree circumference averaged 229 cm 28.in or 72.88cm (N = 83) for tree dens, 154 cm (N = 27) for tree nests, and 195 cm (N = 94) for tree roosts. The majority of trees that were selected as day bed sites were red oaks (45%), followed by hemlocks (14%), pines (13%), and yellow poplars (12%) (Table 17). If we consider individual tree bed types, 70% (N = 70) of tree dens were red oaks, 89% (N = 27) of tree nests were hemlocks and pines, and 48% (N = 81) of tree roosts were hemlocks and pines, followed by 27% red oaks and 16% yellow poplars. Tree dens were located significantly (ANOVA, $P < .05$, Duncans Multiple Range Test $\alpha = .05$) lower ($\bar{X} = 10.7$ m, N = 59) than either tree roosts ($\bar{X} = 13.6$ m, N = 76) or tree nests ($\bar{X} = 13.3$ m, N = 13). This is not surprising considering that the height of a den cavity above the ground is usually less than 12.2 m (Stuewer, 1943a; Berner, 1965). The height of dens in Cades Cove compares favorably to those reported by Stuewer (1943), Hardy (1979), and Taylor, C. I. (1979) but was much greater than the 3.8 m height reported by Berner (1965). The idea that

TABLE 17. Differential usage of tree types as day beds by raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

Tree Type	Frequency of Use by Raccoons (%)	N
Quercus spp. (Red Oak)	45.0	321
Quercus alba (White Oak)	8.3	58
Quercus spp. (other oaks)	4.6	32
Liriodendron tulipifera (Tulip Poplar)	12.2	85
Tsuga canadensis (Hemlock)	13.5	94
Pinus spp. (Pine)	12.9	90
Diospyros virginiana (Persimmon)	0.14	1
Robinia app. (Locust)	0.28	2
Acer spp. (Maple)	1.3	9
Platanus occidentalis (Sycamore)	0.14	1
Ulmus spp. (Elm)	0.14	1
Prunus serotina (Black Cherry)	0.14	1
Carya spp. (Hickory)	0.14	1
Nyssa sylvatica (Black Gum)	0.28	2
		698

tree dens are selected by pregnant females around the time of parturition (Schnell, 1970; Schneider et al., 1971) was supported by this study. The exact reason for this is unknown but may be related to the relative security of tree dens from use by conspecifics (Table 14) or other animals.

Examination of the data made it necessary to investigate whether raccoons were selecting day bed sites on the basis of frequency encountered, or if particular sites and/or tree types were being selected. If the latter were true, locations of particular day beds could influence seasonal and annual home ranges. To address this question, 7 randomly selected vegetation transects were walked in the areas of greatest day bed usage. The cumulative area of the transects was 7,800 m^2 (0.8 ha) and the results are reported in Table 18. Pines, hemlocks, and yellow poplars occurred more frequently than any other tree type. Although these frequencies closely coincided with frequency of use of these tree types, their average circumferences were less than those of the trees which were used by raccoons. The major inconsistency was seen with red oaks. The use of these trees as tree dens (45%) was very much in contrast to the frequency at which it occurred (0.6%). The reason for this can be related to the fact that red oaks were very susceptible to decay and insect attack because of their porous heartwood (Fowells, 1965) and thus show faster and more extensive decay than other trees (Scheffer et al., 1949). The high utilization of elm, red maple, and beech tree dens by raccoons in northern latitudes has also been attributed to rapid cavity formation among these species (Baumgartner, 1939). Furthermore, the mean circumference of 270 cm for tree dens in

TABLE 18. Results of 7 vegetation transects in Cades Cove, Great Smoky Mountains National Park.

Tree Type	N	Mean Circumference (cm)	% of Total
Fraxinus spp. (Ash)	29	44	2.4
Liriodendron tulipifera (Tulip Poplar)	174	82	14.2
Prunus serotina (Black Cherry)	6	27	0.5
Carya spp. (Pine)	37	47	3.0
Pinus spp. (Pine)	270	81	22.0
Tsuga canadensis (Hemlock)	160	46	13.0
Cornus spp. (Dogwood)	103	28	8.4
Acer spp. (Maple)	85	44	6.9
Nyssa sylvatica (Black Gum)	33	35	2.7
Oxydendrum arboreum (Sourwood)	146	44	11.9
Sassafras albidum (Sassafras)	1	52	0.1
Betula spp. (Birch)	5	26	0.4
Ilex opaca (Holly)	5	26	0.4
Fagus grandifolia (Beech)	5	28	0.4
Juglans spp. (Walnut)	1	87	0.1
Platanus occidentalis (Sycamore)	14	58	1.1
Robinia pseudoacacia (Black Locust)	1	66	0.1
Quercus alba (White Oak)	138	116	11.2
Quercus spp. (Red Oak)	7	128	0.6
Quercus spp. (Other Oaks)	6	66	0.1
TOTAL	1226		
MEAN		57	

Cades Cove is similar to that found by Stuewer (1943a) and Preble (1940). Other studies in East Tennessee, however, point to the use of slightly smaller trees as tree dens. Taylor, C. I. (1979) measured 50 tree dens of 12 species and reported a mean circumference of 181 cm and Hardy (1979) found a mean circumference of 170 cm for 30 tree dens. Apparently, these tree measurements were more a reflection of the timber stand characteristics and past logging practices in the study areas than the selectivity of tree dens by the raccoons (Taylor, C. I., 1979). Thus, the data from the Cades Cove raccoon population seems to indicate preferential use of specific tree types and tree sizes for day bed sites. Although other studies point out that raccoons will essentially occupy any tree containing a cavity of suitable dimensions (Stuewer, 1943a; Hardy, 1979; Taylor, C. I., 1979), it appears that particular tree species form more suitable cavities than others and that even particular tree sizes may be selected when a choice is available. This phenomenon has also been observed in den site selection by black bears in the Great Smoky Mountains National Park, with red oaks again being one of the most popular tree species selected (Johnson and Pelton, 1981). These data could have important forest management implications for agencies concerned with maintaining healthy wildlife populations. Since den availability for species such as raccoons and bears can be crucial to the life history of the animal, selective cutting techniques could be used to ensure availability of trees of particular species and sizes.

Rock dens used by raccoons had an average entrance size of 19 ± 4.8 cm x 21.1 ± 3.4 cm (N = 6) and ground dens an average entrance size of 26.5 ± 2.4 cm x 23.5 ± 2.3 cm (N = 10). All of the rock dens that were selected resembled deep cave-like structures that were fully protected from external ambient conditions. During the transects, 16 ground dens, 2 rock dens, and 1 barn were encountered. Ground dens, in the form of woodchuck burrows, were extremely numerous in Cades Cove and were obviously not utilized by the raccoons with the frequency they were encountered. As well as having to compete with foxes, skunks, and oppossums for ground dens, raccoons greatest competition probably came from groundhogs themselves. In 1978 there were reported to be 1.38 groundhogs per hectacre in Cades Cove (Taylor, C. I., 1979). Although raccoons have been known to share dens with groundhogs, they are also known to have aggressive encounters with each other (Butterfield, 1954). Both rock and barn dens are relatively sparse in Cades Cove and appeared to be used disproportionately to their numbers.

Once it was established that raccoons were selective in choosing day bed sites, it was important to examine the possible factors governing the selection process. Since temperature appeared to be one of the major factors affecting raccoon activity (Stuewer, 1943b; Whitney and Underwood, 1952), it was speculated that the microclimate of a den would greatly affect its suitability as a day bed site. This idea was first substantiated by Berner and Gysel (1967) who found that the most important characteristics of den sites were the amount of precipitation and wind allowed inside the den cavity and the stability of its temperature as compared to the external temperature. The relationship between den temperatures and ambient temperature had previously been examined with nest boxes (McComb and Noble, 1981), raccoon tree dens (Stains, 1961;

Berner and Gysel, 1967), and raccoon ground dens (Berner and Gysel, 1967). However, there had been no reports investigating temperature fluctuations at several den types simultaneously. In this study, temperatures were obtained during all seasons for rock dens, ground dens, barn dens, and tree dens using remote reading thermographs. The objective was to correlate seasonal fluctuations in den temperatures, ambient temperatures, and den usage patterns. Since den sites were used primarily during the daylight hours, temperature readings that were obtained at 1200 hours on randomly selected days of a particular month were used to obtain average monthly and seasonal den temperatures (Tables 19 and 20). Although there were no significant differences (ANOVA, $P > .05$) between mean annual temperatures for any of the den types, there were significant seasonal differences (ANOVA, $P < .05$, Duncans Multiple Range Test $\alpha = .05$).

During spring and summer, there were no significant differences (ANOVA, $P > .05$) between any of the den temperatures and ambient temperature. The high use of tree dens by females during these seasons was probably related to a secure den for parturition and weaning. There were also no significant differences (ANOVA, $P > .05$) between any den temperature and ambient temperature during the fall months and this corresponded to no significant differences (ANOVA, $P > .05$) in den type as well. However, rock dens were significantly warmer (ANOVA, $P < .05$, Duncan's Multiple Range Test, $\alpha = .05$) than all other den types and then ambient temperatures during the winter months. It was also during this time that rock dens showed the greatest frequency of use by both male and female raccoons. Female raccoons also used tree dens during the winter

TABLE 19. Mean monthly temperatures (^{o}C) for 4 den types and for ambient temperature in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

Month	Den Type				Ambient
	Rock (n)[a]	Barn (n)	Tree (n)	Ground (n)	
September	15.0 (5)	22.2 (10)	20.6 (8)	26.1 (5)	22.2 (8)
October	--	12.2 (8)	13.9 (7)	--	18.8 (13)
November	14.4 (7)	6.7 (9)	4.4 (10)	11.1 (4)	19.0 (1)
December	12.8 (7)	5.0 (10)	3.9 (6)	5.6 (8)	10.0 (10)
January	11.7 (6)	4.4 (5)	1.7 (7)	4.4 (8)	8.9 (8)
February	12.8 (7)	5.0 (10)	2.8 (7)	-2.8 (6)	5.0 (10)
March	12.2 (5)	-3.3 (10)	1.1 (7)	8.3 (9)	5.5 (10)
April	12.8 (3)	13.3 (6)	7.2 (6)	12.2 (10)	16.7 (10)
May	13.3 (6)	21.1 (12)	16.7 (6)	18.9 (11)	17.8 (10)
June	14.4 (3)	23.9 (8)	19.4 (9)	21.7 (7)	22.2 (9)
July	15.0 (5)	23.3 (9)	22.2 (8)	23.9 (3)	27.2 (10)
August	15.6 (4)	24.4 (9)	21.7 (10)	25.0 (9)	27.8 (10)
Range	12.2 - 15.6	-3.3 - 24.4	1.7 - 22.2	-2.8 - 26.1	5.0 - 27.8

[a]Numbers in parentheses represent sample size.

TABLE 20. Mean seasonal and annual temperatures (^{o}C) for 4 den types and for ambient temperatures in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

	Season				
Den Type	Winter (n)[a]	Spring (n)	Summer (n)	Fall (n)	Annual (n)
Rock Den					
Mean	12.4 (20)	12.8 (14)	15.0 (12)	14.7 (12)[b]	13.7 (58)
Std. dev.	0.63	0.55	0.60	0.42	1.30
Range	11.1-13.0	11.0-14.0	14.5-16.0	13.0-17.0	
Barn Den					
Mean	4.8 (25)	10.3 (28)	23.9 (26)	13.7 (27)	13.2 (105)
Std. dev.	0.35	12.4	0.55	7.9	8.0
Range	-1.1-14.4	-12.0-23.0	20.0-26.7	0.0-24.4	
Tree Den					
Mean	2.8 (19)	8.3 (19)	21.1 (27)	12.9 (26)	11.3 (90)
Std. dev.	1.1	7.9	1.5	8.1	7.7
Range	-4.4-14.4	-10.0-20.0	14.4-24.4	-1.6-23.3	
Ground Den					
Mean	2.4 (22)	13.1 (30)	23.5 (19)	18.6 (9)[b]	14.4 (80)
Std. dev.	4.5	5.4	1.7	3.5	9.1
Range	-4.4-6.7	6.1-21.1	20.0-27.8	10.0-26.7	
Ambient Temp.					
Mean	8.0 (28)	13.3 (30)	25.7 (29)	20.0 (22)	16.8 (109)
Std. dev.	2.6	6.8	3.1	1.9	7.7
Range	-1.1-23.3	-2.2-25.6	11.1-33.3	11.0-23.9	

[a]Numbers in parentheses denote sample size.

[b]No data available for the month of October.

months even though the mean temperatures of these dens were relatively low. This was an interesting phenomenon since tree dens often follow similar temperature fluctuations as ambient temperatures and are often cooler than ambient (Stains, 1961; Berner and Gysel, 1967; McComb and Noble, 1981). This can be energetically expensive when most of the resistance to heat loss in a tree den is in the fur of the raccoon, not in the air space or the den wall (Thorkelson and Maxwell, 1974). During a very cold period, C. I. Taylor (1979) found a raccoon dead in a tree den from exposure while another raccoon survived in a ground burrow approximately 900 m away. Yet, tree dens do serve to create a lag time such that temperature fluctuations are behind those of ambient (Stains, 1961). However, it would seem logical that warmer sites such as rock or barn dens would make better winter dens. Factors such as den availability and competition may play a role at this time. Energetically, rock dens appear to be the most optimal winter den site for raccoons. In addition to the inherent advantageous microclimatic conditions of rock dens, these sites allow for winter communal denning (Twitchell and Dill, 1949; Whitney and Underwood, 1952; Mech and Turkowski, 1966; Mech et al., 1966). In this study, the most frequently occurring instances of communal denning by radiocollared raccoons occurred in rock dens during the winter (Table 21).

The importance and suitability of rock dens as sites for raccoon day beds make them a potentially important management tool for raccoons. In areas where suitable trees may not be available for dens or where hunting pressures have become too intense, sites such as old rock quarries and limestone outcrops can take on added importance. In

TABLE 21. Instances of radiocollared raccoons located within the same den in Cades Cove, Great Smoky Mountains National Park, 1979-1980 (A = adult, Y = yearling).

Sexual Grouping	No. of Locations		
A male - A male	2	Rock den (n = 1) Barn den (n = 1)[a] ---	November November
A male - Y female	4	Rock den (n = 4) ---	November December January
A male - Y female	6	Barn den (n = 4)[a] --- Rock den (n = 2) ---	November December
A male - A male - Y female	4	Rock den (n = 4) ---	January
A male - A female - Y female	1	Rock den (n = 1) ---	January
A male - A male - A female	2	Rock den (n = 2) ---	December
A male - A male - A female - Y female	2	Rock den (n = 2) ---	January
A female - A female	2	Rock den (n = 1) --- Tree den (n = 1) ---	February October

[a]Radiocollared raccoons were located within the same barn structure, not necessarily within the same den space.

addition, since raccoons frequently will den in artifical nest boxes (Baker and Newman, 1942; Stuewer, 1943a; Berner, 1965), the construction of artificial den sites can be a valuable management tool. It appears, however, that since day bed selection is governed by a variety of factors, which vary seasonally, a variety of different day bed types should be available for a raccoon population to function optimally.

Movements Between Day Beds

There is a paucity of information concerning movements of raccoons between consecutive day beds even though this is an integral part of their activity. Due to the nature of their nocturnal activity, raccoons can spend over one-half of their entire lives in day beds. Previous studies indicate that day beds are mostly temporary and are seldom used on consecutive days (Calbalka, 1952; Mech et al., 1966; Shirer and Fitch, 1970). This was not the general trend observed in the present study.

Data obtained on consecutive days allowed for documentation of seasonal and annual distances travelled between day bed sites (Table 22). Although there were no significant seasonal differences (ANOVA, $P > .05$) within each sex for distances travelled between day beds, male raccoons consistently travelled significantly further (T-tests, $\alpha = .05$) than females, during all seasons. Although distances travelled appeared to vary greatly between individual raccoons and different seasons, the figures from this study are generally lower than those reported in other studies (Mech et al., 1966; Shirer and Fitch, 1970; Taylor, C. I., 1979). A major factor affecting distances moved between day beds was the frequency that raccoons remained within the same day bed on consecutive days. Female raccoons showed higher day bed reuse patterns than males

TABLE 22. Mean distances travelled (km) between consecutive day beds for male and female radio-collared raccoons in Cades Cove, Great Smoky Mountains National Park 1979-1980

Animal No.	Season: Winter (n)[a]	Spring (n)	Summer (n)	Fall (n)	Annual[b] (n)
Males					
Y61	0.0056 (24)	0.58 (19)	0.34 (22)	0.54 (12)	0.37 (77)
Y54	---	0.18 (13)[c]	0.17 (6)[c]	---	---
Y66	---	0.33 (4)[c]	---	---	---
Y65	---	0.64 (15)	0.77 (20)	---	---
Y58	0.58 (30)	1.40 (16)	0.94 (19)	0.40 (6)[c]	0.83 (71)
Y55	0.47 (7)	---	---	0.95 (6)[c]	---
Total					
Mean	0.35 (61)	0.62 (67)	0.48 (67)	0.63 (24)	0.60 (148)
Std. dev.	0.43	0.69	0.51	0.49	
Range	0.0 - 1.3	0.0 - 3.0	0.0 - 2.0	0.0 - 2.2	
Females					
R01	0.10 (24)	0.38 (22)	0.22 (24)	0.59 (11)[c]	0.31 (81)
R02	0.27 (24)	0.19 (19)	0.15 (17)	0.28 (15)[c]	0.22 (75)
R04	0.061 (26)	0.10 (20)	0.043 (13)[c]	---	0.068 (59
R05	0.013 (17)	0.40 (22)	0.23 (17)	0.10 (12)	0.18 (68)
R09	0.18 (21)	0.30 (20)	0.39 (22)	0.076 (14)	0.24 (77)
R15	0.093 (26)	0.14 (21)	0.09 (22)	0.25 (14)	0.14 (83)
R20	0.047 (24)	0.10 (20)	0.18 (21)	0.38 (15)	0.18 (79)
R55	---	0.067 (6)[c]	0.076 (24)	0.43 (4)[c]	0.19 (34)
Total					
Mean	0.11 (162)	0.20 (150)	0.17 (160)	0.30 (85)	0.19 (557)
Std. dev.	0.23	0.32	0.30	0.42	
Range	0.0 - 1.2	0.0 - 1.3	0.0 - 1.5	0.0 - 2.1	

[a] Numbers in parentheses denote sample size.

[b] Annual distances were not calculated when data from more than 1 season were not available.

[c] Incomplete seasonal data.

over all seasons (Table 23). This was particularly true in the spring and summer months.

Much of raccoon movement data can be explained in terms of the social structure of raccoon populations. During spring, parturition occurs and females remain in maternity dens 50 to 60 days after the birth of the young (Schneider et al., 1971). The young are weaned during summer, so during the fall months, the females must replenish their energy reserves and store additional fat for the winter. During the winter months the female and young might be much more prone to remain in their dens for energetic reasons, than male raccoons who were not stressed by the burden of young. Male raccoons desert the females shortly after copulation and play no role in the family unit.

Scat Stations

Scat stations were first described by Stains (1956) as a place where a raccoon loafs or rests and deposits scats regularly. He found that these scat stations were used and maintained primarily from July through November. Since that report, there have been no additional reports in the literature regarding raccoon scat stations. However, a behavior similar to that described by Stains was observed in this study. While walking in on raccoon day beds, fresh scats were observed on 35 occasions at the base or directly in front of a day bed. Most of the scats were at the bases of trees but they were also found at rock, ground, and barn dens. Stains (1956) does not speculate on the possible reasons for this behavior. Although much more data are needed, it is felt that the presence of these scats may represent a type of scent marking, not uncommon in carnivores. The deposition of feces as a scent

TABLE 23. Percent of times that male and female radiocollared raccoons remained in the same day bed on consecutive days in Cades Cove, Great Smoky Mountains National Park, 1979-1980

Animal No.	Season				
	Winter (n)[a]	Spring (n)	Summer (n)	Fall (n)	Annual (n)
Males					
Y61	96 (24)	37 (19)	59 (22)	45 (12)	63 (77)
Y54	--	36 (13)	0 (6)	--	--
Y66	--	50 (4)	--	--	--
Y65	--	0 (15)	5 (20)	--	--
Y58	27 (30)	0 (16)	10 (19)	14 (6)	15 (71)
Y55	29 (7)	--	--	0 (6)	--
Mean	51 (61)	25 (67)	18 (67)	20 (24)	39 (148)
Females					
R01	62 (24)	38 (22)	75 (24)	54 (11)	59 (81)
R02	67 (24)	53 (19)	24 (17)	17 (15)	42 (75)
R04	58 (26)	50 (20)	62 (13)	--	76 (59)
R06	88 (17)	41 (22)	71 (17)	54 (12)	63 (68)
R09	69 (21)	57 (20)	86 (22)	20 (14)	62 (77)
R15	69 (26)	57 (21)	86 (22)	20 (14)	62 (83)
R20	96 (24)	30 (20)	57 (21)	7 (15)	53 (79)
R55	--	67 (6)	62 (24)	0 (4)	61 (34)
Mean	73 (162)	49 (150)	65 (160)	25 (85)	60 (556)

[a]Numbers in parentheses represent sample size.

marking device is usually accompanied by other types of marking and has been observed in bobcats (Bailey, 1974), the African polecat (Poecilogale albinucha) (Alexander and Ewer, 1959), the tiger (Panthera tigris) (Schaller, 1967), and the puma (Felis concolor) (Hornocker, 1969). Fecal marking may be a form of territorial behavior as long as it is site dependent, conspicuous, and discourages similar behaving individuals (Fretwell, 1972). Since it appears that raccoons may be maintaining certain minimum distances from one another during certain times of the year, the act of fecal marking may aid in this phenomenon. Since Stains found that scat stations were maintained during the summer and fall months it is also possible that this marking may be involved with such things as mating, the bearing and raising of young, yearling dispersal, or sibling recognition. In most carnivores there is a great increase in the frequency of scenting behavior during the mating period (Ewer, 1977). Thus, such scenting behavior does not automatically imply that the species concerned is either territorial or solitary.

The lack of additional data does not allow any conclusions to be drawn regarding scat stations. However, the observations presented here, as well as that found by Stains (1956), do indicate a need to investigate this phenomenon further in raccoons. Very little is known regarding the behavior of raccoons in the wild, and these kinds of data could significantly add to knowledge regarding the animals social interactions and organization.

V. Physiology and Health

Rectal Temperatures

Rectal temperatures of 88 raccoons averaged 38.3^{o} C (range 35.2 - 40.3^{o}C). No significant differences (T-test, α = .05) were found between the sexes. Sample sizes were too small for seasonal analysis. Although rectal temperatures varied up to 1.5^{o}C between recaptures for a particular animal, the average rectal temperature found in this study is similar to the value of 38.8^{o}C (range 33.8 - 40.8^{o}C) found by Hoff et al. (1974a) for raccoons in Florida.

Hematological Parameters

Knowledge of the hematology and blood chemistry of wild animal species can provide important information on the physiological state of a population (LeResche et al., 1974; Seal et al., 1975; Lee et al., 1977). In order to properly interpret such data however, one must have baseline values from different age and sex animals over all seasons. Thus, during the course of this study, 153 whole blood samples were collected from 122 individual raccoons over 4 seasons. The mean hematologic values obtained (Table 24) are comparable to those by Hoff et al. (1974a) for raccoons in Florida, and to those of Kennedy (1935) and Jacobs (1957) for raccoons in general.

Since there were no significant differences (T tests, α = .05) between the sexes for any of the blood parameters, data were pooled for some analyses. Using discriminant analysis to evaluate all blood parameters together, age classification was divided into 2 groups: young, nonreproductive raccoons (age class 1), and older, sexually

TABLE 24. Mean blood parameters for raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

Blood Parameter	Sample Size (N)	Mean		Std. Deviation
Hemoglobin (g/dl)	118	11.0	4.0 - 15.0	1.7
Hematocrit (%)	118	33.6	13.0 - 45.0	5.1
Total plasma protein (g/dl)	118	8.6	6.0 - 11.0	0.89
Total white blood cells/mm^3	118	12,114	2,200 - 23,500	3,957
Segmented neutrophils/mm	113	8,070	840 - 17,775	3,696
Non-segmented neutrophils/mm	49	284	71 - 2,783	399
Lymphocytes/mm	113	3,163	363 - 9,555	1,636
Monocytes/mm	98	405	4 - 2,180	405
Eosinophils/mm	54	397	22 - 2,004	420
Total red blood cells/mm	118	7.3×10^6	$3.0 - 10.0 \times 10^6$	1.3×10^6

mature animals (age classes 2 - 5). Using this division, 68.7% of the grouped cases were correctly classified according to the SPSS program. The standardized discriminant function coefficients (Table 25) indicated that plasma protein levels accounted for the greatest variability between these 2 age groups. There was an increase in plasma protein levels with increasing age (Table 26). Using this same analysis, seasonal data was divided into the non-reproductive period and the reproductive period for both males and females. The non-reproductive period was defined as October through March when young have been weaned and the greatest activity of raccoons concerns food availability and the building up of fat reserves for winter. The reproductive period was defined as April through September when older males were mating, younger males were dispersing and females were undergoing ovulation, estrus, mating, pregnancy, parturition, and lactation. Using these groupings, 65.5% of the cases for male raccoons were correctly classified and 73.0% of the cases for female raccoons were correctly classified according to the SPSS discriminant program. The standardized discriminant function coefficients (Table 27) indicated that for male raccoons, red blood cell levels and eosinophil numbers accounted for the greatest variability between these 2 time periods. Both parameters increased from the non-reproductive to the reproductive period (Table 28). For the female raccoons, the standardized discriminant function coefficients (Table 27) indicated that red blood cell levels and hemoglobin concentrations accounted for the greatest variability between these 2 time periods. Both parameters increased from the non-reproductive to the reproductive period (Table 28). Examining the blood parameters individually for all raccoons

TABLE 25. Standardized discriminant function coefficients (d_i's) showing the relative contribution of the variables used in the analysis to the discriminant function for the blood parameters vs. age analysis for raccoons of Cades Cove, Great Smoky Mountains National Park.

Variables[a]	Discriminant Function Coefficients
Plasma protein	0.81360
Hemoglobin	0.22149
Lymphocytes	-0.26084
Nonsegmented neutrophils	-0.38864
Eosinophils	-0.27276

[a]All other blood parameters were determined to be nonsignificant by the SPSS program and were dropped from the analysis.

TABLE 26. Untransformed means of blood parameters for young non-reproductive (class 1) and older sexually mature raccoons (classes 2 - 5) of Cades Cove, Great Smoky Mountains National Park, 1979–1980 (N = 115).

Blood Variable	Young, Non-reproductive Raccoons		Older, Sexually Mature Raccoons	
	Mean	Std. deviation	Mean	Std. deviation
Hemoglobin (g/dl)	10.51	1.98	11.50	1.46
Plasma protein (g/dl)	8.07	0.89	8.87	0.76
White blood cells (per mm^3)	113.53	37.52	126.08	40.40
Segmented neutrophils (per mm)	6926.51	3849.16	8250.31	4054.19
Non-segmented neutrophils (per mm)	174.67	439.17	81.97	129.21
Lymphocytes (per mm)	3115.11	1665.18	2962.56	1770.04
Monocytes (per mm)	294.53	255.25	422.23	580.95
Eosinophils (per mm)	118.22	197.28	199.86	355.18
Basophils (per mm)	40.87	102.78	53.74	119.40
Red blood cells x 10^6 (per mm)	7.04	1.41	7.48	1.15

TABLE 27. Standardized discriminant function coefficients (d_i's) showing the relative contribution of the variables used in the analysis to the discriminant function for the blood parameters vs. seasonal analysis for both male and female raccoons of Cades Cove, Great Smoky Mountains National Park.

Variables[a]	Discriminant Function Coefficients
Males	
Lymphocytes	-0.47291
Monocytes	-0.45439
Eosinophils	0.79624
Basophils	0.51502
Red blood cells	0.75463
Females	
Hemoglobin	-0.89043
White blood cells	0.40110
Non-segmented neutrophils	-0.37663
Monocytes	-0.50779
Basophils	0.39803
Red blood cells	1.46689

[a]All other blood parameters were determined to be nonsignificant by the SPSS program and were dropped from the analysis.

TABLE 28. Untransformed means of blood parameters for male and female raccoons of Cades Cove, Great Smoky Mountains National Park, during reproductive and non-reproductive periods (N = 89).

Blood Variable		Reproductive Period Mean	Reproductive Period Std. deviation	Non-reproductive Period Mean	Non-reproductive Period Std. deviation
Hemoglobin (g/dl)	males	11.49	1.64	11.12	2.45
	females	11.16	1.40	9.82	3.28
Plasma protein (g/dl)	males	8.56	0.79	8.36	0.57
	females	8.58	1.03	7.97	2.59
White blood cells (per mm^3)	males	124.33	35.48	134.68	164.43
	females	125.26	41.70	107.72	46.19
Segmented neutrophils (per mm)	males	7627.85	4279.46	6651.44	2536.68
	females	7819.98	4318.98	6744.69	4050.00
Non-segmented neutrophils (per mm)	males	161.05	455.92	121.40	172.68
	females	91.28	150.75	127.51	176.21
Lymphocytes (per mm)	males	2868.79	1738.51	2955.52	1364.47
	females	3112.88	1939.89	2735.49	1819.96
Monocytes (per mm)	males	370.51	641.57	370.51	641.17
	females	351.64	393.01	385.59	378.99
Eosinophils (per mm)	males	217.25	482.75	95.20	144.86
	females	209.14	320.72	162.97	234.59
Basophils (per mm)	males	60.85	137.67	10.16	36.67
	females	72.02	103.16	20.67	95.97
Red blood cells x 10^6 (per mm)	males	7.67	1.06	7.00	1.61
	females	7.56	1.01	6.10	2.21

(Table 29), plasma protein showed significantly (ANOVA, $P < .05$, Duncans Multiple Range Test $\alpha = .05$) lower levels in fall than during any other season. Hemoglobin levels were significantly lowest in fall and winter (ANOVA, $P < .05$, Duncans Multiple Range Test $\alpha = .05$) and highest in spring. Red blood cell numbers were significantly (ANOVA $P < .05$, Duncan's Multiple Range Test $\alpha = .05$) lower in winter and highest in spring and summer. Segmented neutrophils were significantly (ANOVA, $P < .05$, Duncans Multiple Range Test $\alpha = .05$) highest in summer and lowest in winter and fall, and hematocrit levels were significantly (ANOVA, $P < .05$, Duncans Multiple Range Test $\alpha = .05$) highest in spring than during any other season.

There are numerous factors that can affect different blood parameters in wildlife. In the raccoon, one of the more important factors may be diet, particularly the protein and energy content of the food. Seal et al. (1978a) showed that there are positive correlations between red blood cell counts and crude protein intake and an inverse correlation between hemoglobin levels and crude protein intake in deer fawns. Bahnak et al. (1979) further showed seasonal trends in hematocrits and serum protein levels, with hematocrits being highest in winter and lowest in summer, and serum protein levels dropping significantly in deer fawns on low protein diets during lactation. Similar trends can be detected in the Cades Cove raccoon population. In most areas of the Great Smoky Mountains National Park, the crude protein content of food items for black bears is highest in the early spring, lowest in late fall and winter, and intermediate in late spring, early fall, and summer (Eagle, 1979). Since the food of black bears is very similar to that

TABLE 29. Mean seasonal values of blood parameters of raccoons from Cades Cove, Great Smoky Mountains National Park, 1979-1980.

Variable	Season							
	Winter (37)[a]		Spring (49)		Summer (48)		Fall (36)	
Hemoglobin (g/dl)	10.5	0.5	11.1	0.4	11.2	0.2	9.7	0.4
Plasma protein (g/dl)	8.4	1.1	8.4	0.3	8.6	0.1	7.7	0.3
White blood cells/mm^3	127.6	22.6	107.2	6.2	130.6	5.0	110.6	7.4
Segmented neutrophils/mm	6594.9	573.7	6991.5	536.5	8031.4	676.8	6757.5	574.8
Non-segmented neutrophils/mm	107.9	30.3	221.7	59.4	78.5	21.3	92.3	24.8
Lymphocytes/mm	3028.9	292.2	2441.6	189.8	2962.0	307.8	3325.9	261.7
Monocytes/mm	396.1	67.6	354.7	40.8	299.0	53.4	285.6	37.1
Eosinophils/mm	126.2	30.9	213.1	47.6	113.9	31.0	281.1	81.0
Basophils/mm	5.4	3.8	64.0	16.7	73.5	18.9	34.2	14.8
Red blood cells x 10^6/mm	6.2	0.3	7.3	0.3	7.6	0.1	6.8	0.3

[a]Numbers in parentheses represent sample sizes.

of raccoons in the Smokies, these data apply to raccoons as well. Red blood cell counts, hemoglobin levels and plasma protein levels were lowest in fall and winter, seasons when the crude protein contents of the available foods were lowest. Conversely, red blood cell levels were highest in spring when crude protein levels were highest. There can also be differences in the dietary intake of younger and older animals which may contribute to differences in blood parameters. Nursing juvenile raccoons have diets very low in protein since raccoons' milk is 88% water and only 4% protein (BenShaul, 1962). Furthermore, blood parameters such as red blood cell counts can be affected by physiological changes caused by muscular activity (Smith and Kumpf, 1932), fear or excitement (Wintrobe, 1933), or dehydration (Wintrobe, 1949). All of these changes are associated with an increase in red blood cell counts, which may further explain seasonal trends, particularly that seen between reproductive and nonreproductive periods. Changes in eosinophil counts may be caused by hormonal changes related to excitement or increased contact with other raccoons. Speirs (1955) has demonstrated a relationship between eosinopenia and increased pituitary-adrenocortical activity. This relationship has even been suggested as a means of monitoring population density (Christian, 1963).

Wildlife Diseases

One hundred and seventeen blood samples were tested for the presence of antibodies to 5 pathogens. These agents included rabies virus, pseudorabies virus, canine hepatitis virus, canine distemper virus, and parvovirus. Of these samples, 49 were obtained from males of various ages (21--class 1, 10--class 2, 12--class 3, 3--class 4, and

3--class 5). All samples were negative for rabies, pseudorabies, and canine distemper. Five raccoons showed questionable titers (1:10) and 5 animals showed definite titers (1:20 - 1:40) for both canine hepatitis virus, and parvovirus (Table 30). The animal with the greatest parvovirus titer (Y55) was radiocollared and tracked from 28 September 1979 through 27 March 1980, but showed no abnormal movement patterns.

The 5 diseases that were examined in this study all have special relevance to raccoons. Canine distemper has been well documented in raccoon populations (Goss, 1948; Robinson et al., 1957; Habermann et al., 1958) and has been known to reach epizootic proportions (Hoff et al., 1974b). Keeler (1978) documented such an epizootic in Cades Cove. The presence of canine distemper in natural populations has become so widespread that it is regarded as a significant factor in controlling carnivore populations (Gorham, 1966). Analysis for rabies was considered important because raccoons are becoming an increasingly important reservoir and source of rabies in Florida, Georgia, and Louisiana (Kappus et al., 1970; Kaplan, 1977). However, it is not surprising that no evidence of rabies was found in Cades Cove raccoons since the disease is spread primarily by translocated animals (Nettles et al., 1979). Parvovirus was tested because it has become an important source of mortality in dogs and it has recently been isolated in raccoons (Nettles and Gustafson, 1980). Raccoons have also been suggested as possible vectors of pseudorabies (Kanitz et al., 1974). Recent transmission experiments with raccoons and swine indicated that pseudorabies was not transmitted between raccoons, but was transmitted reciprocally between raccoons and swine by contact, and when either consumed infected

TABLE 30. Raccoons showing positive titers for parvovirus or canine hepatitis in Cades Cove, Great Smoky Mountains National Park, 1979-1980.

Animal	Sex[1]	Age Class[2]	Disease	Antibody Titer	Physical Condition	Fate
R11	F	3	Parvovirus	1:20	Loss of facial hair broken canines Extremely worn molars	Found dead 48 days after capture
Y55	M	3	Parvovirus	1:40	Appeared healthy Extremely calm in trap	Recaptured 7 times over 12 months
Y111	M	2	Canine hepatitus	1:20	Raw wound on nose Ears torn Loss of hair on both forearms Calm in trap	Unknown
R49	F	3	Canine hepatitis	1:20	Appeared healthy Extremely calm in trap	Unknown
R57	F	4	Canine hepatitis	1:20	Extreme loss of hair on head region	Unknown

[1] M = Male, F = Female

[2] 1 = 0-14 months, 2 = 15-38 months, 3 = 39-57 months, 4 = 58-86 months, 5 = > 86 months

carrion of the other (Kirkpatrick et al., 1980). Lastly, canine hepatitus was investigated because virus surveys in wild mammals indicated high proportions of raccoons have been exposed to infectious hepatitis virus (Parker et al., 1961; Jamison et al., 1973).

There are other diseases that were not examined in this study which occur in raccoons. These include feline laryngitis, feline gastroenteritis, purulent fibrinous pleuritis and pericarditis, and tuberculosis (Whitney and Underwood, 1952; Stains, 1956).

Overall, the Cades Cove raccoon population appeared to be free of the 5 major diseases that were investigated. Furthermore, the lack of any significant number of raccoons with antibody titers allows one to speculate that raccoons may not play a crucial role as carriers of these diseases.

Blood Microfilariae

Studies have revealed the presence of microfilariae and their adult forms in numerous species of wildlife; transmission from wildlife to humans may occur (Hawking, 1961). Due to their potential importance concerning public health, a knowledge of their presence and distribution in different hosts and vectors can be important.

Microfilaria are adapted to live in tissue fluid or blood where they may spend several months. Production of these microfilariae by the adult forms can last up to 7 years (Anderson, 1957; Hawking, 1961; Olsen, 1974). Previous studies concerning raccoons have reported the presence of 5 species of microfilariae from the blood (Chandler, 1942; Price, 1955, 1959, 1962; Ash and Little, 1964; Herman and Price, 1965; Smith, 1980).

Throughout the study period, 148 whole blood samples were examined for microfilaria using the Knotts test. One hundred and eight of these samples (73%) were positive for microfilariae. All but 1 of the samples contained only Tetrapetalonema llewllyni described by Price (1955, 1959, 1962). The remaining sample contained 1 Dipetalonema procyonis as well as T. llewellyni. The T. llewellyni averaged 250 - 300 microns in length and 2.5 microns in diameter. The single D. procyonis was 220 - 230 microns by 5 microns. Prominent morphological characteristics observed in all the microfilariae included a blunt, bulbous head shape, no sheath, and a curved button hook tail. Any discrepancies regarding measurements and morphology may have been the result of the way in which blood specimens were handled, techniques used for preparing specimens, age differences of the microfilaria, or the drug used for anesthesia. Dipetalonema sp. in blood stored for 4 to 6 hours at room temperature increases in width and length over those obtained from fresh samples (Sawyer, 1963). Standardized conditions were not always possible in the field.

Female raccoons had a greater incidence of microfilaria (78%) than male raccoons (67%). For all raccoons, there was a much lower incidence of microfilaria in age class 1 raccoons than in all other age classes (Figure 13). Seasonally, spring and summer showed the greatest numbers of raccoons positive for microfilaria (Figure 14).

The transmission of microfilaria depends on both the vector and the host. Although there are a number of potential vectors such as mosquitoes, fleas, ticks, black flies, and deer flies, other factors such as host behavior, host morphology, vector density, and successful

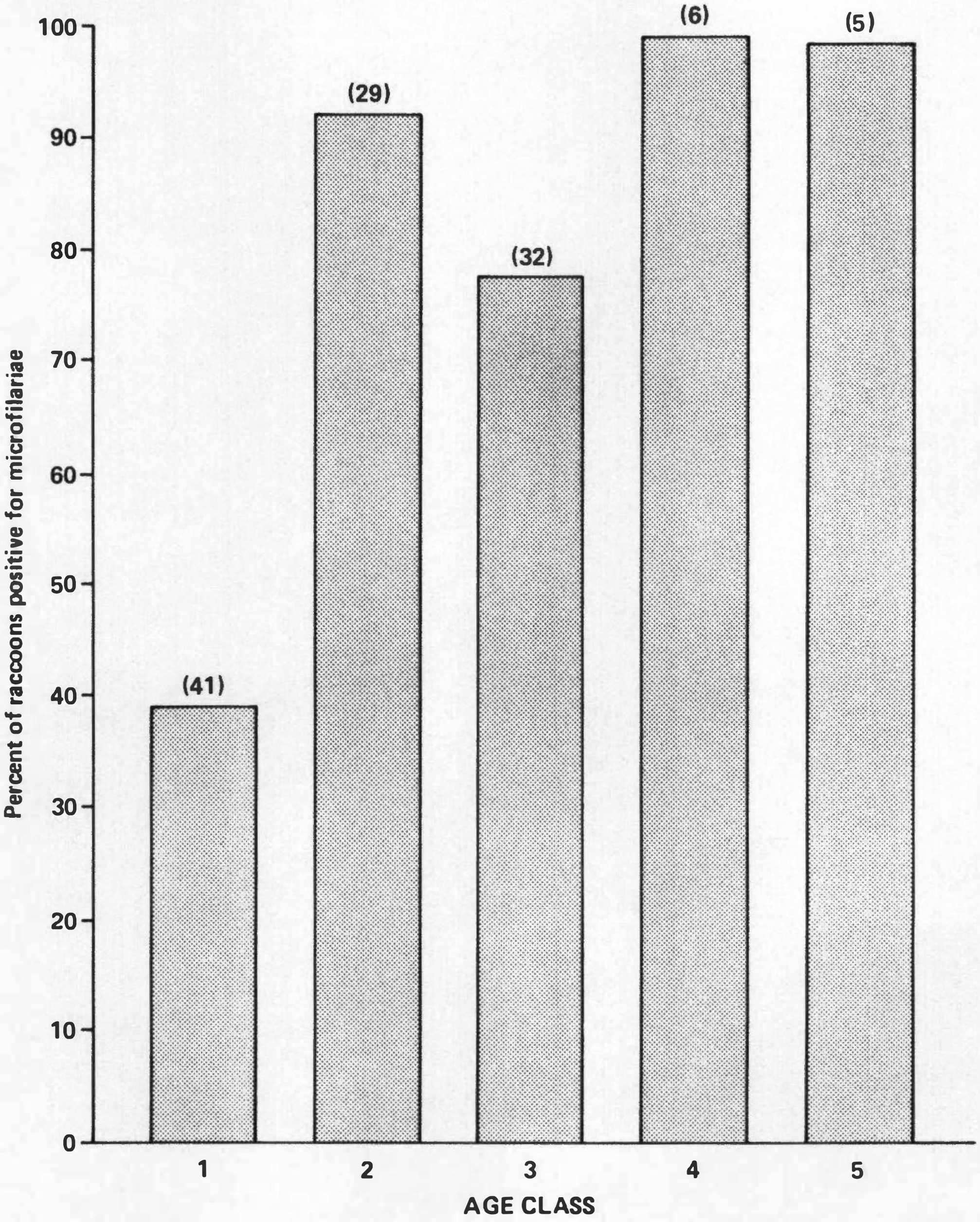

Figure 13. Frequency of raccoons positive for blood microfilariae, by age class, in Cades Cove, Great Smoky Mountains National Park, 1979-1980. Numbers in parentheses indicate sample size.

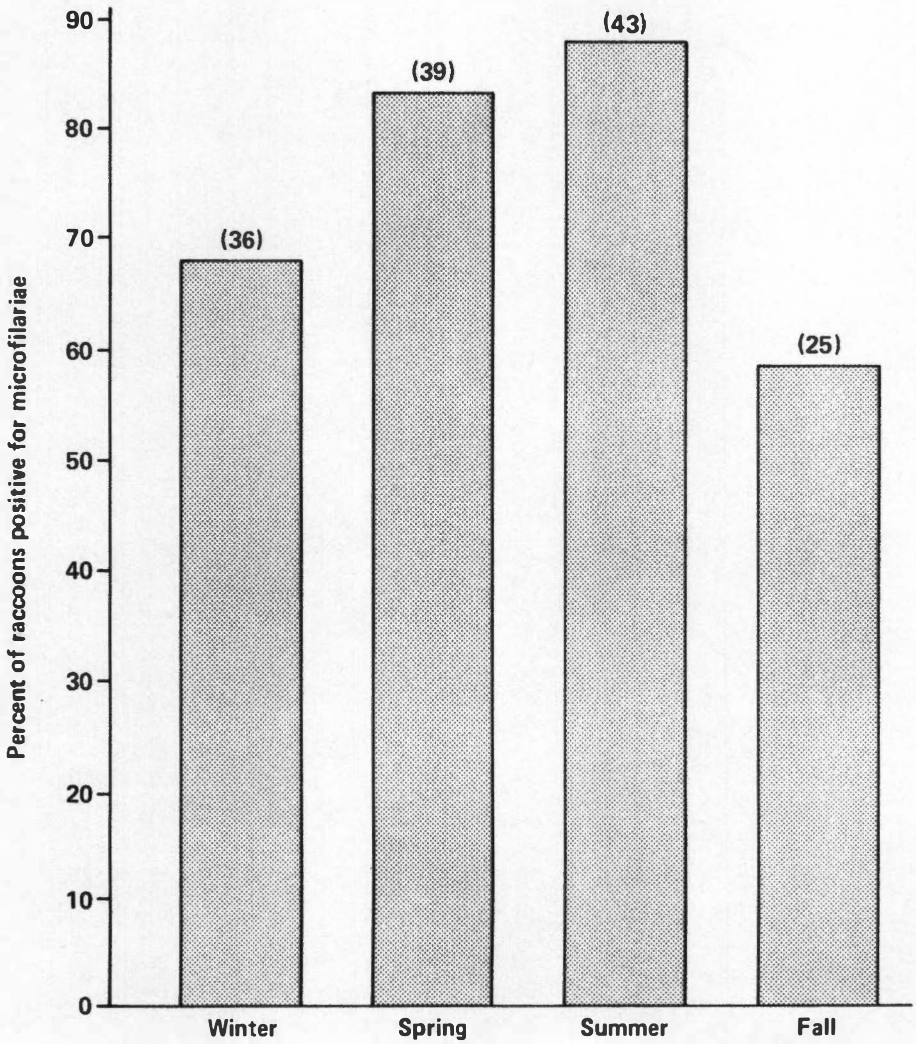

Figure 14. Frequency of raccoons positive for blood microfilariae, by season, in Cades Cove, Great Smoky Mountains National Park, 1979-1980. Numbers in parentheses indicate sample size.

mouthpart penetration into host capillaries also play major roles in developing host-vector relationships (Magnarelli, 1979). Furthermore, correct environmental conditions must prevail for a vector to survive and for the filaria to develop (Hawking, 1961). There can also be a marked periodicity of microfilariae in the peripheral blood (Olsen, 1974), which has been linked to both phototropic behavior and activity of the intermediate host (Anderson, 1957). In some species, the peak number of microfilaria in the peripheral blood occurs during the maximum biting activity of the vector (Hawking, 1961; Gubler, 1966). Physiological defensive mechanisms against some microfilaria can include numerous neutrophils (Beaver, 1965), and eosinophilia (Jung, 1967; Pachero, 1968).

Despite the high percentage of microfilaria in the raccoons of Cades Cove, the study indicated a healthy, thriving, raccoon population. It may be speculated that the *T. llewellyni* have developed a symbiotic relationship with the raccoons that is not detrimental to their health. This is not surprising since the successful propagation of a parasite depends on its ability to cause no serious injury to its host (Lavoipierre, 1958).

Ectoparasites

Little is known of the ecology of tick vectors of disease (Sonenshine, 1975), especially in raccoons. Yet this knowledge is vital for meaningful predictions or control programs of future trends in tick borne diseases. The contribution of an ectoparasite study to the research reported here was that it could be correlated with other data concerning the ecology of the raccoon population.

From 17 November 1979 to 28 September 1980, the presence and numbers of ectoparasites were noted on captured raccoons. During this time, 386 ectoparasites were collected from the facial areas of 77 raccoons (38 female, 39 males). When ectoparasites were extremely numerous, they were not all removed from the raccoon. All the ectoparasites were ticks except for 1 bot fly larva. Two hundred and sixty-eight of the ticks were identified as Dermacentor variabilis, the American dog tick. The remaining 103 were identified as Ixodes sp; 34 were identified as I. texanus, 12 as I. cookei. All identification was based upon criteria listed by Ko (1973), Levine (1978), Sonenshine (1979) and USDHEW (1967). These 3 tick species have been previously reported in raccoons (Sonenshine and Stout, 1971; Good, 1972; Cooney and Burgdorfer, 1974). Dermacentor variabilis has received wide attention due to its potential as a vector for rocky mountain spotted fever and tularemia. In 1974, serologic studies carried out in the Tennessee Valley Region (Burgdorfer et al., 1974; Cooney and Burgdorfer, 1974) indicated a very low incidence of Rickettsia rickettsi antibodies (8%, N = 666) but a relatively high incidence of Francisella tularemsis antibodies (19%, N = 620). The raccoon showed the highest prevalence of the tularemia antibodies (45%, N = 161) of 22 mammal species that were examined. This is not surprising because D. variabilis is the only tick from which these agents have been isolated, and the raccoon is one of the most important mammalian hosts for this tick (Sonenshine and Stout, 1971; Sonenshine, 1975). Ixodes sp. are also commonly found on raccoons but have not been implicated in the transmission of many diseases. However, I. cookei is a vector of Powassan virus, a cause of human encephalitis in northern Ontario (McLean et al., 1964).

To obtain a clear picture of seasonal differences, each tick genus was considered separately. Both Ixodes species were considered together because the species of all the specimens could not be identified. The adult stages of D. variabilis were prevalent in spring and particularly in summer (Figure 15). Members of this species were not found during winter and fall. Very few nymphs and larvae were found. The majority of nymphs were collected during the summer months. The small sample sizes for nymphs and larvae were due in part to sampling methods, but mainly to the fact that larvae and nymphs of D. variabilis do not usually feed on medium sized mammals (Sonenshine and Stout, 1971). The trend observed in these data compare favorably with the life cycle of D. variabilis. Adult tick activity is supposed to extend from April through mid-August and peak in May or June, while nymphal activity extends from May through August with a peak in June (Garvh et al., 1978). Very different patterns were observed with Ixodes sp. in this study (Figure 16). Ixodes was collected throughout all 4 seasons with much larger numbers of nymphs and larvae obtained compared to D. variabilis. This is because the raccoon is an important host of the immature stages of Ixodes (Sonenshine and Stout, 1971), and it is the preferred host of I. texanus (Bishopp and Trembley, 1945). The adult forms of Ixodes were prevalent in Cades Cove during the spring months while the majority of nymphs and larvae were collected during the winter months. This closely follows their life cycle. Ixodes cookei is found most months of the year, particularly in October and November (Tugwell and Lancaster, 1963). Ixodes texanus adults and

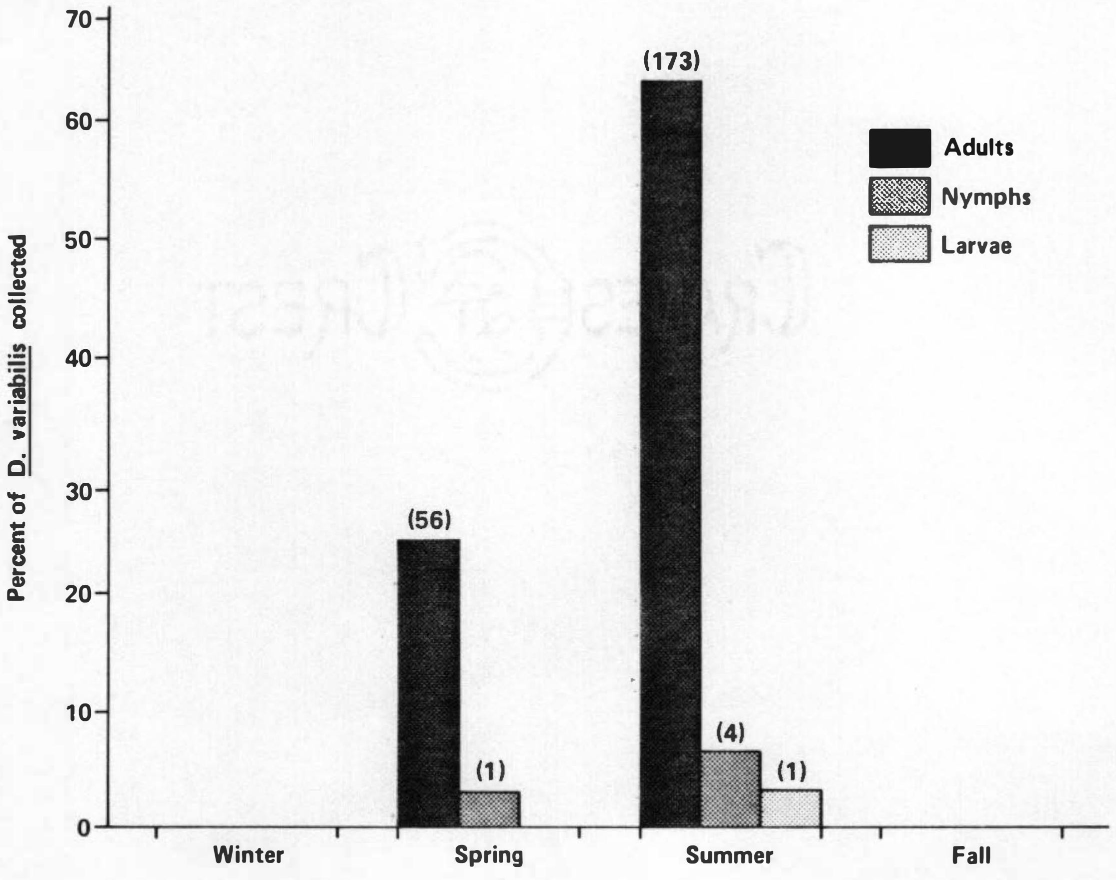

Figure 15. Seasonal frequencies of Dermacentor variabilis collected from raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980. Numbers in parentheses represent sample sizes.

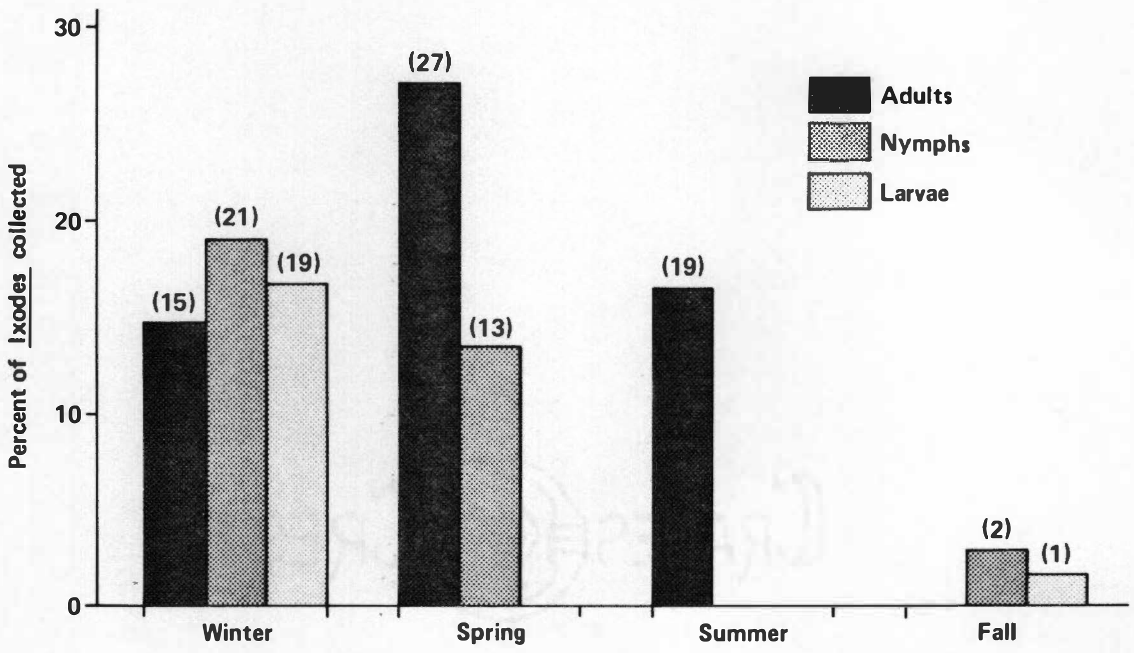

Figure 16. Seasonal frequencies of Ixodes sp. collected from raccoons in Cades Cove, Great Smoky Mountains National Park, 1979-1980. Numbers in parentheses represent sample sizes.

nymphs are mostly prevalent in May while larvae occur more frequently in the colder months (Sonenshine and Stout, 1971). Of course, the major bias in all these data was the fact that not all ectoparasites were collected, particularly the nymph and larval stages.

CHAPTER V

CONCLUSIONS

I. Population Size and Structure

Mark-recapture data on the raccoons of Cades Cove suggested overall sex and age ratios that were indicative of a stable, healthy population. Although the relative density of 1 raccoon per 17 ha was average compared to other studies, the ecological density was 1 raccoon per 10 ha. This discrepancy indicates the need in considering differential habitat utilization when studying or managing for animals such as raccoons. In Cades Cove, nocturnal movement patterns indicated that open fields were important foraging and travel areas, but the forests were the areas of day bed sites.

II. Population Dynamics

Seasonal trends in activity, movement patterns, home range sizes, and day bed selection indicated that raccoons show changing patterns of social organization. Although they do not appear to show strict territoriality as defined by Burt (1943), there are indications of avoidance, scent marking, and agonistic behavior during certain times of the year, particularly by adult males. Since they are capable of neighbor recognition (Barash, 1974), these behaviors may be related to home range defense against nonresident males, as observed in the red fox (Preston, 1975). The abrupt seasonal changes in raccoon movements and social structure appear to be closely tied to breeding and reproduction. During spring, particularly the month of April, the raccoons in Cades Cove show their largest home range sizes, the largest shift in activity centers, and their highest nocturnal travel rates. Activity centers of adult males also are the furthest apart during spring. These patterns of behavior are probably linked to the search for mates by males and the need for females to seek out optimal maternity dens. Furthermore, it appears likely that the dissolution of sibling bonds begins at this time (Fritzell, 1977). By the time of parturition in June, yearlings are being forced to disperse from their natal areas. This phenomenon was of greater importance in yearling males while yearling females often remained in their natal areas.

During other times of the year, the raccoons showed much less movement and greater tolerance for each other. This was exemplified during the winter months when they had their smallest home ranges and were least active. Adult males had their activity centers closest to each other during this time and both sexes showed instances of communal denning. There appeared to be no true winter lethargy and activity continued, albeit at a decreased level, throughout the winter.

Some of the seasonal changes in home range sizes and activity centers may have been related to the use of favored den sites. Although tree dens were the most important maternity sites, rock dens played a key role during the winter months. This was particularly true of Tory Shields Cave which was used by 7 different radiocollared animals 112 times. The frequent use of rock dens during winter may be related to their stable temperature regime as compared to ambient temperatures. Thus, rock dens would require minimal energy expenditure for temperature regulation by the raccoon compared to the use of other day bed types. The tree species which was used most frequently as day beds was red oaks. This was probably related to the greater likelihood of cavity formation in red oaks compared to other tree types. The fact that 7 different categories of day beds were used by the raccoons, and that favored sites were not used in the frequency that they were encountered has important management implications. Since day beds are crucial for winter denning, escape from predators, and parturition, the lack of both good day bed sites or a selection between different day bed types could severely limit a population. This should be considered when habitats are altered or raccoons are being managed.

The mean litter size of 2.8 young per female that was found in this study is similar to other litter sizes in southern latitudes. There appeared to be very little juvenile mortality due to natural causes. The relatively low average longevity of 30 months found in this study resulted in apparent population stability in Cades Cove. There also appeared to be differential male mortality in older age classes as indicated by changes in the sex ratios. This could be related to increased male interactions and agonistic behavior involved with breeding and home range defense; this is substantiated by the wounds and scarring found on older males.

III. Physiology and Health

Comparison of hematological parameters with other studies, as well as the rarity of animals with antibody titers to 5 important wildlife diseases, supports the conclusion that the Cades Cove population is healthy. The density estimation, as well as the lack of distemper virus antibodies in the blood, further indicates resiliency to disease such as canine distemper that devastated the population in 1973 (Keeler, 1978). In addition, the raccoons appear to have developed a symbiotic relationship with microfilariae and ticks that utilize the raccoons as hosts. Yet, the fact that raccoons are susceptible to a wide array of important diseases and are host to a number of parasite species, make them a potentially important indicator species to monitor zoonoses (Trainer, 1970).

Changes in certain key blood parameters can also be used to monitor seasonal changes in diet, habitat utilization, and reproductive condition. In this study, plasma protein levels differed between young, nonreproductive raccoons and older, sexually mature raccoons. Red blood cell counts and hemoglobin levels in females and red blood cell counts and eosinophil counts in males differed between nonreproductive and reproductive periods of the year.

CHAPTER VI

SUMMARY

1. A study concerning the ecology and physiology of a natural population of raccoons was conducted from 15 September 1979 through 30 September 1980 in the Cades Cove area of the Great Smoky Mountains National Park.

2. Live trapping, ear tagging, radiotelemetry, and blood analysis were used to examine physical parameters and the size, structure, dynamics, physiology, and health of the population.

3. During 858 nights of trapping, 153 raccoons were captured a total of 288 times, for an adjusted trap success of 45%. There were no seasonal differences in trap success.

4. The only significant (T-tests, $\alpha = .05$) morphological differences found between the sexes were that male raccoons were heavier and had larger rear paw lengths. The majority of raccoons showed the typical gray and black pelage characteristics.

5. The Cades Cove study area contained an estimated 118 ± 59 raccoons for a density of 1/17 ha, or an ecological density of 1/10 ha. Sex ratios were approximately 1:1 for all raccoons but were biased towards females in the older age classes. Age ratios formed a bottom heavy pyramid with a 2:1 ratio of young to older animals.

6. Of 55 individual male raccoons examined, 56% had descended testes with the highest frequency of descended testes observed in spring and summer and the lowest during winter.

7. Parturition was estimated to be in early June with an average of 60 days spent in the litter den. These data were obtained using radiotelemetry on 4 pregnant female raccoons and further substantiated by the capture and age estimation of 22 pre-weaned juveniles.

8. Assuming a gestation period of 63 days, conception occurred in late March to early April. Based upon the observation of 4 family units in the field, a mean litter size of 2.8 young/female was estimated.

9. The general trends in activity for 14 radiocollared raccoons indicated a sharp increase in activity from 1800 to 2100 hours, a gradual decline until 0300 hours, followed by a sharp decline until sunrise. Specific seasonal trends indicated that larger numbers of raccoons were active over longer periods of time during the fall months, and fewer animals were active during peak hours during the winter months.

10. Using an elliptical home range model, male raccoons had annual home range sizes of 7.5 km^2, and females had significantly smaller home range sizes (ANOVA, $P < .05$) of 3.0 km^2. Seasonally both sexes had significantly larger (ANOVA, $P < .05$) home ranges during spring than any other time of year. This was primarily due to movements observed during the month of April.

11. Shifts in activity centers averaged 0.21 km for males and 0.14 km for females with no significant differences (ANOVA, $P > .05$) between the seasons. However, during spring, particularly in April, there was a significantly (ANOVA, $P < .05$) larger shift than there was between other seasons.

12. There was extensive home range overlap by all age raccoons of both sexes. Distances between seasonal activity centers indicated

that the 2 oldest males maintained their greatest distance from one another during April, and the least distance during winter.

13. There were no significant differences (ANOVA, $P > .05$) in nocturnal travel rates between male and female raccoons. However, males showed significantly (ANOVA, $P < .05$) faster rates of travel during spring (.57 km/hr) than all other seasons, and females showed significantly (ANOVA, $P < .05$) slower rates of travel during winter (.21 km/hr) with no significant (ANOVA, $P > .05$) differences between other seasons.

14. The limited dispersal data obtained in this study indicated a dispersal date of early June at approximately the same time that parturition occurred. Although there was evidence of some dispersal by yearling females, cumulative recapture data indicated that yearling females dispersed more infrequently than yearling males.

15. The average longevity of raccoons in Cades Cove was estimated at 29 to 30 months with the upper observed age limit approximately 86 months. Age class data as well as the physical condition of older raccoons indicated that there may be increased male mortality in the older age categories.

16. Throughout the study 330 day beds of raccoons were located using radiotelemetry. These day beds were used by raccoons on 1,492 occasions. These data indicated that raccoons of both sexes may use favored day bed sites repeatedly.

17. Generally, rock and tree dens were preferred to other day bed sites. The use of rock dens was particularly prevalent during winter for both sexes.

18. The results of 7 vegetation transects indicated that the

species and sizes of trees that were used as day bed sites were not chosen with the frequency that they were encountered. Circumferences of trees that were used by raccoons averaged 229 cm for tree dens, 154 cm for tree nests, and 195 cm for tree roosts. The preferred species selected as day bed sites were red oaks (45%) followed by hemlocks (13.5%), pines (13%), and yellow poplar (12%). Seventy percent of tree dens were red oaks, 89% of tree nests were hemlocks and pines, and 75% of tree roosts were hemlocks and red oaks. Tree dens were located significantly lower (ANOVA, $P < .05$) on trees than either tree roosts or tree nests.

19. Results of the transects also indicated that barn, rock, and ground dens were not used with the frequency that they were encountered. Rock and barn dens were used to a much greater extent than their availability would suggest, while ground dens were used to a much lesser degree.

20. Comparisons of temperatures of the different den types with ambient temperatures indicated that seasonal use of different day bed types may, in part, be related to their microclimates.

21. Communal denning was observed on 23 occasions: 17 cases occurred within rock dens, 5 cases within barn dens, and 1 case within a tree den.

22. Male raccoons moved significantly greater distances between consecutive day beds (0.6 km) than females (0.2 km). Both sexes exhibited the largest movements during spring and fall. Female raccoons showed a greater tendency to remain in the same day bed on consecutive occasions than males during all seasons.

23. On numerous occasions raccoon scats were found at or near day bed sites. This may represent a type of scent marking which is more important during certain times of the year than others.

24. Rectal temperatures of raccoons of both sexes averaged 38.3^{o}C.

25. Discriminant function analysis indicated that the blood parameter accounting for the greatest difference between nonreproductive animals (age class 1) and sexually mature animals (age classes 2 - 5) was plasma protein. Younger animals had lower levels of plasma protein than older raccoons. The blood parameters accounting for the greatest difference between the reproductive period (April - September) and the nonreproductive period (October - March) were red blood cell counts and hemoglobin concentrations in females, and red blood cell and eosinophil counts in males. In both males and females, the blood parameters accounting for the greatest variability increased from the nonreproductive period to the reproductive period.

26. Examining the blood parameters individually, plasma protein showed significantly lower levels (ANOVA, $P < .05$) in fall than during any other season. Hemoglobin levels were significantly lowest in fall and winter (ANOVA, $P < .05$). Red blood cell numbers were significantly lowest in winter and highest in spring and summer (ANOVA, $P < .05$). Segmented neutrophils were significantly (ANOVA, $P < .05$) highest in summer and lowest in winter and fall, and hematocrit levels were significantly highest in spring than during any other season (ANOVA, $P < .05$).

27. Of 117 serum samples tested for antibodies to 5 disease

agents, only 5 samples had titers. Three raccoons had antibody titers (1:20) for canine hepatitis virus and 2 raccoons had antibody titers (1:20 - 1:40) for canine parvovirus.

28. Seventy-three percent of 148 whole blood samples examined for microfilariae were positive. All but 1 of the positive samples contained only Tetrapetalonema llewllyni. The remaining sample contained both Dipetalonema procyonis and T. llewellyni. Raccoons of all ages had microfilariae but a smaller proportion of younger (age class 1) raccoons were infected. Spring and summer had the greatest percentage of animals with blood microfilariae.

29. All but 1 of the 386 ectoparasites collected from 77 raccoons were ticks. The exception was a bot fly larva. Two hundred and eighty-six of the ticks were Dermacentor variabilis, the American dog tick, and the remaining 103 were Ixodes sp. The majority of adult D. variabilis were collected during spring and summer but very few nymphs or larvae were found throughout the year. Ixodes was found during all times of the year but the majority of adults were collected in spring and summer and the majority of nymphs and larvae in winter.

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APPENDIX

TABLE 31. Seasonal and annual home range activity centers for radiocollared raccoons in Cades Cove, GSMNP, 1979-1980. Numbers represent UTM grid coordinates.

Animal No.	Winter	Spring	(April)	Summer	Fall	Annual*
Y54	-	448431	450434	445427	-	-
Y55	445448	442445	-	-	440445	443447
Y58	454430	448429	453424	448436	448432	450432
Y65	-	453426	459430	449421	449420	451423
Y61	456433	456428	466431	452426	453429	454429
Y66	-	452431	-	-	-	-
R01	456434	466437	462437	460432	460433	460434
R02	451432	452430	458432	447430	449431	450430
R04	448430	447431	449434	446428	448430	447430
R06	455433	458428	460431	457426	454430	456430
R09	456436	460434	462438	461433	460434	459434
R15	454433	456433	462436	453433	452432	454433
R20	446431	448430	452433	446431	446430	447430
R55	-	-	-	448430	448428	-

*Annual activity centers were not calculated when data from more than 1 season was missing.

VITA

Alan Robert Rabinowitz was born in Brooklyn, New York on December 31, 1953. He attended elementary schools in Far Rockaway, New York until 1966 when his family moved to Cedarhurst, Long Island. It was in Cedarhurst that he graduated from Lawrence High School in June 1970. The following September he entered Western Maryland College and in June 1974 he received a Bachelor of Arts degree in both Biology and Chemistry. In the fall of 1976, he accepted a teaching assistantship at The University of Tennessee, Knoxville and began study towards a Masters degree in animal ecology. He completed his Masters degree in June, 1978 after having worked with Dr. Merlin Tuttle on the foraging strategies of the endangered gray bat. He remained at The University of Tennessee, Knoxville to pursue a doctoral degree in wildlife ecology under Dr. Michael Pelton.