MOVEMENT PATTERNS OF RACCOONS *(PROCYON LOTOR)* IN WESTERN TENNESSEE

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ABSTRACT

Raccoons *(Procyon lotor)* were studied from October 1977 to February 1979 on Shelby Forest Wildlife Management Area and Meeman Biological Field Station in western Tennessee. Nine male and seven female raccoons were equipped with radio transmitters, and movement patterns monitored an average of 25 days per season. Mean seasonal home ranges of adults (as calculated using a bivariate model) varied from 35 ha to 261 ha and from 11 ha to 205 ha for males and females, respectively. Home ranges overlapped extensively and varied between sexes and among seasons and individuals. The average range length for males and females was 2,067 m and 1,487 m, respectively. Low temperature and snow cover reduced activity and caused raccoons to remain in dens for extended periods. A preference for tree cavities over ground burrows as den sites was noted.

INTRODUCTION

Raccoons, *Procyon lotor,* range extensively throughout the Neartic realm and, due to their economic importance, have been the subject of numerous biological investigations (see Lotze and Anderson, 1979; Kaufmann, 1982). Of the previous studies, many have included investigations relating to activity (e.g., Stuewer, 1943; Stains, 1956; Johnson, 1970; Keeler, 1978), and movements of raccoons have been studied by several investigators in eastern Tennessee (see Minser and Pelton, 1982). However, a paucity of information is available concerning movement patterns of raccoons in western Tennessee. Since population characteristics tend to vary from one geographic region to another, biological information obtained from habitat types in some geographic regions may not be applicable to others. In order to better understand the biology of this species in western Tennessee, additional ecological studies are needed.

The purpose of this investigation was to assess movement patterns of *P. lotor* in hardwood forest of the Mississippi River floodplain in western Tennessee. Additionally, we provide information relating to den utilization and the influence of temperature on activity patterns.

STUDY AREA

The study was conducted on Shelby Forest Wildlife Management Area and Meeman Biological Field Station in Shelby County (approximately 32 km north of Memphis), Tennessee. Three distinct types of deciduous hardwood forest characterized the study area (upland forest with gently rolling terrain; forest of steep, sloping terrain and small ravines of the third Chickasaw Bluff; lowland forest adjacent to the Mississippi River).

Upland forest and adjacent bluff habitat were well drained and remained relatively dry. Lowland forest was subject to annual flooding, and parts remained wet for most of the year.

Upland forest habitat had a dominant overstory of oak *(Quercus* spp.), hickory *(Carya* spp.), and beech *(Fagus grandifolia)* with a ground cover of honeysuckle *(Lonicera* sp.), blackberry *(Rubus allegheniensis),* and nettle *(Urtica* sp.). This forest type was interspersed with old fields containing various grass species in different successional stages. Five ponds (< 0.5 ha) furnished permanent water in the upland forest with temporary water provided by several intermittent streams.

Beech, oak, hickory, and elm *(Ulmus* sp.) dominated tree growth on steep slopes of the Chickasaw Bluff with a relatively sparse ground cover, except for small patches of nettle and greenbrier along two spring-fed streams. Steep hills of the Chickasaw Bluff had a slope of approximately 40% and elevation of approximately 51.8 m above the lowland forest (elevation = 70 m).

Lowland forest habitat was composed of cottonwoods *(Populus deltoids),* elms, and hackberry *(Celtis* sp.) with an extensive ground cover of nettle and honeysuckle. Two permanent spring-fed streams, with origins in the bluff forest, flowed into the lowlands creating a relatively permanent swamp.

Temperatures ranged from -10.0°C on 6 February 1978 to 36.6°C on 30 June 1978. Monthly temperature means reached a minimum of 0.4°C in January 1978 and a maximum of 28.7°C in July 1978. Annual precipitation was approximately 127.0 cm with a mean monthly average of 13.4 cm during the study. The frost period usually began in early November with the last killing frost occurring around 20 March. An average of 9.5 cm of snow fell during January and February 1978 and 1979.

MATERIALS AND METHODS

From 29 October 1977 to 18 February 1979, 16 raccoons (nine male, seven female) were equipped with radio transmitters, and movements monitored an average of 25 days per season. Transmitter failure prevented collection of continuous seasonal data on any individual for the duration of the study. Average transmitter life was 79 days (range = 12-134 days).

Raccoons were trapped in Havahart and folding Tomahawk live traps baited with fish. After capture, animals were anesthetized with ether, sexed, and aged (following Grau et al., 1970). Numbered ear tags were used in marking raccoons for future identification. Each animal was equipped with a motion sensitive, lithium powered transmitter (weight of 85 g to 110 g) with an external whip antenna. Raccoons were located using a 24-channel receiver and a three-element Yagi antenna. Triangulation was accomplished utilizing an eight-element Yagi antenna mounted on a vehicle as described by Verts (1963). Nocturnal movements were monitored an average of 10 nights per month beginning approximately 1 hour before sunset and ending approximately 1 hour after sunrise. Information on daily resting or den use was obtained periodically after cessation of night activity. All locations were plotted on 1:24,000 scale United States Geographical Survey maps to determine home ranges.

Home ranges were calculated using a bivariate home range model, BV (Koeppl et al., 1975), a minimum area method, MA (Mohr, 1947), and a range diameter or circular method, RD (Lay, 1942; Stuewer, 1943). The three methods were included for comparison with other studies. Home range estimates are reported as bivariate estimates at the 95% confidence level unless otherwise stated. Home range differences among seasons and between sexes were analyzed using a single-classification analysis of variance. Stepwise multiple regression was used to examine home range size in relation to selected environmental variables (average seasonal temperature, precipitation, percent sky cover, photoperiod). All statistical tests were used from the Statistical Package for the Social Sciences (SPSS; Nie et al., 1975). Significance tests were at $P < 0.05$ unless otherwise indicated. Weather data were recorded by the National Weather Service located at Memphis International Airport, Memphis, Tennessee (approximately 41 km south of the study area).

Table 1. Sex, age, length of period monitored, and home range estimates[1] for raccoons studied on Shelby Forest Wildlife Management Area and Meeman Biological Field Station in western Tennessee.

Animal Number	Sex	Age	Transmitting Period	Number of Locations	Bivariate	Minimum Area	Range[2] Diameter	Range[3] Length
01	male	adult	20 Oct 1977 to 10 Dec 1977	107	115	80	179	1560
02	male	adult	24 Nov 1977 to 16 Mar 1978	86	146	151	596*	2804
03	male	adult	28 Oct 1978 to 12 Feb 1979	181	41	58	141	1390
04	male	adult	07 Mar 1978 to 09 Apr 1978	47	152	140	639	2877
05	male	adult	06 Jun 1978 to 25 Aug 1978	109	157	166	439	2389
06	male	adult	08 Jun 1978 to 25 Aug 1978	89	293	224	345	2145
07	male	adult	17 Mar 1978 to 28 Mar 1978	38	96	51	95	1121
08	male	adult	03 Jun 1978 to 17 Aug 1978	102	333	281	476	2487
09	male	adult	11 Dec 1977 to 19 Feb 1978	93	218	109	242	1828
male average home range size					172	140	350*	2067
10	female	adult	08 Nov 1978 to 12 Feb 1979	115	13	13	13	585
11	female	adult	31 Dec 1977 to 24 Mar 1978	97	75	108	191	1584
12	female	adult	11 Nov 1977 to 24 Mar 1978	118	56	67	121	1268
13	female	juv	02 Mar 1978 to 09 Apr 1978	14	68	23	42	756
14	female	adult	06 Jun 1978 to 12 Aug 1978	64	161	90	203	1609
15	female	adult	06 Jun 1978 to 13 Aug 1978	125	137	162	299	1950
16	female	adult	06 Jun 1978 to 25 Aug 1978	111	318	259	650	2657
female average home range size					118	103	217*	1487

[1]Home ranges are reported in hectares.
[2]Values marked with a single asterisk (*) indicate a significant difference ($P < 0.002$) between home range methods.
[3]Range length is reported in meters.

RESULTS

Results relating to sex, age, and home range (including length of period monitored, number of radio locations, and range length, greatest distance between radio locations) are summarized in Table 1. There were no statistical differences in size of home ranges between sexes. Mean home range size of nine adult male raccoons was 172 ha (Table 1) with a seasonal range of 35 ha to 261 ha (Table 2). Seasonal home ranges of six adult females and one juvenile female ranged from 11 ha to 205 ha (Table 2) with a mean of 118 ha (Table 1). Seasonal home ranges of adult males were also not significantly larger than those of adult females although females generally had smaller home ranges (Table 2). Male raccoons moved greater average distances (2,067 m) between extreme locations than females (1,487 m). Male raccoon 04 and female raccoon 16 moved the greatest distance between locations, 2,877 m and 2,657 m, respectively (Table 1). Home ranges of male and female raccoons fluctuated seasonally (Figure 1) with summer 1978 home ranges being significantly larger than winter 1977-1978, winter 1978-1979, and fall 1978.

Home ranges in upland forest were not signficantly different from those examined in bluff and lowland forest. Although upland forest habitat was adjacent to bluff habitat, home ranges did not appear to overlap between these two areas. However, male and female home ranges did overlap extensively within each habitat type. Home range shapes are presented in Figures 2 and 3 as determined from the minimum area method which allows graphic representation of the actual data points.

A comparison of seasonal home ranges with corresponding seasonal climatological data indicated length of photoperiod to be highly significant with 43.3% of the home range variation accounted for by this variable. Other variables were not found to be significant and only explained an additional 3.4% of the variation. A total of 46.9% of the variation was accounted for by average seasonal temperature, precipitation, percent sky cover, and photoperiod. Seasonal home ranges and corresponding seasonal climatological data as well as a correlation matrix including home range values and selected environmental variables are presented in Allsbrooks (1981).

During a period from 9 January 1978 to 10 February 1978, the ground remained covered with 2.5 cm to 10.0 cm of snow with an average minimum temperature of -4.6°C. During this period, four raccoons remained in den sites an average of 28 days. Two raccoons occupied ground dens, and two occupied tree cavities. Daily checks of each den site for tracks revealed no activity outside dens. Motion sensitive transmitters indicated periodic diurnal and nocturnal shifting within dens, but no animals were located outside dens.

Table 2. Seasonal home range estimates for nine male and seven female raccoons studied on Shelby Forest Wildlife Management Area and Meeman Biological Field Station in western Tennessee. Home ranges represent bivariate estimates (95% confidence level) and are reported in hectares.

		1977	Season[1]			1979	
Group	Raccoon No.	Fall	Winter	Spring	Summer	Fall	Winter
Males	01	97	113				
	02		70	222			55
	03					35	47
	04			152			
	05				157		
	06				293		
	07			96			
	08				333		
	09		218				
male average		97	134	157	261	35	51
Females	10					11	14
	11		37	153			
	12		18	137			
	13			68			
	14				161		
	15				137		
	16				317		
female average			28	119	205	11	14

[1]Fall = September, October, and November; Winter = December, January, and February; Spring = March, April, and May; Summer = June, July, and August.

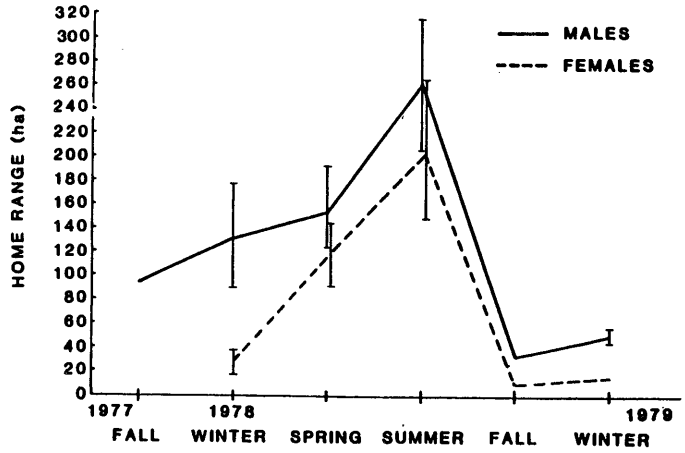

Figure 1. Male and female seasonal home ranges of raccoons monitored on Shelby Forest Wildlife Management Area and Meeman Biological Field Station in western Tennessee. Home ranges are bivariate estimates (95% confidence level). Vertical lines represent ± one standard deviation of the mean. Samples sizes for each season correspond to animals listed in Table 2.

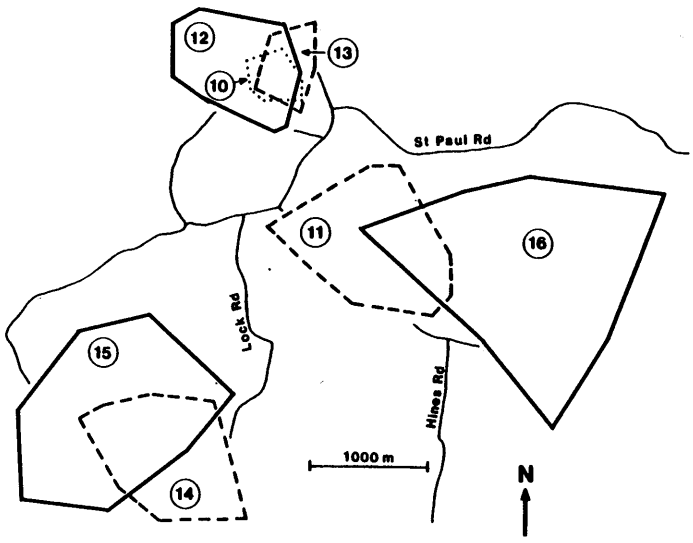

Figure 3. Home range shape and overlap of seven female raccoons on Shelby Forest Wildlife Management Area and Meeman Biological Field Station in western Tennessee. Home range shapes were determined by connection of outermost points. Numbers refer to individual raccoons and coincide with those listed in Table 1.

The winter of 1978-1979 was less severe than the previous winter. Three raccoons denned an average of 9 days during 4 January to 13 January 1979. This activity corresponded to a period of cold temperatures and snow cover. Average minimum temperature during this period was -6.6°C with a total accumulation of 5.1 cm of snow. Snow began melting with increasing temperatures around 10 January, and, by 15 January, all three raccoons had resumed nightly foraging activities and apparently never denned for more than a 2-day duration for the remainder of the study.

Of 254 den and resting sites located, 74.4% occurred in cavities with an average diameter-breast-height of 109.8 cm. Ground dens were utilized 25.6% of the time. Tree cavities were used extensively as daily resting sites while ground dens were used only on few occasions. Raccoons seldom used the same resting site more than once and appeared to choose the most convenient site available in the area where nightly foraging activities were concluded. Transmitter equipped raccoons from bluff habitat visited the adjacent swamp area on occasion to forage but always returned to resting sites within bluff forest. Resting sites were usually located within 100.0 m of water. Beech trees were utilized more than other tree species as den sites (Figure 4). Allsbrooks (1981) presented den locations for individual raccoons.

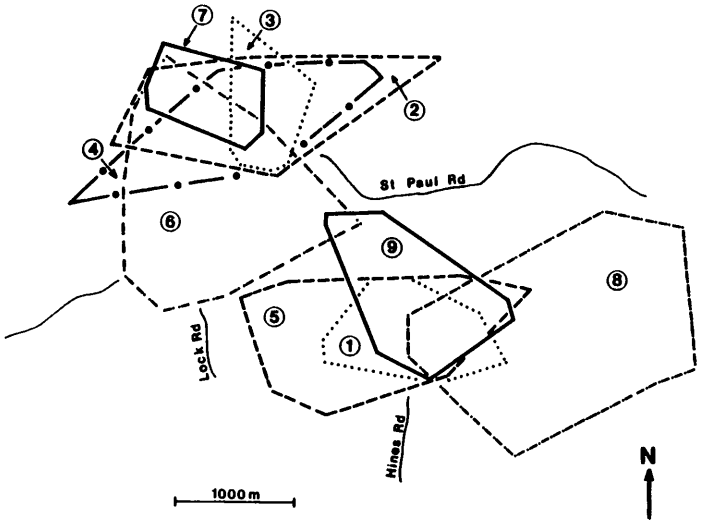

Figure 2. Home range shape and overlap of nine adult male raccoons monitored on Shelby Forest Wildlife Management Area and Meeman Biological Field Station in western Tennessee. Home range shapes were determined by connection of outermost points. Numbers refer to individual raccoons and coincide with those listed in Table 1.

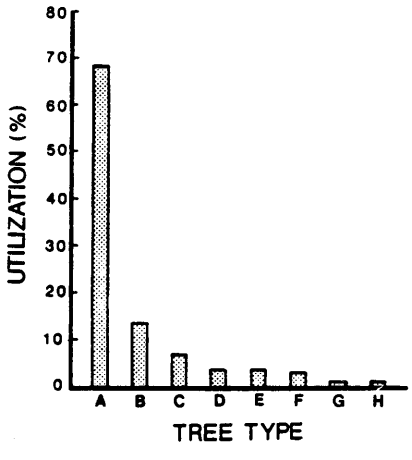

Figure 4. Tree utilization (as den and resting sites) by raccoons as determined from 189 locations on Shelby Forest Wildlife Management Area and Meeman Biological Field Station in western Tennessee. Tree types were as follows: (A) beech; (B) cottonwood; (C) sugar maple; (D) oak; (E) dead trees (unidentified sp.); (F) yellow poplar; (G) sweetgum; and (H) elm.

DISCUSSION

Home ranges are dynamic and are subject to many physical and biological factors (Hayne, 1949). Numerous estimates of raccoon home ranges are presented in the literature and have varied from 5.1 ha (MA) in a Cincinnati suburb (Hoffmann and Gottschang, 1977) to 4,946.0 ha (MA) in the prairie pothole region of North Dakota (Fritzell, 1978). While a lack of standardization in techniques make comparisons of home range estimates difficult, results of the present study appear to be similar to those reported by other works in the eastern United States (see Kaufmann, 1982). Range diameter estimates of 203.7 ha and 108.5 ha for adult male and female raccoons, respectively, have been reported from Michigan (Stuewer, 1943). Johnson (1970) investigated raccoon movements in Alabama river-swamp habitat and found a summer home range of 49.4 ha (MA) for a 1 year old male and a combined winter and spring range of 99.2 ha (MA) for an adult male; a combined winter and spring range of 46.2 ha (MA) was reported for a young female. In Illinois, seven raccoons monitored for periods up to 18 days had home ranges (MA) of 54.7 ha and 68.0 ha (Ellis, 1964). Hardy (1979) investigated movements of eight (native) raccoons from eastern Tennessee and found an average home range of 414.3 ha (BV). Taylor (1979) reported average home ranges of seven male and 11 female translocated raccoons in eastern Tennessee of 655.8 ha (BV) and 210.6 ha, respectively. Taylor (1979) found no significant differences between home ranges (BV) of translocated raccoons (live-trapped in western Tennessee) and home ranges of native eastern Tennessee animals. As determined from this study, home ranges (BV) in western Tennessee are smaller than those reported by Hardy (1979) and Taylor (1979), possibly reflecting higher raccoon densities and better quality habitat. Ellis (1964) found that in areas of quality habitat and high population density, raccoons moved less and occupied smaller home ranges. Densities in western Tennessee (see Leberg, 1985; Moore and Kennedy, 1985*a*; Kennedy et al., 1985; and Kennedy et al., 1986) are, in general, greater than those reported for eastern Tennessee (Minser and Pelton, 1982; Nottingham, 1985); this could account for the variation in home range estimates between the two areas. However, home ranges reported by Taylor (1979) and Hardy (1979) are larger than most home ranges found in the literature (Kaufmann, 1982) and may be somewhat misleading. Taylor (1979) presented data which indicated the influence of a year-round dog training season on the movement patterns and ranges of raccoons in eastern Tennessee. Dog training and illegal hunting reported by both Taylor (1979) and Hardy (1979) could have contributed to the larger home ranges found in their studies and may have had more influence on home range variation between areas of eastern and western Tennessee than habitat and density differences.

Stuewer (1943), Johnson (1970), Fritzell (1978), Taylor (1979), Hardy (1979), and others reported male home ranges to exceed those of females. Although male home ranges were larger than female ranges in western Tennessee, the difference was not statistically significant. Small sample sizes and large individual variation in this study may account for the inability to statistically show sexual difference in home range size.

Seasonal fluctuation in raccoon home range size has received little attention by previous investigators. The present study indicated that home range sizes vary with seasons; however, because of the low correlation between home range size and number of locations per animal ($r = -0.040$), home ranges presented in Figure 1 are probably representative of those on the study area. Although much of the seasonal home range variation was accounted for by length of photoperiod, its effect on home range size remains unclear. Summer home ranges in western Tennessee were signficantly larger than winter and fall ranges, which is contradictory to Stuewer (1943) and Johnson (1970) but is supported by Taylor (1979). Stuewer (1943) and Johnson (1970) reported increasing home range sizes as food became scarce, but their findings were based on limited data. Taylor (1979) indicated fall-released raccoons had significantly smaller home ranges than raccoons released during summer months. Taylor (1979) also reported home ranges established by raccoons released in December were significantly smaller than ranges of raccoons released in June. Larger spring and summer home ranges in western Tennessee are probably related to food availability and individual food preference. Raccoons feed extensively on aquatic invertebrates, fruits, and berries during spring and summer and often move far outside their usual range to exploit an attractive food source (Baker et al., 1945; Hamilton, 1951; Johnson, 1970). This may be a possible explanation of larger spring and summer home range sizes. Smaller home ranges in fall and winter may reflect an increased utilization of mast crops and a less selective diet. When food becomes scarce, raccoons probably utilize the most readily available food source. During the study, mast-producing species were abundant on the study area; this provided a localized food source that could be utilized with a minimum expenditure of energy. These findings, in contrast to Stuewer (1943) and Johnson (1970), indicated that smaller home ranges (or reduced foraging area) during the winter season, when food is scarce, minimize energy expenditure. This would be selectively advantageous for survival during this period.

Inhibitory effects of low temperature and snow on activity of raccoons has been reported by Stains (1956) and Cunningham (1962) and is supported by the present study. During two successive winter periods of this study, raccoons became inactive and remained within their dens as temperature dropped below freezing in conjunction with a ground cover of snow. Activity resumed as snow cover began to disappear with rising temperatures. During winter, when food supples are scarce, it would be increasingly difficult for an opportunistic ground feeder such as the raccoon to locate food supplies beneath snow cover. Surveys of the study area revealed few raccoon tracks or diggings until the snow began to melt, suggesting that activity was appreciably reduced. Intolerance of raccoons to cold temperatures and snow has been reported by Cabalka et al. (1953) and Stuewer (1943). Additionally, Johnson (1970) indicated low trap success when temperature fell below -3.8°C, and Sharp and Sharp (1956) reported that raccoons became inactive when temperatures dropped below -4.4°C.

Although raccoons in southeastern states reportedly exhibit no winter denning period (Stuewer, 1943), the present study indicated that western Tennessee raccoons are capable of denning for extended periods during adverse weather conditions. Denning behavior in western Tennessee may be related to food availability (prior to winter), and the deposition of enough subcutaneous fat to sustain the animals during short periods without food intake. However, in late winter, some raccoons on the study area had lost approximately 50% of their body weight (Moore and Kennedy, 1985*b*); this suggested that food was in short supply during this period. Additional investigation of denning behavior is needed to determine what effect food availablity and pre-winter fat deposition may have on annual denning behavior in Tennessee and other southern states.

The type den site (tree, ground) used by raccoons varies throughout its range and is dependent upon the physiographic characteristics of the region occupied. Suitable den sites must provide protection from severe weather conditions, a secure environment to raise young, and refuge from predators (Preble, 1940). High use of tree dens (74.4%) in the present study (see Figure 4) probably reflected the large number of suitable den cavities present on the study area. Taylor (1979) reported 70.0% use of tree dens, 21.0% use of ground dens, and 10.0% use of leaf nests by raccoons in eastern Tennessee. In addition, other studies conducted in southern states have shown high utilization of tree cavities as den sites (e.g., Hardy, 1979; Johnson, 1970). These

results correspond to those of the present study. While use of rocky crevices and ground burrows as den sites has been reported by Giles (1942), Shirer and Fitch (1970), Taylor (1979), and others, ground burrows were used only on few occasions in the present study; rock outcrops were not present on our study area. Greater use of tree dens in western Tennessee is probably a result of fewer ground burrows and may reflect milder winter conditions where the added protection of ground burrows would not be necessary. However, during the winter of 1973, two raccoons occupied ground dens for an extended period; this suggests that ground burrows may be chosen over tree cavities when adverse weather conditions persist. Berner and Gysel (1967) reported that preference in den sites was determined by microclimatic factors (amount of precipitation and wind allowed inside the den and stability of internal temperature).

Mech et al. (1966), Johnson (1970), Shirer and Fitch (1970), Schneider et al. (1971), and others have reported selection of squirrel leaf nests as daytime resting sites. Taylor (1979) reported raccoons in eastern Tennessee prefer leaf nests in summer since these nests are cooler and contain fewer insect pests. However, in western Tennessee, raccoons were never recorded in leaf nests. Raccoons lying in these nests would likely be subject to continual harrassment from mosquitoes during summer and fall periods.

Results of this study suggested that raccoons seldom use the same den site regularly and appeared to choose the most convenient site available in areas where nightly foraging activity ceased. Since foraging activities were highest near water, den sites were usually chosen close to water. The relationship of raccoons to water has been discussed by Leberg (1985). Taylor (1979) and Hardy (1979) reported average distances from den site to water sources of 128 m and 105 m, respectively. Beech trees were used extensively as den sites in the present study. This species was numerous on the study area and provided a large number of potential den sites. Although Stuewer (1943) reported that raccoons may not choose beech as den sites because of the difficulty of climbing the smooth, hard bark, results of the present study indicated that raccoons have little difficulty utilizing this tree species.

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