**Ecology of Raccoons at High Knob Recreation Area, Virginia**

by

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(ABSTRACT)

The ecology of raccoons (*Procyon lotor*) in High Knob Recreation Area, Virginia was studied from 1988 to 1990. Thirty raccoons were trapped and radio-collared, and 123 raccoons were collected from hunters and subsequently necropsied. Hunting was the primary cause of adult mortality. The annual survival rate was 0.54 according to a method described by Pollock et al. (1989). The finite rate of increase as calculated from life and fecundity tables was 0.929 indicating the population may have been decreasing slightly. Most raccoons examined were in good condition based on two condition indices. Good condition of these raccoons is likely related to the areas' excellent mast crops in 1988 and 1989.

Only 77% of live-trapped and 80% of hunter-collected raccoons produced litters. Lower productivity in High Knob raccoons as compared to other studies is believed to be habitat quality related. Acorns (*Quercus* spp.) and beech nuts (*Fagus grandifolia*) were the most important food items making up 29.2% and 20.8% of aggregate weight, respectively. Home range sizes were larger among males (649.1 $\pm$ 112.6 ha) and females (239.0 $\pm$ 40.0 ha) at High Knob than home range sizes reported from high quality habitats, which may reflect the poorer quality of habitat at High Knob. Home range overlap was extensive. On average, 67% of each home range was overlapped by 3 to 4 other home ranges. Activity and movements were depressed during the winter. Consistent use by raccoons of any particular forest stand type in relation to its availability was not found at High Knob. This is probably because of the homogeneity of the forest stand types. It is unlikely that raccoon populations will ever be as high at High Knob as in lowland areas due to poor habitat suitability.

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# Table of Contents

# List of Illustrations

# List of Tables

# Introduction

The raccoon (*Procyon lotor* Linnaeus) is a common, opportunistic species found throughout the United States, Mexico, and the southern provinces of Canada. Raccoons are adaptable to many changes in their environment and are known to be very tolerant to humans and their activities. Raccoons are found throughout Virginia. They are relatively numerous in coastal and Piedmont regions of eastern Virginia. However, raccoon populations west of the Blue Ridge are at much lower densities. Kellner (1953) noted that raccoons were scarce west of the Blue Ridge Mountains and in some sections of southwestern Virginia, raccoons were said to be rare or nonexistent. Desirable raccoon habitat is widely scattered and limited in size in the mountainous sections of Virginia. Differences in raccoon population densities between coastal and mountain regions are believed to be because of differences in both habitat quality and hunter harvest of raccoons. Coastal regions with an abundance of swamps, marshes, and other water bodies provide not only more water-associated foods, but also better refuge from hunters and other predators than that provided in upland habitats. Clements (1972) pointed out that Virginia mountain habitat was not conducive to maximum raccoon production. Some extensive logging operations in southwestern Virginia are also believed to have reduced adequate habitat for raccoons (McLaughlin 1953).

Raccoons are an important fur species. In the 1920's raccoon fur brought high prices, as demand was high. As raccoon fur became less popular, prices fell. Then, in the 1970's as supply was low and other furs became less available, prices rose again. Recently, prices have been dropping as popularity for "real" raccoon fur has dwindled (Kaufmann 1982). Also, the number of raccoons sold to fur dealers from 1981 to 1986 has steadily decreased. Pelt prices were around $9.87/pelt from 1981 to 1986 bringing the total value of raccoon furs sold in the state $614,753/year (Virginia Comm. Game and Inland Fish. 1987).

The raccoon is also a popular game species. Raccoon hunting is a traditional American sport dating back to the pioneers (Johnson 1970). Appalachian regions in particular have a rich raccoon hunting past. Special hunting dogs have been bred to chase and "tree" raccoons at night. In Virginia, hunters and trappers killed more than 62,000 raccoons (Virginia Comm. Game and Inland Fish. 1987) in 1986. Demand for raccoon hunting remains quite high. However, demand for raccoon hunting probably is much greater in western Virginia than it is in eastern Virginia. Thus, pressure on raccoon populations because of hunting is high in southwestern Virginia. The result of high hunter demand and low population densities of raccoons in mountainous Virginia has created a problem for both hunters and the Virginia Department of Game and Inland Fisheries. Raccoon hunters have wished to solve this problem by translocating raccoons from eastern Virginia or other states to supplement mountain populations. However, the success and economic feasibility of this technique has been questioned by many studies (Kellner 1953; Allen 1980; Minser and Pelton 1982).

Raccoons harbor a variety of parasites and disease organisms, some of which are infective to domestic animals and man. Perhaps, the most critical of these, in terms of public health, is canine distemper and rabies. The raccoon is a major rabies reservoir in the southeastern United States and is presently the critical carrier of rabies in the continuing epizootic in the mid-Atlantic region of North America (Rupprecht et al. 1989). Despite recent research into efficacy of oral vaccines, the epizootic continues.

Although raccoons have been a well studied species in many parts of the country, little is known of the movements and habitat preferences of raccoons in southwestern Virginia. Some 1950's studies are helpful in documenting potential limiting factors and describing population dynamics. Some management guidelines also were produced by these studies. However, research on the ecology of the raccoon in southwestern Virginia is essential for making accurate management decisions. Management in the past has included the stocking activities of sportsman's groups and the regulation of hunting and trapping.

The overall goal of this research was to provide quantitative data on resident raccoon population ecology in southwestern Virginia. Information on survival, reproduction, food habits, home range, movements, activity, and factors affecting raccoon abundance will make it possible to draw conclusions from which management recommendations can be made. These recommendations may result in improved raccoon management in Virginia. Specific objectives of this study were:

1. To determine factors affecting raccoon abundance in the High Knob Recreation Area, Virginia.

2. To determine characteristics of resident raccoons including survival rates, reproduction, food habits, home range, movements, activity, parasites, and disease.

3. To identify raccoon use of habitats at High Knob Recreation Area, Virginia as they relate to habitat availability.

4. To determine activity patterns of raccoons during winter months.

# Literature Review

There is an abundance of information in the literature detailing raccoon biology, ecology, and physiology. This study is fairly broad-based and will attempt to detail much of the biology and ecology of raccoons in southwestern Virginia. Aspects of raccoon ecology reviewed will include mortality, age and sex determination techniques and ratios, reproduction, parasites and diseases, food habits, activities, home range, movements, densities, winter dormancy, and habitat use.

## *Mortality*

Mortality in raccoons is primarily due to activities of humans (hunting, trapping, automobiles) and habitat deficiencies in the late winter and early spring leading to malnutrition (Whitney and Underwood 1952; Sanderson 1960; Johnson 1970). Johnson (1970) calculated a 5% juvenile (0-12 months) mortality rate between birth and the beginning of the fall hunting season. Juveniles may have higher rates of mortality during the winter because of starvation as they have less body tissue to lose during the winter. Weight losses of 50% in winter are common in Minnesota (Mech et al. 1968). Raccoons suffering from malnutrition may die of starvation, but more commonly die because of decreased resistance to parasites and diseases, predation, or a combination of these.

Whitney and Underwood (1952) reported that bobcats (*Felis rufus*), fishers (*Martes pennanti*), red foxes (*Vulpes vulpes*), and owls are all possible predators of the raccoon. In Virginia, only bobcats, red foxes, and owls have the potential to reach population levels that could result in significant predation on raccoons. Frederick et al. (1986) theorized that no one of these species seems to be an important predator of raccoons in Kentucky.

There is abundant literature on raccoon parasites and diseases. Among the endoparasites that may have significant effects on raccoon populations are dozens of species of nematodes, cestodes, trematodes, and acanthocephalans, several of which were discussed by Whitney and Underwood (1952) and Frederick et al. (1986). Raccoons also are known to be hosts to a variety of ectoparasites including ticks, fleas, and sucking lice. The only diseases known to have significant impacts on raccoon populations are canine distemper and rabies (Johnson 1970). Raccoons also are subject to toxicity from heavy metals (Hoff et al. 1977) and pollutants (Bigler et al. 1975). Parasites and diseases of raccoons will be discussed later in this paper.

Raccoons in the wild have been reported to live as long as 16 years (Johnson 1970), but most die during their first two years. Johnson (1970) found Alabama raccoons lived an average of 3.1 years. Olsen (1983) reported that life expectancy rates increased after the first year and remained at 2.0 to 2.3 years until after age 7. Mortality rates were about 50% the first year of life and declined to 36-37% by age 2 or 3 and remained low until age 7 in Massachusetts (Olsen 1983). Woods (1978) reported that Tennessee raccoon mortality rates were about 18.2% for juveniles (0-12 months), while adults in Tennessee, Michigan, and Missouri (Stuewer 1943b; Sanderson 1950; Woods 1978) experienced little nonharvest mortality.

McLaughlin (1953) reported that "raccoon habitats in mountainous sections are confined to smaller waterways and are thus more susceptible to complete coverage by hunters". McLaughlin (1953) also reported that the average harvest of 30 counties was 7.6 raccoons per hunter. Most juvenile mortality is believed to be due to hunting because of the inexperience of the juveniles (Sanderson 1950). Hunting in Massachusetts accounted for 54% of the total known mortality followed by trapping and automobile-caused deaths (both 15%) (Olsen 1983). Olsen (1983) found a 25% annual loss to hunting and trapping observed in exploited populations in Massachusetts.

## *Age and Sex Techniques and Ratios*

Sex determination in raccoons is a fairly easy technique which involves examination of the external genetalia. In the male the external urinary opening is usually > 50 centimeters anterior to the anus, whereas in the female it is not more than 26 centimeters anterior to the anus (Sanderson 1950). Age determination in raccoons is much more difficult and many papers exist that detail the various techniques. Stuewer (1943a) aged raccoons using ear and hind foot growth, weight, tooth wear, and teat length, but could only classify raccoons into two age classes using these criteria. Johnson (1970) found 90% of raccoons under 2.7 kg were juveniles. However, because body weight is variable in different habitats, body weight is probably not a good criterion.

Sanderson (1950) and Grau et al. (1970) found that parous adults have longer, darker teats than young-of-the-year and nulliparous adults. Sonenshine and Winslow (1972) used condition of the teats in females and pelage, body weight, and extensibility of the penis in the male to determine age-group in live-trapped raccoons in Virginia. Sanderson (1950) found that presence of unossified cartilage on the distal end of the os penis during the fall and winter marks an animal as less than one year old; also adults have more pointed os penis ends which are easily extruded through the preputial orifice. Young raccoons in their first winter can be identified by x-rays of the distal ends of the radius and ulna where the epiphysis is distinct and not fused with the shafts of those bones. Raccoons with epiphyses joined with the diaphyses were considered to be in their second or subsequent winters (Petrides 1959). Lens weights were used to determine exact month of birth for animals less than one year old and to separate adults from young-of-the-year (Sanderson 1961a). However, Grau et al. (1970) and Johnson (1970) reported that age determination using lens growth for raccoons > 12 months of age is less reliable.

During the past 15 years dental characteristics have been used widely to examine age of a variety of animals. Montgomery (1964) estimated ages of raccoons less than 110 days old by eruption of some deciduous and permanent teeth. Six age classes from 1 month to 3.5 months were categorized by tooth eruption. Stuewer (1943a) was able to separate young-of-the-year from adults by the length and wear of the upper canines. Grau et al. (1970) studied eye lens nitrogen, cranial suture closure, tooth wear, and incisor cementum layers. Tooth wear criteria divided known-aged samples into five relative age groups from 0 to 86 months, but aging of individuals by this method was found to be inaccurate. Histological sectioning of known-aged teeth was found to be the best method for observing layering in the cementum tissue. Throughout the year cellular cementum gradually builds up, faster in the summer and slower in the winter, resulting in light (summer) and dark (winter) bands. Grau et al. (1970) found that annular dark rings in cementum formed each February. This technique, although subjective, was accurate for aging individuals through their fourth year, but underestimated the age of animals over 4 years old. This method separated raccoons into eight age classes as follows: Young-of-the-year, 1,2,3,4,5,6-7, and > 7 years (Grau et al. 1970). Lower canine teeth of raccoons were sectioned for age determination by the cementum annuli technique classifying unknown-aged animals into 10 age-classes from 0.5 to 9.5 (Frederick et al. 1986).

Sex ratios of live-trapped raccoons observed in Virginia record a bias toward males (1.64:1) (Sonenshine and Winslow 1972). Urban (1970) recorded a similar ratio of 1.87:1 in Ohio. However, these may be due to a live-trap bias toward males of the population (Urban 1970) and/or because males move around more than females, especially in the breeding season (Kaufmann 1982). Frederick et al. (1986) found a statewide average in Kentucky also biased toward males (1.39:1) Johnson (1970) presented a table showing that in six studies, raccoon sex ratios were almost even (1:1 plus or minus 0.1). In eight studies, males decidedly outnumbered females and in three studies females decidedly outnumbered males (Johnson 1970). Deviations in sex ratio from the expected 1:1 ratio may be real in different areas or may be due in part to susceptibility of males and females to trapping at various seasons of the year or because of trapping techniques.

Urban (1970) reported that the juvenile:adult ratio of live-trapped raccoons in Ohio was 1.28:1 (n = 30), however Sonenshine and Winslow (1972) found a juvenile:adult ratio of 0.2:1 (N = 82) in live-trapped raccoons of eastern Virginia. Other juvenile:adult ratios are 0.92:1 (n = 474) from hunter-collected raccoons in Massachusetts (Olsen 1983) and 0.99:1 (n = 566) from trapper-collected raccoons in Kentucky (Frederick et al. 1986). Johnson (1970) stated that latitudinal differences in age structure of raccoon populations is related to differences in greater winter mortality, productivity, and harvesting pressure in different geographical locations.

## *Reproduction*

Most females mate when they are 10 months old, producing one litter when they are one year old (Petrides 1950), while males usually do not breed until their second year. Raccoons in the northern portion of the United States tend to breed between January and March. In Virginia, Clements (1972) reported that breeding season peaks between 15 February and 15 March.

The raccoon placenta is classified as zonary and deciduate since at parturition a portion of the uterine epithelium is expelled with the placenta (Creed and Biggers 1963). Normally, there are three pairs of teats: thoracic, abdominal, and inguinal. According to two reports, Stuewer (1943b) and Sanderson (1950), the relationship between the number of young born and the number of placental scars found on the raccoon uterus is 1:1. This relationship is not prevalent in all mammals because of fetal death and resorption; however, evidence supports this relationship in raccoons. Sanderson (1950) found evidence that placental scars persist into the second year in raccoon uteri.

Average gestation is 63 days (Sanderson 1961b) with most births in Virginia occurring in late April and May. However, births have been reported as late as 15 August (Berard 1952). The breeding cycle may be modified by temperature (Sanderson 1961b) and/or lengthening photoperiod (Bissonnette and Csech 1938). The young in colder climates may be born earlier to allow for increased weight gain before the initiation of winter.

Litter sizes from one to eight have been reported; however, mean litter sizes tend to range from two to five (Kaufmann 1982). In Virginia, mean litter sizes have been reported as 4.4 ($n = 5$) (Kellner 1953) and 3.3 ($n = 11$) (McLaughlin 1953). Frederick et al. (1986) reported a mean litter size of 3.1 ($n = 38$) in Kentucky. Though there is some tendency of females in southern regions to have smaller litters, there is no really convincing geographical correlation with litter size (Johnson 1970). Reports on the sex ratio for newborn litters have not varied significantly from 1:1 (Kaufmann 1982). At birth, eyes and ear canals are closed, but usually open after 18 to 24 days. Bissonnette and Csech (1938) found protein content of the raccoons' diet before the breeding season had a marked influence on the number (%) of captive raccoons that were pregnant. McLaughlin (1953) theorized that raccoons from Tidewater regions may have a higher pregnancy percentage than those in mountainous regions because of higher protein contents of aquatic foods used throughout the Tidewater region.

Infants first leave the den and begin following their mother when she forages when they are 8 to 12 weeks old. Most infants are weaned when they are 16 weeks old (Schneider et al. 1971).

## *Parasites and Disease*

There is an abundance of literature concerning raccoon parasites and diseases. Whitney and Underwood (1952) discuss the symptoms and treatment of some of the raccoon parasites and diseases. Frederick et al. (1986) compiled a list of endoparasites, ectoparasites, and diseases reported to occur in raccoon populations and their respective references. Frederick et al. (1986) listed 57 trematode species, 8 cestode species, 53 nematode species, and 4 acanthocephalan species of endoparasites, as well as 19 species of mites and ticks, 11 species of fleas, and 7 species of lice that parasitize raccoons externally. There are also 29 types of diseases from Babesiosis to Venezualan equine encephalitis that are reported to occur in raccoon populations (Frederick et al. 1986). Stuewer (1943a) and Kellner (1953) suggested that in more southern latitudes, raccoons seldom die from parasitic infections. Raccoon deaths because of infections caused by *Baylisascaris procyonis* may occur; however this mortality is probably an insignificant portion of the total mortality acting on the population (Kazacos 1983; Frederick et al. 1986).

Frederick et al. (1986) discussed several generalities concerning the influence of ecto- and endoparasites on mortality rates in raccoon populations: (1) Parasitic infections cause an insignificant portion of total mortality in raccoon populations of southern latitudes. (2) Parasitism of either type may be a significant mortality factor in years with extreme winter conditions that act to reduce the nutritional base. (3) Mortality rates because of parasitic infections are negligible when considering the raccoon population of an entire state.

The only diseases likely to have significant impacts on raccoon populations according to Johnson (1970) are canine distemper and rabies. Canine distemper has been documented as causing epizootics in raccoon populations (Mech et al. 1968; Johnson 1970). Although apparently less common in raccoons than canine distemper, rabies sometimes causes epizootics (Kaufmann 1982). Most investigators theorized that the outbreak of rabies is most closely related to density (Frederick et al. 1986). Both rabies and canine distemper pose threats to wild and domestic animal populations and human health. The rabies outbreak in the mid-Atlantic states in the late 1980's and early 1990's is reported to have begun in the late 1970's in northern Virginia and West Virginia (Jenkins and Winkler 1987).

## *Food Habits*

The raccoon is both opportunistic and omnivorous, eating hundreds of plant and animal foods. In most habitats, plants are more important than animals in the raccoon's diet (Kaufmann 1982). Kellner's (1953) study of raccoon food habits found a shift in foods consumed from plants to animals in the late fall to early spring in western Virginia (because of increasing scarcity of plant foods during this period). Most studies show that plant foods are used more year-round, but the proportion of animal foods generally rises in the winter months (Allen 1980). Food items found by Kellner (1953) in percent frequency of occurrence are as follows in decreasing order: fleshy fruit (96%) > insects (72%) > unidentified (27%) > seeds and mast (23%) > mammals (20%) > crayfish, frogs, and snails (8%) > avian (4%). Most food taken by raccoons in late spring, summer, and fall is of plant origin. Kellner (1953) listed the ten most important specific food items of raccoons in southwest Virginia as follows: wild grape (*Vitis* spp.), grasshoppers (Orthoptera), huckleberries (*Vaccinium* spp.), acorns (*Quercus* spp.), beetles (Coleoptera), blackberries (*Rubus* spp.), wood borers (Buprestidae), cherries (*Prunus* spp.), corn (*Zea mays*), apples (*Malus* spp.). Kellner (1953) suggested that food is a limiting factor of raccoons in southwest Virginia due to (1) short growing season (2) absence of abundant aquatic foods and (3) climatological features that make fruit failure common (early frosts, absence of wind during pollination). McLaughlin (1953) also studied raccoons in southwest Virginia and found that oak acorns were an important primary food from January to March. Dutton (1987) recorded a forest overstory composition of 48.5% oak dominated, with the remainder tulip poplar (*Liriodendron tulipifera*) in the High Knob region of southwestern Virginia. He went on to suggest that oak mast production showed a cyclic pattern with peaks occurring every 7 to 8 years in this area.

Sonenshine and Winslow (1972) found that insects, particularly ground beetles (Carabidae) and water beetles (Dytiscidae) were the most important food items in an aquatic habitat of eastern Virginia. Whereas plant foods (98%), particularly corn (76.2%) were the most important food items in a Piedmont region that included marginal farming, pastureland, and woodlands (Sonenshine and Winslow 1972).

## *Activities, Home Range, Movements, and Densities*

Raccoons are nocturnal animals (Urban 1970) and tend to be most active between 1900 (81.3% active) and 0500 (74.4% active), with peak activity at 0100 (95.5% active) (Olsen 1983).

Most of the literature supports activity periods from sunset to sunrise. However, Ellis (1964) tracked five raccoons in Illinois and found movement during 74 percent of the daylight periods with an average movement of 196 meters per daylight period. Raccoons spend most of the daytime period at or near the den (Urban 1970). Olsen (1983) found raccoons more active in August and September than earlier in the year.

Raccoons are distributed in a clumped fashion. Raccoons were found to be distributed along waterways within 0 to 199 meters of the water's edge (Sonenshine and Winslow 1972). Stuewer (1943a) found the greatest distance from den site to water was 366 meters.

Raccoons are capable of long range movements over short periods of time. Lynch (1967) reported that a radio-tagged raccoon in Manitoba moved 158 air miles (264 km) in 164 days. Urban (1970) reported the average distance moved per hour (nocturnal) for all raccoons (n = 9) was 161.5 meters. Ellis (1964) reported shorter movements per hour as 118.9 meters with average daylight movements of 196 meters. Urban (1970) reported that considerable movements occurred over short time periods followed by long periods of time spent in small, shallow water areas. Schneider et al. (1971) reported that raccoons spent more time in marshes, swamps, and oak woods, whereas long movements outside the usual home range are made to frequent temporary food resources such as cornfields and/or fruit orchards.

Many authors agree that some juvenile males and females disperse from their natal home range in the fall or winter (Stuewer 1943a; Urban 1970). Schneider et al. (1971) suggested that young raccoons remain in their mother's home range until after their first winter. In the northern United States, dispersal may be delayed until spring or summer of the second year. Both juvenile male raccoons tracked by Urban (1970) moved off the study area and showed no home range pattern. Geis (1966) had two juvenile females move no more than 0.4 km, whereas three juvenile males moved 1.6 km to 4.8 km from their natal home range.

There is great variation in the home range sizes reported for raccoons. According to Kaufmann (1982) this is caused by differences in the age and sex of the raccoons reported and by differences in population density, length of study, season, habitat quality, and methods of obtaining and analyzing data. Johnson (1970) and Olsen (1983) both used telemetry to determine home range size, but Olsen (1983) only monitored animals from April to September, whereas Johnson monitored raccoons over the entire year. Stuewer (1943a) estimated home range from sighting observations and live-trapping. Urban (1970) observed raccoons in the fall and spring using telemetry. Most of the maximum home range diameters are between 1 and 3 km, with a few up to 6.4 km (Stuewer 1943a; Urban 1970; Johnson 1970; Schneider et al. 1971). Juvenile males are reported to have home ranges of 49 ha (Johnson 1970). Juvenile females have reported home range sizes of 46 ha (Johnson 1970). Olsen (1983) reported that juvenile raccoons had home range sizes of 78 ha. Adults generally have larger annual home range sizes as reported by Schneider et al. (1966) ranging from 1.6 to 4 km in diameter. Adult males generally have larger home ranges than adult females, and may temporarily expand their ranges during the mating period to visit several females. Female home ranges on the other hand are restricted the first few weeks after their litters are born (Kaufmann 1982). Johnson (1970) and Olsen (1983) reported adult male home range sizes as 99 ha and 186 ha respectively. Olsen (1983) reported adult females as having home range sizes of 135 ha. Total home range sizes of raccoons in hectares as reported by Ellis (1964), Urban (1970), and Olsen (1983) are as follows: 11-77 ha (average 36.5 ha), 48.4 ha, and 138.6 ha respectively. In general most home ranges in the literature vary between 40 and 100 ha; however larger home ranges have been reported. Fritzell (1978a) reported home ranges averaging between 656 ha and 2560 ha depending on sex and age in North Dakota. Butterfield (1944) found average distances moved were 0.4 km with a maximum of 1.6 km. Adult males, but not adult females, were found to be territorial (Johnson 1970; Schneider et al. 1971); however mutual isolation does exist between neighboring females (Schneider et al. 1971).

Densities, as with home ranges, vary for the same reasons (habitat quality, season, etc.). Sonenshine and Winslow (1972) found eastern Virginia raccoons with densities of 1.04 to 0.07 raccoons per hectare (mean 0.42 raccoons/ha.). Leberg and Kennedy (1988) found Tennessee raccoon densities varied between 0.18 raccoons per hectare in mature bottomland forest to 0.01 raccoons per hectare in a pine-deciduous forest stand. Leberg and Kennedy (1987) found raccoon densities ranging from 0.19 to 0.06 raccoons per hectare in bottomland and bluff shoreline habitat and densities supported in upland-hardwood and pine-hardwood varying between 0.03 and $< 0.01$

raccoons per hectare. Minser and Pelton (1982) also studied raccoons in Tennessee and found densities varied between 0.04 and 0.06 raccoons per hectare. Frederick et al. (1986) found Kentucky raccoon densities varied between 0.01 raccoons per hectare after the harvest and 0.02 raccoons per hectare before the harvest.

## *Winter Dormancy*

Variation in seasonal activity cycles occurs depending on latitude. Kaufmann (1982) mentioned that in northern latitudes, where permanent snow cover and subfreezing temperatures are common throughout the winter, raccoons may typically sleep for several months in den trees or other sheltered sites. He went on to say that in northern portions of the United States inactivity may last from November until February, March, or early April. However, he did not mention a source or reference from which this information came. In southern states raccoons are active throughout the winter based on telemetry recordings, except for occasional periods of several days when temperatures are unusually low (Johnson 1970). Leberg and Kennedy (1987) found highest visitation to scent stations in June and July and lowest in December and January. Similarly, Sumner and Hill (1986) reported that visitation to scent-stations from November through March was one-third less than visitation frequencies from April and October. Moore and Kennedy (1985) speculated that in most cases, low visitation rates in winter reflected reduced raccoon abundance due to hunting and trapping and diminished movements because of colder ambient temperatures. Some authors agree that the appearance of permanent snow cover is more important than low temperatures in initiating dormancy (Stuewer 1943a; Mech and Tarkowski 1966).

Sharp and Sharp (1956) considered low temperatures ( $< 24°$ F) to be the controlling factor inducing periods of semihibernation in the population. Adult raccoons were inclined to "lay-up" during periods when temperatures were 24° F or lower at nightfall, but some animals remained active. However, Sharp and Sharp (1956) concluded that snowfall before mid-February induced a stimulus to semihibernate of greater intensity than that resulting from snowless periods of subzero temperatures.

Morrison (1960) stated that fat reserves in mammals within the size range of badgers (*Taxidea taxus*) would not be enough to sustain animals over a winter season without a substantial reduction in metabolism. However, Harlow (1981) concluded that there is little need for extensive hypothermia in mammals of this size because of their relatively large body mass and fat reserves.

## *Habitat Use*

The distribution of the raccoon extends across southern Canada from British Columbia to Nova Scotia and throughout the United States, Mexico, and Central America except for portions of the northern Rocky Mountains and the Baja strip. Raccoon abundance in relation to habitat type has been studied in several southern states. Leberg and Kennedy (1982) and Minser and Pelton (1988) found highest densities and proportions of juveniles and females occurred in bottomland deciduous forests and the lowest densities were found in upland, pine-deciduous forests.

Cadwell (1963) found raccoon use of habitats in Florida as follows (in decreasing order): swamps, farmlands, hammocks, sandhills, and flatlands. Raccoons of southern West Virginia are generally associated with farmlands and wetlands (Allen 1980). Olsen (1983) tested habitat use by Massachusetts' raccoons in proportion with habitat type occurrence and found that raccoons selected shallow freshwater wetlands and, where available, agricultural lands (primarily corn fields). Olsen (1983) also reported exploited raccoons under-used small softwood forests and larger mixed wood forests while over-using intensive agricultural areas, whereas unexploited raccoons under-used larger softwood forests and larger hardwood forests. Olsen (1983) recorded exploited raccoons as having shifted from wetlands to agricultural lands. However, Fritzell (1978a) found raccoons selecting buildings, woodlands, and wetlands in that order, over cultivated areas, pasture, and open fields.

Urban (1970) found that Ohio raccoons used marsh areas 50.6% of the time and dikes near the marshland 38% (fall) to 35% (spring) of the time, where 87% of the habitat was marshland. The study area made up of 50% shallow water had 73% of nightly foraging in these areas. Muskrat houses were used extensively as dens by 89% of the radio-tagged raccoons. Raccoon densities studied by Leberg and Kennedy (1988) were found to be 2 to 11 times higher at a site that was associated with permanent water. Similarly, low raccoon populations in a Piedmont study area in Virginia was thought to be due to the lack of aquatic habitat (83% of raccoon captures were within 30 meters of the water's edge) (Sonenshine and Winslow 1972). Crawford (1950) suggested that raccoon densities may be related to soil fertility. Thus, in unglaciated areas such as Kentucky and Virginia where soil fertility is low, raccoon densities should be lower than those found in the glaciated Midwest. Stream quality also seems to be important, especially in coal mining areas, which often produce acidic streams that are not conducive to plant and animal life (Allen, 1980).

Many studies have noted the importance of water as a source of food and refuge for raccoons (Johnson 1970; Minser and Pelton 1982). Similarly, deciduous trees provide den sites and foods, such as mast (Johnson 1970). Cropland and bottomland habitat often sustain raccoon populations in years of low mast production. During these periods, raccoons switch from a mast diet to unharvested grain or aquatic-based food. As oak mast is considered to be essential to high raccoon survival, extensive clear-cutting of hardwood forests along with their conversion to pine plantations or pasture will likely cause reductions in raccoon populations, because of a reduced acorn crop (Johnson 1970).

Raccoons use a variety of shelters for den sites. Hollow trees are most commonly used as winter dens (Stuewer 1943a). Other authors have reported ground beds in cattail marshes, muskrat houses, caves, ground dens, and cracks in rocks. Abandoned buildings also are used by raccoons as den sites (Garner, pers. commun. 1989). However, according to many authors, raccoons prefer den trees, particularly when within 400 meters of a permanent water supply. When den trees are not available, ground burrows dug by foxes (*Urocyon cinereoargenteus* and *Vulpes vulpes*), groundhogs (*Marmota monax*), and skunks (*Mephitis mephitis*) are used as den sites. Sleeping sites and dens may be anywhere in the home range. Kellner (1953) found that den trees were quite abundant in southwestern Virginia and were therefore not considered to be a limiting factor. McLaughlin (1953) found chestnut oaks (*Quercus montana*) between 30 and 91 centimeters dbh (because of their high acorn production and their potential to be used as den sites) to be the most important cover type for raccoons in Craig county, Virginia. Raccoons may shift their sleeping sites daily during most of the year; however some sites are used more than others (Mech and Tarkowski 1966). Winter dens are also sometimes changed; however this is not as common.

>12 in DBH -> index 5
(scale 1->5)

10-12 - 4

9 - 3

8 - 2

7 - 1

<7 - 0

# Study Area

The 12,500 ha High Knob study site (Figure 1) is located on the Clinch Ranger District of the Jefferson National Forest in southwestern Virginia. It is 8 km southeast of Norton, Virginia on the southern section of Wise County and the northern section of Scott County. Seventy-one percent of High Knob is owned by the U. S. Forest Service (USFS) and 29% is privately-owned land. Elevation ranges between 457m and 1269m. The topography is dominated by steep slopes and numerous ridges and valleys.

There are many streams and ponds throughout the study site that vary in depth between 2.5 and 61 cm (approximately). Stream substrates are high in sand, clay, gravel, and rocks. Many of the first order streams may be seasonal (drying in the fall). The soils found on the High Knob area are shallow to moderately deep, excessively drained, and are characterized as loamy, with an average pH of 4.6 (Dutton 1987). The USDA (1985) reports that approximately 85% of the soils have a moderate to high productivity potential for tree growth. However, the soil pH is abnormally low at High Knob.

The High Knob area is dominated by deciduous hardwood species. Yellow poplar--white oak--northern red oak (*Liriodendron tulipifera--Quercus alba--Q. rubra*) and white oak--northern red oak--hickory (*Carya* spp.) forest cover types composed 27.3% and 40.3% of the area, respectively, according to USFS forest stand data. But according to Dutton (1987) nearly all of the

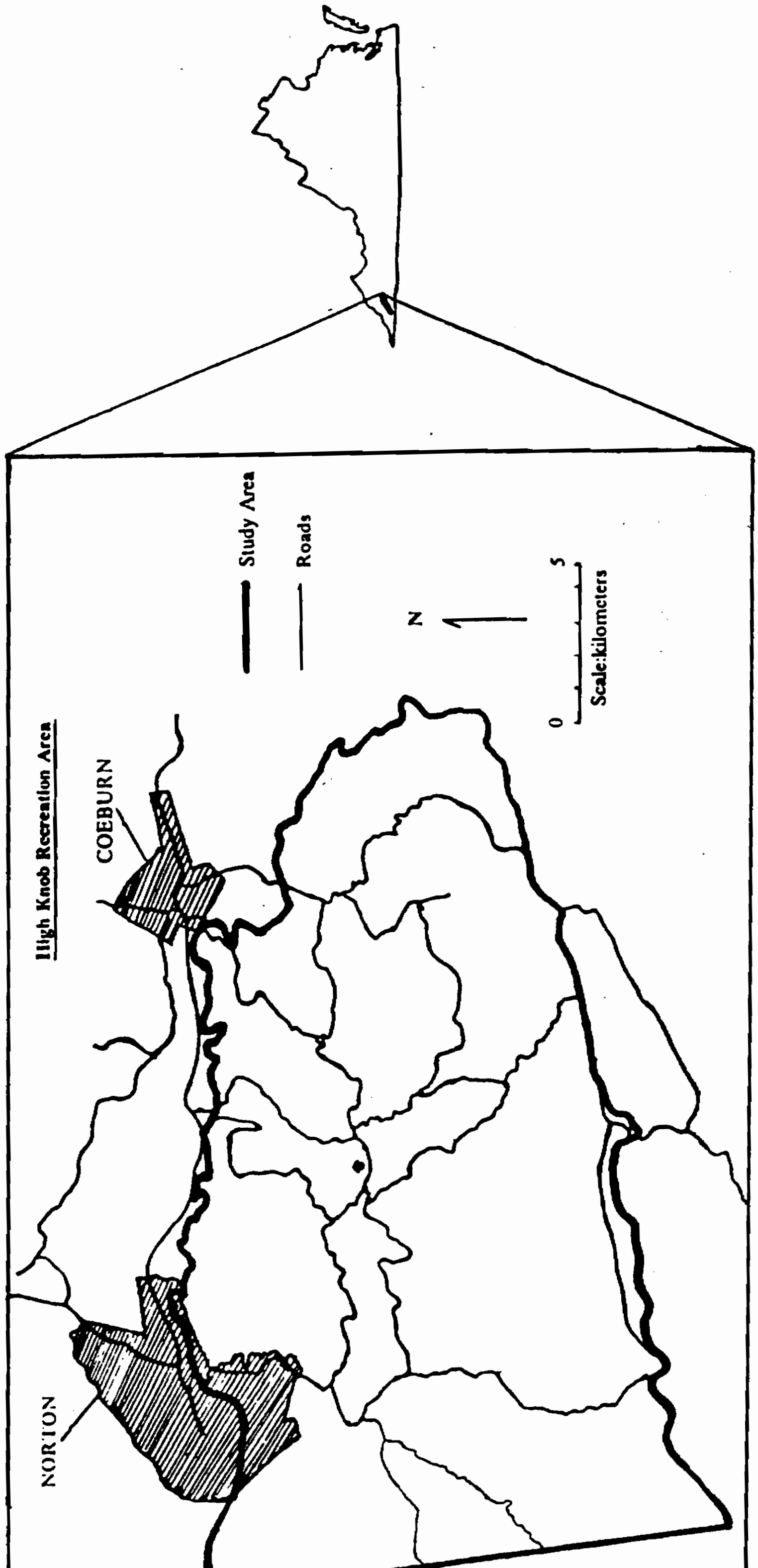


**Figure 1.** Clinch Ranger District, Virginia, 1990.

stands designated yellow poplar--white oak--northern red oak were dominated by yellow poplar. Within these stands at least 70 % of the dominant and co-dominant crowns are hardwoods. Other stand types in the area included sugar maple--beech--yellow birch (*Acer saccharum--Fagus grandifolia--Betula alleghaniensis*) and white pine (*Pinus strobus*) each covering about 1% of the study area. Scarlet oak (*Q. coccinnea*) and northern red oak stands together covered only 1% of the area. Chestnut oak--scarlet oak (*Q. prinus*) stands made up less than 1% of the area, but were common on harsh, southwesterly facing slopes. Small stands of yellow poplar, pitch pine (*Pinus rigida*), and hemlock (*Tsuga canadensis*) also were included on the study area. Rhododendron (*Rhododendron maximum*) and mountain laurel (*Kalmia latifolia*) are common understory plants particularly along stream banks and southwesterly facing slopes. Ferns were also a common understory plant from March to October.

Virtually all of the High Knob area has been harvested for timber since the mid-1800's. Between 1977 and 1983 between 0 and 132 ha of timber were harvested at High Knob (Dutton 1987). From 1983 to 1986 harvesting of timber increased steadily from 132 ha to 263 ha. However, the timber harvest dropped considerably between 1986 and 1990 (Figure 2) in the High Knob region. Hunting, fishing, and other recreational activities are common on the Clinch Ranger District (Verlon Smith 1989, pers.commun.).

The mean annual maximum and minimum temperatures from 1988 to 1989 were 24.4° C and -3.7° C, respectively (NOAA 1988-1990) (Table 1). Mean average temperature during the study period (May 1989 - June 1990) was 12.9° C. Total precipitation during the study period was 194.1 cm and total snowfall during this period was 109.7 cm. During the winter, temperatures usually range between -8° C and 13° C and there are approximately 25 days with snow accumulations (Dutton 1987).

A variety of agricultural areas, small towns, and forested regions surround the study area. To the north, Norton, Wise, and Coeburn are along Rt. 58 (Alt.) with considerable urban development. Recreation areas and small agricultural fields lie to the east. Portions of the mostly forested Clinch Ranger District are south and west of the study area.

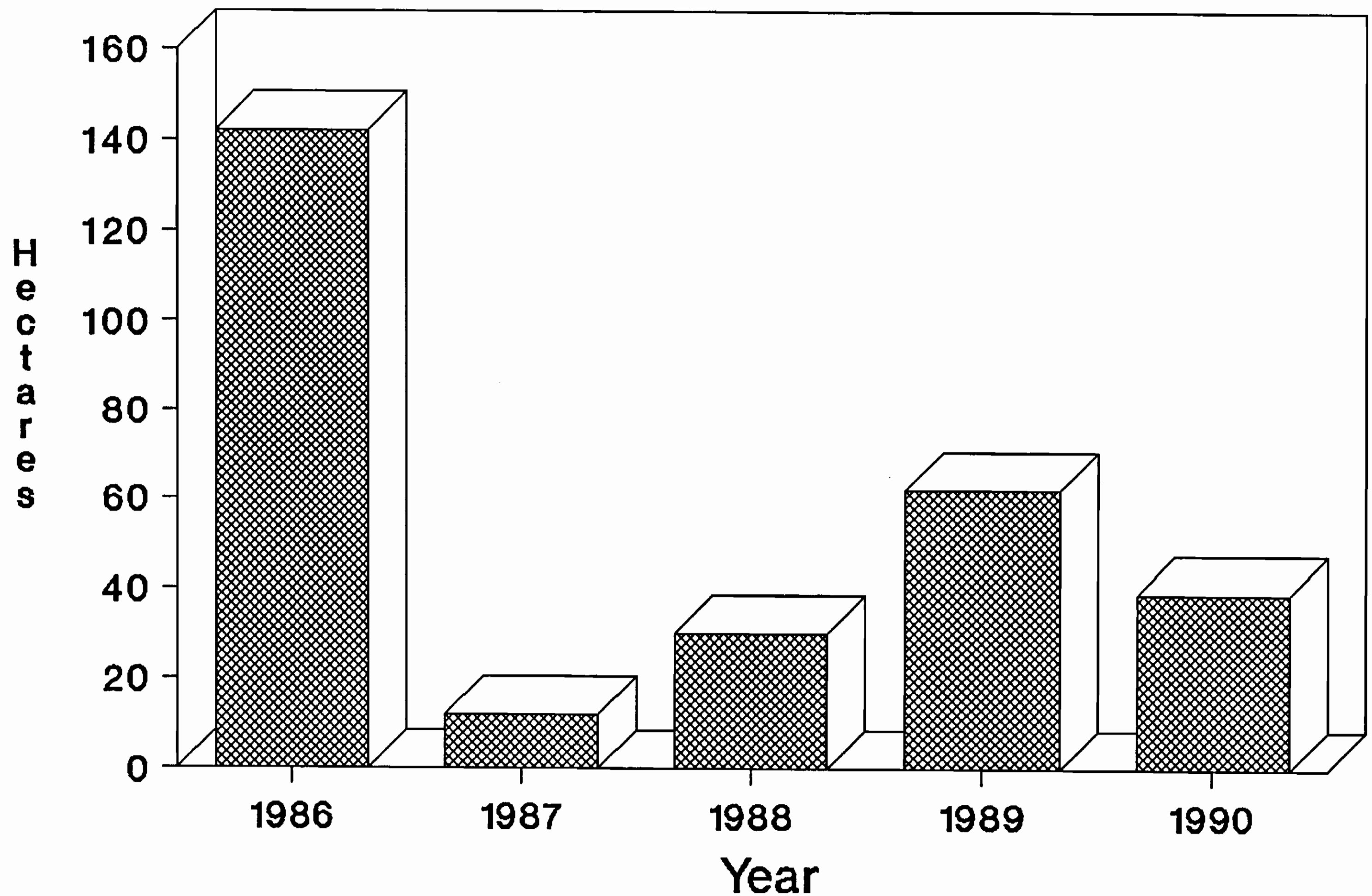


**Figure 2.** The number of hectares harvested within the High Knob Recreation Area from 1986 to 1990.

**Table 1.** Weather patterns around High Knob Recreation Area, Virginia over the duration of the study period, 1989-1990.

| Month | Temperature (C°) Mean | Maximum | Minimum | Total Precip (cm) | Total Snowfall (cm) | Maximum Snow depth (cm) |
|---|---|---|---|---|---|---|
| May 1989 | 13.7 | 27.2 | -2.2 | 16.9 | 8.4 | 2.5 |
| June | 19.4 | 28.9 | 9.4 | 29.5 | 0.0 | 0.0 |
| July | 21.6 | 30.0 | 12.2 | 16.3 | 0.0 | 0.0 |
| August | 21.0 | 28.9 | 6.7 | 18.5 | 0.0 | 0.0 |
| September | 17.4 | 27.8 | 0.0 | 19.1 | 0.0 | 0.0 |
| October | 13.2 | 26.1 | -2.2 | 12.0 | 2.8 | 0.0 |
| November | 7.3 | 22.1 | -9.4 | 10.6 | 16.0 | 0.0 |
| December | -3.2 | 15.6 | -23.9 | 5.9 | 37.3 | 15.2 |
| January 1990 | 4.9 | 16.7 | -10.6 | 8.0 | 11.9 | T |
| February | 7.2 | 20.6 | -12.8 | 13.0 | 7.9 | 5.1 |
| March | 9.4 | 25.0 | -7.8 | 9.1 | 11.7 | 7.6 |
| April | 12.3 | 28.3 | -7.8 | 10.3 | 13.7 | T |
| May | 16.3 | 24.4 | 5.3 | 15.5 | 0.0 | 0.0 |
| June | 20.2 | 28.3 | 8.9 | 9.4 | 0.0 | 0.0 |

* All weather data is based on National Weather Service information collected in Wise, Virginia (elevation 783 m).

T = ( < 0.05 cm)

# Materials and Methods

Trapping began 10 May 1989 and continued until 15 September 1989. Live raccoons were captured using collapsible Tomahawk 207 live-traps (25x30x81 cm) (Tomahawk Trap Co., Tomahawk, WI). Traps were baited with a fruit and corn-based bait paste (Mike Marsyada, W. Hazelton, PA) and/or sardines. Frederick et al. (1986) found systematic grid distributions of traps (14.5 ha) both unsuccessful and time inefficient in mountainous areas of Kentucky. Raccoons tend to be clumped in distribution and located along waterways (Sonenshine and Winslow 1972); therefore trap distribution corresponded with streams, ponds, and marshes. Traps were set no closer than 0.1 mile apart (0.16 km). On average, 37 traps were set per night. Traps were checked every morning to allow afternoon processing of any raccoons captured. Traps were moved periodically (approximately every 4 to 7 days) to distribute trapping pressure over a wider area.

Each live-trapped raccoon was sedated with ketamine hydrochloride (Ketaset) (Frederick et al. 1986; Garner 1987; Kreeger 1987) at a dose level of 18-22 mg/kg (0.1 cc/lb) of body weight. On chemical restraint, an opthalmic ointment (Bacitracin) was administered to prevent possible eye damage (Bigler and Hoff 1974). Raccoons were individually numbered using aluminum rototags (Natl. Band and Tag Co., Newport, KY) placed in both ears. Thirty of the live-trapped raccoons also were radio-collared using radio transmitters (150-152 MHz, Advanced Telemetry Systems, Isanti, MN) with activity sensors attached to a medium mammal collar. Mercury switch activity sensors were activated by head and neck movement triggering changes in signal rate. Raccoons were considered active if signal rate changed more than three times during observations which lasted between 1 and 5 minutes (approximately). Movement of raccoons was calculated using radioed observations. All consecutive observations taken in $< 24$ hours of each other were used as reference points for movement. Distance between these points and time lapsed between observations were recorded. Movement was then calculated as distance (meters) / difference in time between observations (hours). Measurements of total length, tail length, hind foot length, ear length, girth, neck and head circumference, and weight were taken. Sex was determined and information on trap location was recorded. Ticks inside the right ear were counted to give an index of tick infestation. The entire raccoon was not searched for ticks as this would be too time-consuming and too difficult to accurately measure. The condition of captured raccoons was recorded by palpating the raccoon about the pelvic girdle and rib cage as an index (subjective) of fat deposition along those areas. Raccoons were considered to be in excellent condition if the pelvis was full and layers of subcutaneous fat were easily detectable. Raccoons in good condition had full pelvic areas, but had a thin layer of fat over the pelvis and ribs. Raccoons in fair condition were bony, and their ribs and pelvic girdles felt rather sharp and defined with no fat layer detectable. Raccoons were in poor condition, if they were obviously thin and bony. Length of upper and lower canines was recorded as was tooth wear, amount of tartar, and number of broken canines. Juveniles still having deciduous teeth were noted (Montgomery 1964). For yearling and older animals, age was determined by examining teat condition and pigmentation in the females or the baculum status in the sheath (ossification of cartilage on the distal end of the os penis) for males (Stuewer 1943a; Sanderson 1950). Canine length and wear along with relative body size also were used to separate animals into different age groups (Stuewer 1943a). Female teats were checked for signs of lactation. Nontarget species that were trapped were immediately released and were not handled.

Carcasses were collected from hunters in Wise, Scott, and neighboring counties (Dickenson and Russell) during the legal hunting season (15 October - 15 January), and frozen. Carcasses were examined later and total length, body length, tail length, hind foot length, ear length, girth, neck and head circumference, and weight were recorded. Since many of the hunter collected raccoons collected were skinned by hunters a conversion factor was used to estimate full body weight (including skin) of these skinned raccoons. This conversion factor was simply the mean difference (full body weight divided by the skinned body weight) (1.244 $\pm$0.014) between the non-skinned weights and skinned weights of 20 raccoon carcasses. The weights of the remaining 100 skinned raccoons were then multiplied by this conversion factor to get an estimate of total weights. Sex, date of death, cause and location of death also were recorded. General condition of the carcass was noted by subjective examination (palpation) and given a rating of 1 to 4 (1 = excellent, 4 = poor). This index had the same criteria as the index used on live-trapped raccoons. Kidneys with their perirenal fat attached also were used to determine the condition of the animal. The kidney fat index (KFI) is an objective index using the equation: KFI = (perirenal fat weight/kidney weight) × 100% to determine the condition of different individuals (Riney 1955; Kirkpatrick 1980). Female reproductive tracts were removed and fixed in 10% formalin. Later these tracts were examined for placental scars to determine litter size.

Stomachs were removed at necropsy and contents were placed in 10% formalin. Stomach contents were washed later with water in a #30 sieve with an opening size of 0.0234 in (0.6 mm) to separate unequal-sized particles, The contents then were separated into different groups and identified to species or lowest taxa possible. After separation individual food items were oven-dried and weighed (to the nearest .0001 gm). Food items were expressed as frequency of occurrence, percent of occurrence, dry weight, and aggregate percent of dry weight.

Carcasses also were examined for obvious signs of disease or extreme parasitism. Organs were checked for necrosis or edema. The intestinal tract from the duodenum of the small intestine to the distal portion of the colon was opened longitudinally and examined for endoparasites. No quantitative measures of parasites were pursued; only qualitative recordings of different types of parasites. Parasites collected were only those able to be seen by the naked eye. Other organs such as the heart, lungs, liver, and kidneys also were examined for signs of disease, parasitism, or necrosis caused by toxicity. All parasite samples were preserved in 10% formalin.

Raccoon skulls were separated from the body and frozen. Later, skulls were placed in a hot water bath (70°- 80° C) for several hours. Lower canines then were extracted and sent to Matson's

Laboratory (Milltown, MT) for aging. Aging was performed by examining the cementum annuli rings on the teeth as reported by Grau et al. (1970).

Raccoons were selected for radio-collaring based on age (only adults were selected) (Garner 1988, pers. commun.). Radio-receivers (TR-2 receiver and TS-1 scanner/programmer, Telonics, Mesa, AZ) were used with a hand held 2 element antenna (RA-2AK, Telonics) and an omni-directional truck-mounted antenna (RA-5A, Telonics). Radio transmitters with activity sensors operated at 150-152 MHz. Raccoons were located sporadically up until 15 June 1989 because trapping activities dominated available time. Raccoons were intensively monitored between 16 June 1989 and 2 March 1990. Raccoons were located once during the day and once at night for four consecutive days and nights every other week from 16 June to 21 July 1989. Raccoons then were located once during the day and once at night for three consecutive days and nights every other week from 21 July 1989 to 2 March 1990, except during the 1989 deer hunting season (20 November to 3 December). Finally, raccoons were located once during the day and once at night for three consecutive days and nights every month from 2 March till 27 April 1990. Raccoon activity continued to be recorded once per month for May and June 1990 to get estimates on survival. Locations were observed primarily (99%) between 1000 and 2400 hours. Locations were initially plotted on copies of United States Geological Survey (USGS) 1:24,000 topographic maps, using basic triangulation procedures. Peaks in signal strength were used to locate directional azimuths. The location chosen as a point was the center of the triangulated area. Date, time, and activity also were recorded. These points were then transferred to a master topographic map. The master topographic map was later digitized using AREV (Advanced Revelation, Version 1.1 by Revelation Technologies, Inc. of New York, NY) and ARC/INFO (Geographic Information System, Version 5.0 by Environmental Systems Research Institute of Redlands, CA) which assigns Universal Transverse Mercator (UTM) coordinates to each point.

All home ranges were determined using Telem (Coleman and Jones 1986). Home ranges were determined by the convex polygon method (Mohr 1947) and the harmonic means method (Dixon and Chapman 1980). Home range overlap was examined using ARC/INFO. Radio transmitters have an unknown effect on movements of animals. However, one must assume that this effect is minimal, if data from radio-tracked animals are to be considered valid representations of normal movements (Urban 1970).

Habitat use of specific cover types in relation to habitat availability was determined using radio-tracking data and cover type maps of the study area, respectively. The digital habitat database for the High Knob region on the Jefferson National Forest (JNF) was supplied by the Forest Service (USDA 1989) through GIS software and hardware resident at Virginia Polytechnic Institute and State University (VPI & SU). The Clinch Ranger District was the first district on the JNF to have a complete digital database. Much of this database was completed and "edited" by Kenney (1990). This database was crucial to this project since development of a spatial database is both expensive and time-consuming. No modifications were made to cover-types because of time constraints. Habitat use was examined using coordinates for radio-locations and merged with the vegetation cover map. The 132 specific vegetative communities were grouped into 6 habitats for analysis of raccoon habitat preferences. All habitat types were based on dominant canopy coverage. Actual habitat availability was determined three ways. (1) Individual raccoon habitat availability was characterized as those habitat types within each individual's home range (convex polygon) and habitat use was defined by the radio-locations for that individual. (2) Male and female habitat availability was determined by combining habitat types within all the male or female home ranges. (3) Finally, for all raccoons, a composite range determined by union of the convex polygon home ranges of 30 individuals was compiled and considered available habitat. The smallest habitat type digitized was 0.08 ha.

Raccoon radio-locations used for home range analysis and habitat preference assessment met the following criteria: one observer, most (79.4%) of the triangulated locations used 3 bearings or more, the other (20.6%) triangulated locations used 2 bearings, all night-time bearings (1800-0300 hours) were collected within 30 minutes, all bearings were separated by at least 30°. The standard deviation of bearing error averaged 4.9° ($N = 20$). Error polygon size averaged $1.5 \pm 0.9$ ha. Out of 20 trials 75% of actual locations were within the 90% error polygons determined through triangulation procedures. One would expect at least 90% of observations to fall within the 90% error polygon, but in these trials fewer actual locations than expected are observed in the error polygon. Bias estimation was calculated by the difference in degrees between the actual radio location and that determined by hand-held equipment. On average this error was $14° \pm 16°$ (N = 67). Mean ($\pm$ SD) distance of triangulated locations from true locations (hidden transmitters) was $130 \pm 140$ m (N = 20; average distance from transmitter to observer was 419 m). Mean ($\pm$ SE) distance between observer and raccoon locations in the field was $0.92 \pm 0.01$ km.

Statistical tests used for the analysis of these data were conducted using procedures within the statistical analysis system (SAS) package at VPI & SU. Statistical significance was set at $P < 0.05$ for all statistical tests. Tests used for analysis of the various data include: chi-square, Kruskal-Wallace, Wilcoxon Rank Sum, Kendall's tau, t-test, and z-test for comparing binomial proportions.

# Results

## *Population Dynamics*

### Survival and Mortality

During 10 May to 15 September 1989 I captured 30 individual raccoons 39 times. Trapping effort (38 total captures/2,348 trapnights) resulted in very low overall trapping success (1.3%; 30 initial captures/2,348 trapnights). One female raccoon not included in my trapping efforts was live-trapped by a High Knob resident within the study area on 7 July 1989 and was subsequently radio collared and included in my data set. Other animals trapped included: rabbits (*Sylvilagus floridanus*)-33; opposum (*Didelphis marsupialis*)-32; domestic cat (*Felis domesticus*)-9; woodchuck (*Marmota monax*)-5; red fox (*Vulpes vulpes*)-2; gray squirrel (*Sciurus carolinensis*)-1; domestic dog (*Canis familiaris*)-1; red shouldered hawk (*Buteo lineatus*)-1; and eastern box turtle (*Terrapene carolina*)-1.

Few juveniles were captured because of the timing of the trapping period. Trapping began in May and ended in September (with most trapping ending by mid-August). Most juveniles are born in May and do not travel with their mother until they are 6 to 8 weeks old. Juveniles stay close to the den for an additional 4 weeks. Thus, since trapping and the initiation of juvenile movements did not overlap very much only one juvenile was trapped but was not radio-collared because of collar size restrictions. The time consuming task of telemetry prevented trapping from continuing through the fall, and the chance to radio-mark juveniles.

Survival rates of radiomarked raccoons, using Pollock et al. (1989) equations, were fairly constant during the entire monitoring period (5/11/89 - 6/27/90), except during the hunting season. The survival estimate dropped considerably (Figure 3) during the first month of the 1989 hunting season as 33% (N = 30) of the radiomarked raccoons were killed (Table 2). Few deaths before or after hunting season kept survival distributions fairly constant (Table 3). Thirty raccoons that survived at least 3 weeks for a total 7,849 radio-days were included in calculations of annual survival rates (Table 4). Annual survival rates (Heisey and Fuller 1985) for these raccoons were 0.550 and 0.447 for censored-alive and censored-dead animals, respectively. Heisey and Fuller's (1985) method of survival estimation does not allow the calculation of the fate of censored (lost signal) animals; therefore two categories, i.e., censored-alive and censored-dead, were devised. Censored-alive assumes all censored animals are alive throughout the monitoring period. Censored-dead assumes all raccoons are dead when the radio signal is lost. Actual survival rates will be somewhere between these two estimates. Annual survival was similar between sexes (Table 4) and was found not significantly different using the z-test ($P = 0.49$, $z = 0.014$, $df = 28$) for both the censored-alive and censored-dead estimates. The fate of four censored raccoons is unknown. One raccoon became censored after it lost its radiocollar on 4 July 1989. Another raccoon was lost by 27 February 1990 and two other raccoon signals were lost after 26 March 1990.

Mortality occurred in 13 of the 30 radiomarked raccoons during the monitoring period (Table 2). These animals were all adults, therefore all survival and mortality estimates made on live trapped raccoons represent those of adults. Raccoon hunters were responsible for 10 (6 males,4 females) of the 13 mortalities. These 10 raccoons were killed during the first month of hunting season (17 October - 6 November 1989). No other hunting mortalities occurred during the rest of the season which extended until 15 January 1990. Automobile trauma resulted in the death of one female on

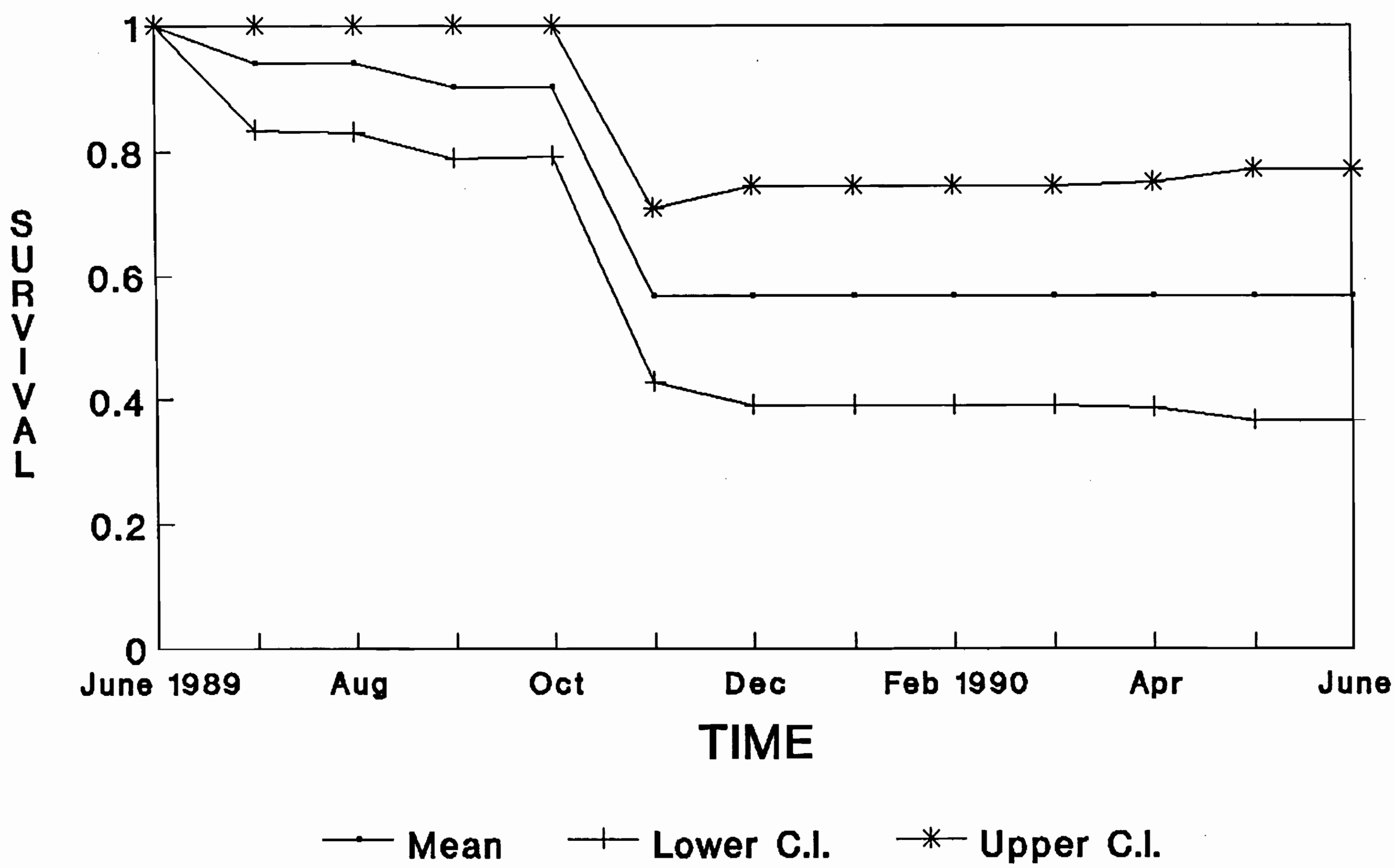


**Figure 3.** Cumulative monthly survival (Pollock et al. 1989) for raccoons within the High Knob Recreation Area, Virginia, 1989-1990.

**Table 2.** Sex, age, cause of death, and date of death of 13 monitored raccoons that died at High Knob Recreation Area, Virginia, 1989-1990.

| Animal # | Sex | Age (yrs) | Cause | Date |
|---|---|---|---|---|
| 151.421 | ♀ | 3 | Automobile | 29 June 1989 |
| 151.880 | ♂ | . | Suspected poaching | 23 August 1989 |
| 151.140 | ♂ | 1 | Hunting | 17 October 1989 |
| 151.480 | ♂ | 4 | Hunting | 18 October 1989 |
| 151.232 | ♂ | 1 | Hunting | 21 October 1989 |
| 151.160 | ♂ | . | Hunting | 23 October 1989 |
| 151.650 | ♀ | 9 | Hunting | 25 October 1989 |
| 151.740 | ♀ | 8 | Hunting | 28 October 1989 |
| 151.820 | ♀ | . | Hunting | 28 October 1989 |
| 151.940 | ♂ | 2 | Hunting | 4 November 1989 |
| 151.270 | ♂ | 2 | Hunting | 4 November 1989 |
| 151.110 | ♀ | 5 | Hunting | 6 November 1989 |
| 151.980 | ♂ | . | Unknown | March 1990 |

**Table 3.** Time-specific survival rates of raccoons in High Knob Recreation Area, Virginia as estimated by radio telemetry, 1989-1990.

| Season | Date | Survival Estimate[a] | 95% C.I. |
|---|---|---|---|
| Pre-season | 5/11/89-7/27/89 | 0.95 | 0.85-1.00 |
| Pre-season | 7/28/89-10/15/89 | 0.96 | 0.87-1.00 |
| Hunting | 10/16/89-1/15/90 | 0.63 | 0.48-0.77 |
| Post-hunting | 1/16/90-3/27/90 | 1.00 | 1.00-1.00 |
| Post-hunting | 3/28/90-6/27/90 | 0.94 | 0.82-1.00 |

[a] Estimate based on method described by Pollock et al. (1989).

**Table 4.** Survival rates of raccoons at High Knob Recreation Area, Virginia as estimated by radio telemetry, 1989-1990.

| Sex | N | Mortality | | Heisey and Fuller (1985)[c] | | Pollock et al. (1989)[d] |
|---|---|---|---|---|---|---|
| | | Censored[a] alive | Censored[b] dead | Censored alive annual survival | Censored dead annual survival | Annual survival |
| Male | 17 | 8 | 10 | 0.52 (0.33-0.83) | 0.42 (0.24-0.73) | 0.52 (0.30-0.75) |
| Female | 13 | 5 | 7 | 0.57 (0.34-0.96) | 0.42 (0.22-0.81) | 0.57 (0.27-0.87) |
| Total | 30 | 13 | 17 | 0.55 (0.39-0.77) | 0.45 (0.30-0.67) | 0.54 (0.36-0.72) |

[a] Censored-alive assumes all censored animals are alive.
[b] Censored-dead assumes all censored animals are dead.
[c] Survival rate estimates (95% C.I.) based on method described by Heisey and Fuller (1985).
[d] Survival rate estimate (95% C.I.) based on method described by Pollock et al. (1989).

29 June 1989 on a heavily traveled two lane highway (Rt. 72) east of the study area. Poaching (suspected) was the cause of another mortality (1 male) that occurred on 23 August 1989. The radiocollar was recovered under a heavy ( > 25 kg) rock in the middle of Little Stony Creek. The last raccoon (1 male) died of unknown causes sometime during March 1990. The carcass of this individual was too badly decomposed on collection to determine cause of death.

A life table (Table 5) was constructed based on information from raccoon carcasses collected from the 88-89 and 89-90 hunting seasons. The life table shows juvenile mortality similar to that of adults according to age information based on cementum annuli analysis from raccoon teeth. The age estimates were provided by Matson's Laboratory. Precision of their estimates based on 6 duplicate samples was 100%. However accuracy of their estimates was untested. Mortality rates were initially around 50%, but after age 2 or 3 mortality rates dropped to 33%-37% until age 7 or 8 when mortality rates increased again. Life expectancy estimates were low initially because of the fairly high juvenile and subadult (13-24 months) mortality, but after age 2 life expectancy increased to 2.0 to 2.2 until age 6-7.

Lotka's (1907) equation $\sum l_x \times e^{(-rx)} \times m_x = 1$ was used to determine the population increase (r), where $l_x$ = age-specific survivorship (Table 5) and $m_x$ = age-specific birth rate (Table 6). Both $l_x$ and $m_x$ were based on information from raccoon carcasses collected from the 88-89 and 89-90 hunting seasons. A FORTRAN program detailed by Caughley (1980) was used to calculate r because of the labor of the iterative process it takes to calculate r. The result was $r = -0.0736$. Converting r into the annual finite rate of increase ($\lambda$) where $r = \ln \lambda$, we get $\lambda = 0.929$, indicating that the population was decreasing by approximately 7.1% per year. Caughley (1980) expressed reservations about this process of calculating the annual finite rate of increase because one of the assumptions made in creating an age distribution is that $r = 0$. Thus, by assuming $r = 0$ one can not then calculate r. This tautology must be considered when evaluating the significance of the annual finite rate of increase calculated for High Knob raccoons. I have accepted the calculated annual finite rate of increase as representative of the High Knob raccoon population.

**Table 5.** Composite time specific life table based on cementum annuli analysis of hunter collected raccoons, 1988-1990.

| Age | % | N | Initial Size | $q_x$ | $l_x$ | $d_x$ | $L_x$ | $e_x$ |
|---|---|---|---|---|---|---|---|---|
| 0-1 | 45.5 | 55 | 121 | 0.454 | 1.000 | 454 | 773 | 1.73 |
| 1-2 | 28.1 | 34 | 66 | 0.515 | 0.546 | 281 | 406 | 1.75 |
| 2-3 | 10.7 | 13 | 32 | 0.406 | 0.265 | 108 | 211 | 2.08 |
| 3-4 | 5.8 | 7 | 19 | 0.368 | 0.157 | 58 | 128 | 2.18 |
| 4-5 | 3.3 | 4 | 12 | 0.333 | 0.099 | 33 | 83 | 2.16 |
| 5-6 | 2.5 | 3 | 8 | 0.375 | 0.066 | 25 | 55 | 1.98 |
| 6-7 | 0.8 | 1 | 5 | 0.200 | 0.041 | 8 | 37 | 1.89 |
| 7-8 | 1.7 | 2 | 4 | 0.500 | 0.033 | 17 | 25 | 1.23 |
| 8-9 | 0.8 | 1 | 2 | 0.500 | 0.016 | 8 | 12 | 1.00 |
| 9-10 | 0.8 | 1 | 1 | 1.000 | 0.008 | 8 | 4 | 0.50 |

$q_x$ = age-specific mortality rate.
$l_x$ = age-specific survivorship.
$d_x$ = number in cohort dying.
$L_x$ = mean number in cohort alive between age classes.
$e_x$ = mean life expectancy.

**Table 6.** Age-specific litter size, percent breeding, and birth rate of raccoons in Wise, Scott, Russell, and Dickenson counties, Virginia as determined from placental scars, 1988-1990.

| Age | Total Females | Parous Females[a] | % Breeding | Placental Scars $\overline{X}$ | Placental Scars SE | Age-specific birth rate[b] |
|---|---|---|---|---|---|---|
| < 1 | 28 | 0 | 0.0 | . | . | 0.00 |
| 1 | 12 | 2 | 16.7 | 3.50 | 0.50 | 0.58 |
| 2 | 5 | 4 | 80.0 | 3.75 | 0.48 | 3.00 |
| 3 | 2 | 2 | 100.0 | 2.50 | 0.50 | 2.50 |
| 4 | 2 | 1 | 50.0 | 3.00 | . | 1.50 |
| 5 | 2 | 1 | 50.0 | 4.00 | . | 2.00 |
| 6 | 1 | 1 | 100.0 | 4.00 | . | 4.00 |
| 7 | 1 | 1 | 100.0 | 3.00 | . | 3.00 |
| 8 | 1 | 1 | 100.0 | 4.00 | . | 4.00 |
| 9 | 1 | 1 | 100.0 | 4.00 | . | 4.00 |

[a] Parous females = females having evidence of pregnancy at the date of capture.
[b] Age-specific birth rate = % breeding × mean placental scars

## Sex Ratio and Age Structure

The sex ratio of the 31 radio-collared raccoons trapped during 1989 was 54.8% males and 45.2% females (121M:100F). A z-test comparing binomial proportions found no significant differences ($P = 0.35$) between the sex ratio of High Knob raccoons and that which was expected (1:1). All but one of the 31 raccoons trapped were adults (96.8%).

Sex ratio of carcasses collected was 51.2% males and 48.8% females (105M:100F, N = 121) and did not differ from 1:1 ($P = 0.42$). Sex ratio of juveniles ( < 1 yr) did not differ from an even ratio (77M:100F, $P = 0.25$, N = 55). Adult ( > 1 yr) sex ratio (N = 66) also did not differ from an even ratio (136M:100F, $P = 0.19$).

Ages of raccoon carcasses (as determined by cementum annuli) ranged from 0 to 9 years (Figure 4). Mean age ($\pm$ SE) was 1.85 ($\pm$ 0.51, N = 121). Ages of males (1.32 $\pm$ 0.24, N = 62) and females (1.30 $\pm$ 0.28, N = 59) were not significantly different, according to the Wilcoxon rank sum test (W = 3432, $P = 0.36$). The juvenile:adult ratio for raccoon carcasses was 83:100. Sex ratio did not differ ($P > 0.05$) from the expected equal ratio in any age category according to chi-square analysis for the raccoon carcasses examined (Table 7).

## Physical Characteristics

### *Length and Weight*

Live-trapped adult raccoons ranged in lengths between 73.8 and 86.0 cm and averaged 80.6 $\pm$ 0.6 cm (Table 8). Lengths and weights of radio-collared raccoons were significantly correlated ($r^2 = 0.33$, $P = 0.01$, N = 31) using Kendall's tau. Males were significantly longer ($P = 0.007$, N = 31) and heavier ($P = 0.021$) than females according to Wilcoxon rank sum test. All measurements

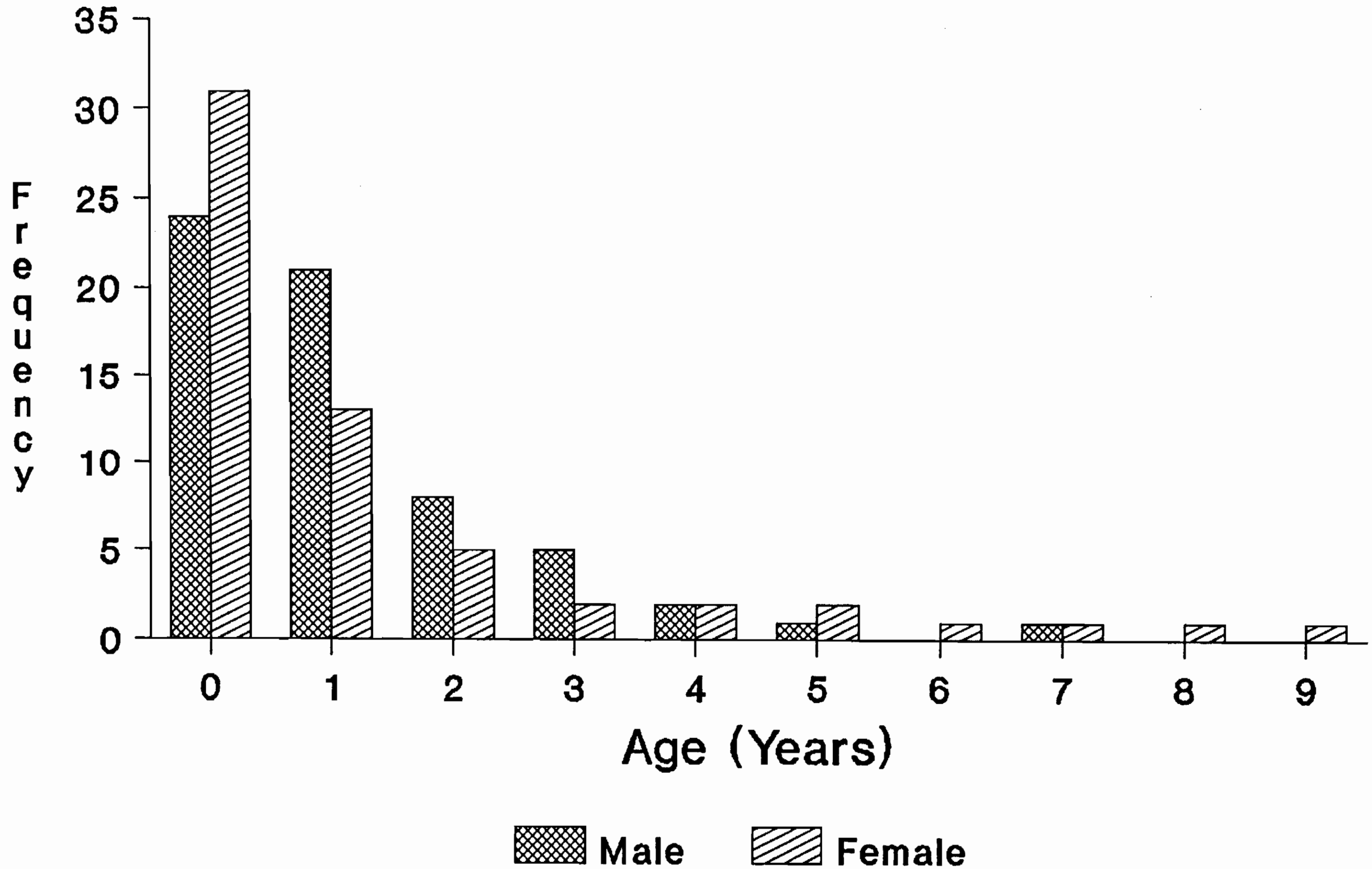


**Figure 4.** Age-frequency distribution (by sex) of raccoons collected from Wise, Scott, Dickenson, and Russell counties, Virginia, 1989-1990.

**Table 7.** Age-sex ratio of all hunter collected raccoons from Wise, Scott, Russell, and Dickenson counties, Virginia, 1988-1990.

| Age | Males | | Females | |
|---|---|---|---|---|
| (years) | % | N | % | N |
| 0 | 43.6 | 24 | 56.4 | 31 |
| 1 | 61.8 | 21 | 38.2 | 13 |
| 2 | 61.5 | 8 | 38.5 | 5 |
| 3 | 71.4 | 5 | 28.6 | 2 |
| 4 | 50.0 | 2 | 50.0 | 2 |
| 5 | 33.3 | 1 | 66.7 | 2 |
| 6 | 0.0 | 0 | 100.0 | 1 |
| 7 | 50.0 | 1 | 50.0 | 1 |
| 8 | 0.0 | 0 | 100.0 | 1 |
| 9 | 0.0 | 0 | 100.0 | 1 |
| Total | 100.0 | 62 | 100.0 | 59 |

collected from live-trapped and hunter killed raccoons including those not discussed in this paper may be found in the Appendices.

Raccoon carcasses from the hunting seasons of 88-89 and 89-90 were 49.7 to 86.4 cm in length, averaging 74.2 ± 0.6 cm (Table 8). A positive correlation was found between length and weight (Figure 5) of these carcasses ($r^2 = 0.70$) with Kendall's tau ($P < 0.001$, N = 106). Males were longer than females ($P = 0.004$, N = 107) using the Wilcoxon rank sum test. Similarly, males were significantly ($P = 0.027$, N = 120) heavier than females. Age was positively correlated with weight according to Kendall's tau ($r^2 = 0.531$, $P = 0.001$, N = 118). Age and length also were positively correlated ($r^2 = 0.513$, $P = 0.001$, N = 105). Analysis using the Kruskal-Wallace test showed significant ($P < 0.001$) differences between the weights and lengths of different age categories, but multiple comparisons using the Wilcoxon rank sum test were not possible because of insufficient sample sizes.

## *Condition Indices*

The subjective condition index given to the radio-collared and hunter collected raccoons (as determined by palpation) was originally in 4 categories (1 = excellent to 4 = poor). Sample sizes were too small with four categories, so excellent (1) and good (2) categories were combined leaving three categories (1 = good, 2 = fair, 3 = poor)

Radio-collared raccoons were in fair to good condition (1.52 ± 0.10, N = 31) on average (± SE) with only one individual rated in poor condition. Females (1.64 ± 0.13), N = 14) were in slightly poorer condition than males (1.41 ± 0.15, N = 16) on average (± SE), but this difference was not significant ($P = 0.258$) according to a Wilcoxon rank sum test. Radio-collared raccoon weights were significantly (P = 0.012) different among condition classes one and two according to a Wilcoxon rank sum test (Table 9). Condition class three was not included in the test because of its small sample size. Among the radio-collared raccoons there was no difference in condition

**Table 8.** Lengths (cm) and weights (kg) among age-sex groups for live-trapped and hunter collected raccoons in Wise, Scott, Russell, and Dickenson counties, Virginia, 1988-1990.

| Category | Male | | | Female | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | $\overline{X}$ | SE | N | $\overline{X}$ | SE | N | $\overline{X}$ | SE | Range |
| Live-trapped | | | | | | | | | | |
| Adults | | | | | | | | | | |
| Length | 17 | 81.9 | 0.6 | 13 | 78.9 | 0.9 | 30 | 80.6 | 0.6 | 73.8-86.0 |
| Weight | 17 | 4.05 | 0.12 | 13 | 3.67 | 0.14 | 30 | 3.89 | 0.10 | 2.90-5.05 |
| Hunter killed | | | | | | | | | | |
| Adults | | | | | | | | | | |
| Length | 34 | 79.3 | 0.7 | 24 | 75.9 | 0.7 | 58 | 77.9 | 0.5 | 69.2-86.4 |
| Weight | 36 | 5.48 | 0.22 | 27 | 4.97 | 0.19 | 63 | 5.26 | 0.15 | 1.55-7.86 |
| Juveniles | | | | | | | | | | |
| Length | 22 | 70.5 | 0.9 | 25 | 68.9 | 1.3 | 47 | 69.6 | 0.7 | 49.7-78.4 |
| Weight | 24 | 3.36 | 0.19 | 31 | 3.11 | 0.16 | 55 | 3.23 | 0.12 | 0.88-6.10 |

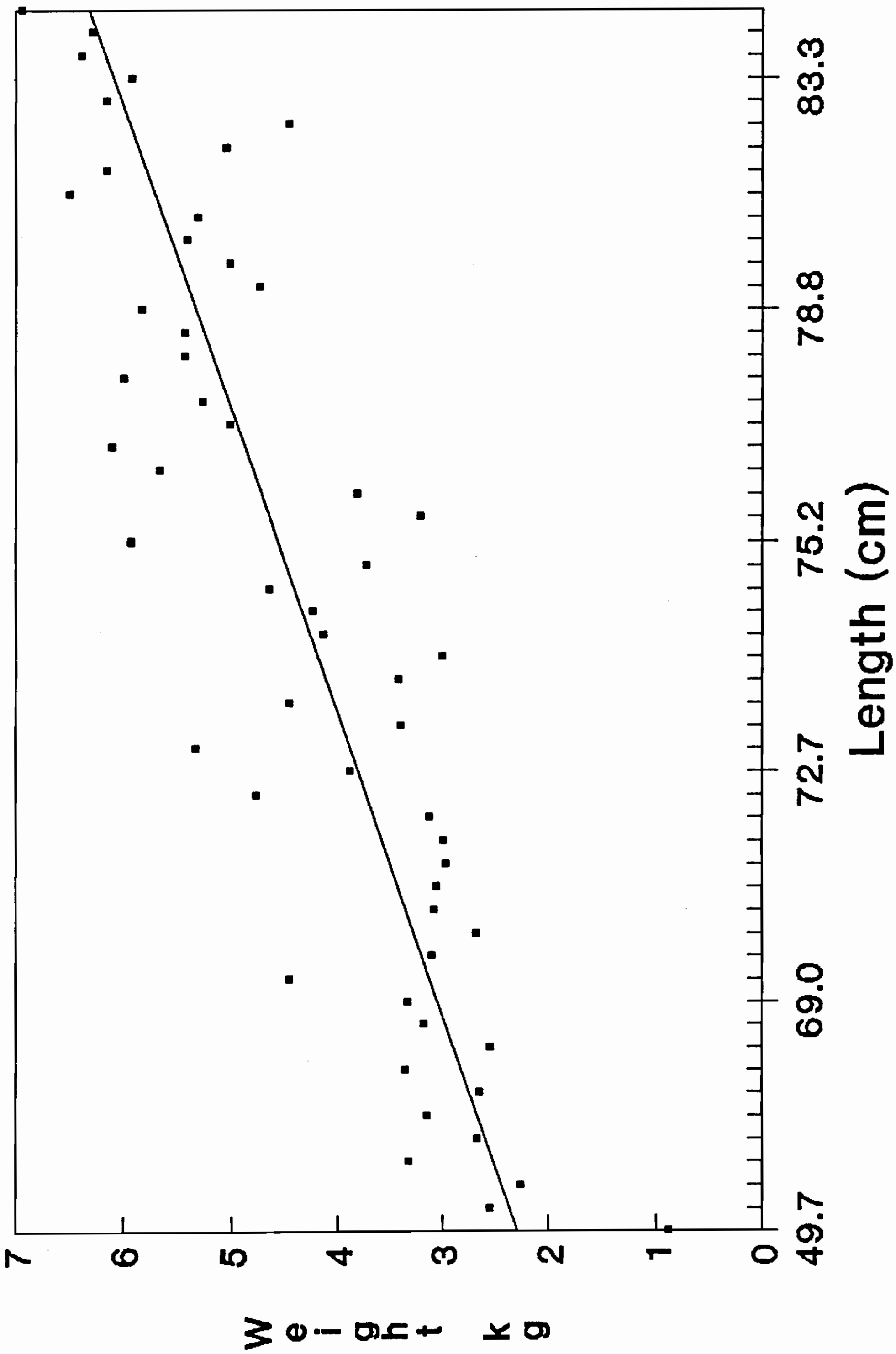


**Figure 5.** Weight (kg) versus body length (cm) of raccoons collected from Wise, Scott, Dickenson, and Russell counties, Virginia, 1989-1990. ($r^2 = 0.70$).

between the raccoons that survived and those that died during the monitoring period according to chi-square analysis ($P = 0.316$, N = 31).

Raccoon carcasses from hunters also were in fair to good condition on average (± SE) according to both the subjective condition index (1.63 ± 0.07, N = 123) and the kidney fat index (KFI) (34.02 ± 1.31, N = 110) (Table 10). The subjective condition index was closely related to KFI and weight (Table 11). Differences (Wilcoxon rank sum test) were found between KFI's ($P = 0.001$) and weights ($P = 0.005$) among all subjective condition classes, indicating that the subjective condition index is a reasonable index of condition. Weight and KFI for juvenile raccoons (Figure 6) were correlated ($P = 0.001$) according to Kendall's tau ($r^2 = 0.57$, $\tau = 0.342$, N = 50). However, adult weights and KFI's were not correlated (P = 0.586).

No differences (P = 0.337) in weight because of month (of death) were found using a three-way ANOVA which included sex and age variables (Table 12 and 13). Males were heavier (P = 0.001) than females and adults were heavier (P < 0.001) than juveniles according to the three-way ANOVA. All interactions among independent variables (weight = dependent variable) had P-values > 0.05 except sex*month (P = 0.002). Differences (P < 0.001) were detected in KFI among month (of death) using a three-way ANOVA which included sex and age variables. No significant (P > 0.05) interactions among independent variables were found, except age*month according to a three-way ANOVA. Duncan's multiple range test (sex and age combined) showed KFI's of raccoons killed in October significantly lower than those of raccoons killed in other months. Small sample size and age*month interaction makes this result difficult to interpret. No difference (P = 0.256) in KFI was found because of sex, but adults had higher KFI's than juveniles (P < 0.001).

## Reproduction

Among the 13 adult female raccoons captured during live-trapping 76.9% had produced litters as judged by the presence of milk in the teats. These females were considered to be parous. Parous

**Table 9.** Weight and subjective condition index for radio-collared raccoons of High Knob Recreation Area, Virginia, 1989-1990.

| Condition Index | Weight | | |
|---|---|---|---|
| | N | $\overline{X}$ | SE |
| 1 | 15 | 4.15 | 0.14 |
| 2 | 14 | 3.63 | 0.11 |
| 3 | 1 | 3.43 | . |

Wilcoxon rank sum test for condition class 1 and 2, $P=0.012$.

**Table 10.** Kidney fat indices of hunter collected raccoons in Wise, Scott, Russell, and Dickenson counties, Virginia, 1988-1990.

| Category | Male | | | Female | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | $\bar{X}$[1] | SE | N | $\bar{X}$[1] | SE | N | $\bar{X}$ | SE |
| KFI | | | | | | | | | |
| Juvenile(< 1yr) | 22 | 29.86 | 2.94 | 28 | 31.19 | 2.65 | 50 | 30.60 | 1.95 |
| Adults(≥1yr) | 33 | 34.05 | 1.87 | 25 | 40.56 | 3.14 | 58 | 36.85 | 1.76 |
| Total | 57 | 32.55 | 2.12 | 53 | 35.61 | 1.58 | 110 | 34.02 | 1.31 |

[1] No significant Sex*Age interaction, P = 0.173.

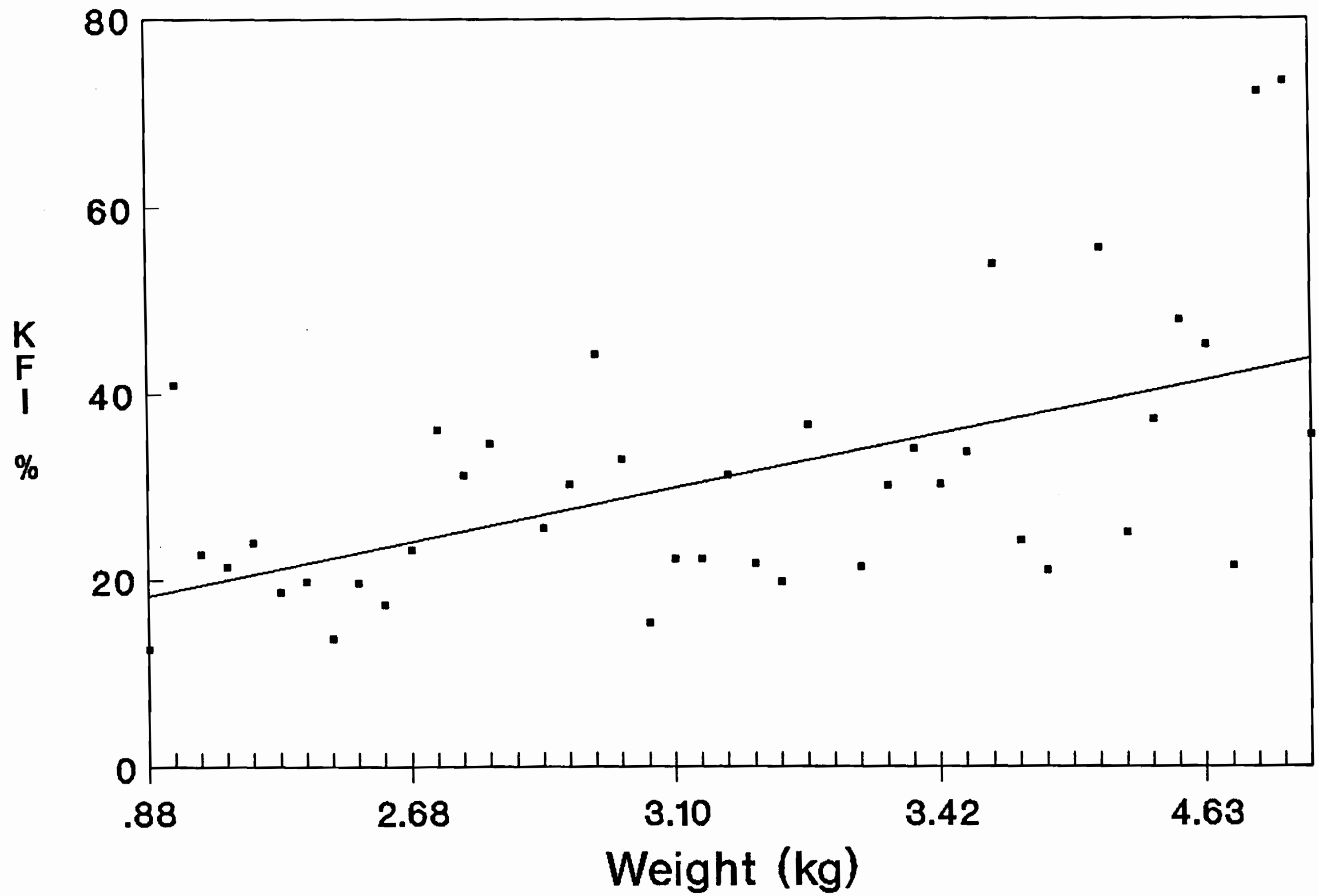


**Figure 6.** Relationship between weight (kg) and kidney fat index (%) for juvenile raccoons collected from Wise, Scott, Dickenson, and Russell counties, Virginia, 1989-1990. ($r^2 = 0.57$).

**Table 11.** Subjective condition index, kidney fat index (KFI), and weight for hunter collected raccoons in Wise, Scott, Russell, and Dickenson counties, Virginia, 1988-1990.

| Condition Index | KFI(%) | | | Weight(kg) | | |
|---|---|---|---|---|---|---|
| | N | $\overline{X}$ | SE | N | $\overline{X}$ | SE |
| 1 | 60 | 41.44 | 1.62 | 65 | 5.05 | 0.16 |
| 2 | 30 | 28.68 | 1.73 | 33 | 3.82 | 0.21 |
| 3 | 20 | 19.77 | 1.21 | 22 | 2.91 | 0.22 |
| Wilcoxon rank test | | $P < 0.001$ | | | $P < 0.005$ | |

**Table 12.** Weight and physical condition index (KFI ± SE) of hunter collected male raccoons by age and month in High Knob Recreation Area, Virginia, 1988-1990.

| Category | Weight(kg) | | | KFI(%) | | |
|---|---|---|---|---|---|---|
| | N | $\overline{X}$ | SE | N | $\overline{X}$ | SE |
| October | | | | | | |
| Juvenile | 6 | 3.07 | 0.15 | 6 | 22.63 | 3.49 |
| Adult | 9 | 5.49 | 0.29 | 8 | 25.18 | 3.73 |
| November | | | | | | |
| Juvenile | 6 | 3.00 | 0.25 | 6 | 24.63 | 3.18 |
| Adult | 5 | 5.74 | 0.29 | 5 | 44.30 | 3.29 |
| December | | | | | | |
| Juvenile | 4 | 4.74 | 0.72 | 4 | 46.04 | 9.24 |
| Adult | 8 | 6.02 | 0.55 | 7 | 36.89 | 3.14 |
| January | | | | | | |
| Juvenile | 5 | 3.10 | 0.17 | 3 | 33.93 | 5.41 |
| Adult | 9 | 4.99 | 0.55 | 8 | 31.93 | 2.42 |

**Table 13.** Weight and physical condition index (KFI $\pm$ SE) of hunter collected female raccoons by age and month in High Knob Recreation Area, Virginia, 1988-1990.

| Category | Weight(kg) | | | KFI(%) | | |
|---|---|---|---|---|---|---|
| | N | $\bar{X}$ | SE | N | $\bar{X}$ | SE |
| October | | | | | | |
| Juvenile | 9 | 3.00 | 0.14 | 8 | 22.35 | 2.37 |
| Adult | 9 | 5.03 | 0.45 | 10 | 31.39 | 4.32 |
| November | | | | | | |
| Juvenile | 5 | 2.98 | 0.16 | 5 | 27.38 | 4.85 |
| Adult | 5 | 4.73 | 0.25 | 5 | 47.17 | 8.22 |
| December | | | | | | |
| Juvenile | 7 | 2.86 | 0.37 | 5 | 32.76 | 7.19 |
| Adult | 1 | 5.61 | . | 1 | 27.80 | . |
| January | | | | | | |
| Juvenile | 7 | 3.12 | 0.37 | 7 | 34.35 | 4.39 |
| Adult | 11 | 5.01 | 0.27 | 9 | 48.50 | 3.88 |

females are defined here as those females that have evidence of pregnancy at the date of capture or from the year preceding. Those females not lactating were considered to be nulliparous. Live-trapped parous females (3.73 ± 0.18 kg) weighed (X ± SE) on average slightly more than nulliparous females (3.47 ± 0.17 kg), but this difference was not significant ($P = 0.35$, N = 13) according to the Wilcoxon rank sum test. No significant differences ($P > 0.25$, N = 13) were found between the subjective condition index (X ± SE) of parous (1.60 ± 0.16) and nulliparous females (2.00 ± 0.0) among the live-trapped raccoons.

Placental scars were found in 51.9% (N = 27) of adult (≥13 months) uteri examined among the raccoon carcasses collected from hunters. The mean (± SE) litter size based on placental scars per parous female was 3.53 (± 0.20). The number of placental scars ranged from 2 to 5 among the raccoon carcasses collected. Only 16.7% (N = 12) of adults aged 13 to 24 months had placental scars (Table 6), where as 80% (N = 15) of adults > 24 months old had placental scars. The proportional difference between the number of parous adults > 24 months old and the number of parous adults ≤24 months was significant (raw chi square = 10.71, $P = 0.001$, df = 1). This difference is reflected in the differences in age-specific birth rates between these two adult categories (Table 6). However, a Wilcoxon rank sum test showed no difference (P > 0.05, N = 14) in mean number of placental scars between parous adults > 24 months and parous adults ≤24 months among necropsied raccoon carcasses (Table 6). Parous females ranged in age between 1 and 9. The average age (± SE) of parous females was 3.93 ± 0.71 (N = 14).

Body weights of necropsied parous female raccoons with different numbers of placental scars were not significantly different ($P > 0.05$, N = 13) according to a Kruskal-Wallace test. Similarly, parous females (4.97 ± 0.31 kg) were not ($P > 0.05$, N = 26) heavier (x ± SE) than nulliparous females (4.88 ± 0.23 kg). However, parous females (36.6 ± 4.2) had significantly ($P = 0.028$, N = 24) lower kidney fat indices (KFI ± SE) than nulliparous females (47.9 ± 3.7). KFI's among parous females with different numbers of placental scars did not differ ($P = 0.19$, N = 13).

## Parasitism and Disease

Adult ticks (*Dermacentor* spp.), collected inside the right ear, were found on 33% of the 30 live-trapped raccoons checked. Among the raccoons that had ticks, there were on average 1.9 ticks per ear. Many of the ticks found were engorged with blood and firmly attached. Several (N = 6) other raccoons that did not have ticks inside the right ear had ticks on other parts of the body. These raccoons were not included in the results because of the difficulties of accurately finding ticks in the thick hair of raccoons in a time-efficient and undamaging method.

Many types of internal parasites were recovered on necropsy of hunter-collected raccoons. Ninety-two (74.8%) of the 123 raccoons necropsied had parasites of one type or another (Figure 7). The 'thorny headed worm' representing the phylum Acanthocephala (probably *Macracanthorhynchus* spp.) was the most commonly found, occurring in 56 of the intestinal tracts. Several nematodes also were found, including ascarids, which were found in 14 of the raccoons. *Physaloptera* spp. and *Gnathostoma* spp., two closely related genera, were the other two nematode types found during necropsy. Finally, cestodes (tapeworms) were found in 16% (N = 123) of the raccoons (Figure 7). Parasite types were found from highest to lowest occurrence in the following order: Acanthocephala = *Physaloptera* spp. > Cestodes = Ascarids > *Gnathostoma* spp. According to a chi-square test, differences ($P < 0.001$, df = 4) existed between frequency of occurrence among parasite types. All of the differences between parasite type occurrences in the intestinal tract were found significant ($P < 0.0025$, N = 123) according to the z-test for comparing binomial proportions, except differences in occurrence of Acanthocephala and *Physaloptera* spp., and cestodes and ascarids. Comparison-wise alpha values were adjusted in these tests using Bonferroni normal statistics (comparison-wise $\alpha$ = experiment-wise $\alpha/2k$, where k = number of simultaneous comparisons) (Miller 1966:67-69).

Parasite occurrences in male and female intestinal tracts were not significantly different ($P > 0.05$, N = 123) according to chi-square analysis. Parasite occurrences in juveniles (0-1 yr) and adult ( > 1 yr) intestines were not significantly different ($P > 0.05$, N = 123) either. However, among

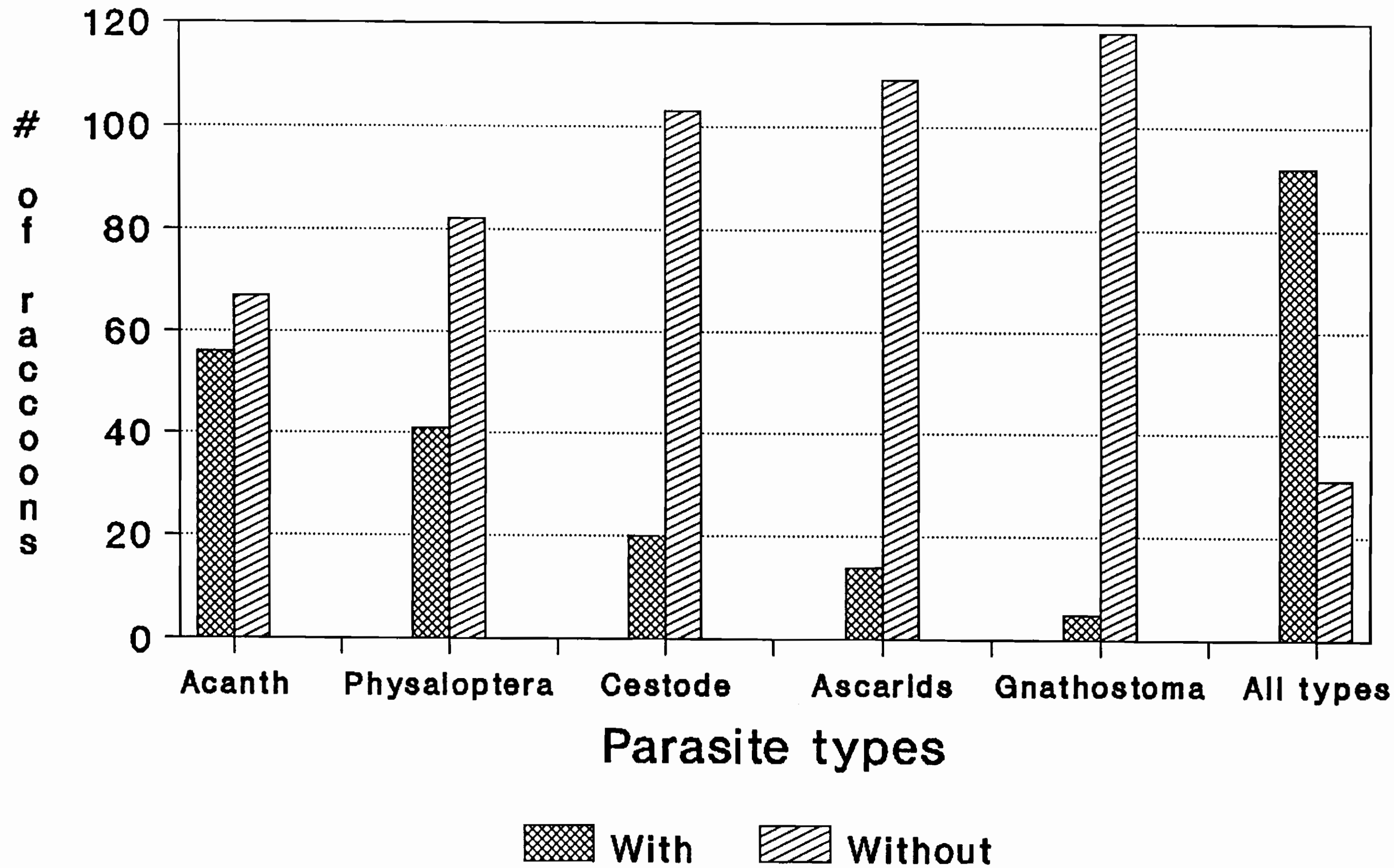


Figure 7. Parasites recovered from raccoons collected from Wise, Scott, Dickenson, and Russell counties, Virginia, 1989-1990.

the parasitic types, ascarids were found in more females than males ($P = 0.015$, N = 123) and in more juveniles than adults ($P = 0.008$, N = 123) according to chi-square (Table 14). There was no difference in condition (as measured by kidney fat index) among the raccoons that were infested with parasites and those that were not. Raccoons infested with different parasite species were not significantly different ($P > 0.05$, N = 123) in condition than those found without different parasite species, except with ascarids (Table 14). Raccoons with ascarids had significantly ($P = 0.004$, N = 123) less kidney fat (worse condition) than those without ascarids according to chi-square.

No evidence of obvious signs or symptoms of disease were found in the live-trapped or hunter-collected raccoons. Necropsy turned up several livers with necrotic spots, but the cause of necrosis remains unknown.

## *Food Habits*

Stomach contents from 121 raccoons collected between 15 October and 15 January revealed 45 food items (Table 15). Plant and animal materials were found in varying percent occurrences and dry weights. Animal matter was commonly seen, but composed a small proportion of the total stomach contents. Mammals, insects, amphibians, and crayfish were the most commonly seen and best represented gravimetrically of all the animal matter found, but together made up only 8.2% of the overall stomach contents weight. Plant matter was seen in most of the stomachs examined and contributed to most (87.2%) of the overall total stomach contents weight. Much of the hard mast meat (acorns, beech nuts, etc) was ingested with the shells as well. No fish remains were found in any of the stomachs.

Plant items had the greatest frequency and weight among the different months (Table 16) of selected food items. Foods with greatest frequency (given first) and dry weight were: *October* - invertebrate; acorn, pokeberry, corn; *November* - invertebrate; beech, acorn; *December* - invertebrate; corn, grape, beech; *January* - invertebrate; acorn, grape, vegetation(other). Food items

**Table 14.** Ascarid occurences among different sex and age groups and condition (kidney fat index) of ascarid infected raccoons from Wise, Scott, Russell, and Dickenson counties, Virginia, 1988-1990.

| Category | Ascarid Infested | Not Infested | Total |
|---|---|---|---|
| Male | 3 | 61 | 64 |
| Female | 11 | 48 | 59 |
| Juvenile | 11 | 44 | 55 |
| Adult | 3 | 63 | 66 |
| Condition(KFI ± SE) | 22.34 ± 2.53 | 35.06 ± 1.37 | |
| N | 9 | 101 | |

were not eaten in different proportions (relative weight) in different months ($P > 0.05$, $N = 117$) according to Wilcoxon rank sum tests, except invertebrates. Invertebrates were found in stomach contents much more in January than in October ($P = 0.005$, $N = 43$). There were no differences ($P > 0.05$, $N = 107$) between average weight of stomach contents between months. Among the selected food items in Table 16, there were no significant differences in relative amounts eaten between juveniles (0-1 yr) and adults ( > 1 yr) according to Wilcoxon rank sum. Tests for sex differences in food items eaten were not pursued as there are no reports of sexual differences in the foods eaten by raccoons.

Raccoons ate primarily (81.5-91%) plant items in the late-fall and early winter of 1988-89 and 1989-90 (Figure 8). Invertebrate and vertebrate food items increased slightly in the early winter, but this difference was not significant ($P > 0.05$, $N = 117$) according to Wilcoxon rank sum. Similarly, the reduction in vegetation in the diet from late-fall to early-winter was insignificant.

## *Home Range*

Annual and seasonal home range estimates were based on ≥23 locations and survival at least 67% of the year or season, respectively. According to Gese et al. (1990), the minimum number of point locations necessary to adequately delineate daytime home range size was 23 for coyotes (*Canis latrans*). Also, according to graphs of home range size versus number of observations for each raccoon monitored, after 23 observations the home range sizes began to level off. Swihart et al. (1988) calculated the time necessary between locations to assume independence was 3.5 hours for coyotes. This was the only estimate I was able to find in the literature pertaining to a necessary time between observations before assuming independence. Mean time (±SE) between locations taken in < 24 hour period for this research project was 7.75 (±0.39) hours, with a range of 3.63 - 14.25 hours. All locations were assumed to be independent because locations were taken once during the day and once at night and these differed by > 3.5 hours.

**Table 15.** Foods recovered from the stomachs of 121 raccoons of Wise, Scott, Russell, and Dickenson counties, Virginia, collected between 15 October and 15 January 1988-1990.

| Food | Occurrence | % Occurrence | Dry Weight(g) | % Aggregate Weight |
|---|---|---|---|---|
| VEGETABLE MATTER | **104** | **29.6** | **1132.2** | **87.2** |
| Acorn (*Quercus* spp.) | 36 | 7.8 | 379.6 | 29.2 |
| Beech (*Fagus grandifolia*) | 17 | 3.7 | 271.1 | 20.9 |
| Corn (*Zea mays*) | 10 | 2.2 | 175.7 | 13.5 |
| Grape (*Vitis aestivalis*) | 18 | 3.9 | 121.0 | 9.3 |
| Pokeberry (*Phytolacca americana*) | 12 | 2.6 | 91.9 | 7.1 |
| Hardmast (unknown) | 5 | 1.1 | 48.4 | 3.7 |
| Russian Olive (*Elaeagnus*) | 1 | 0.2 | 22.8 | 1.8 |
| Red Cedar (*Juniperus virginiana*) | 3 | 0.6 | 8.1 | 0.6 |
| Blackgum (*Nyssa sylvatica*) | 1 | 0.2 | 2.5 | 0.2 |
| Persimmon (*Diospyros virginiana*) | 1 | 0.2 | 1.7 | 0.1 |
| Wintergreen (*Gaultheria procumbera*) | 1 | 0.2 | 0.1 | T |
| Paw Paw (*Asimina triloba*) | 1 | 0.2 | 0.6 | T |
| Hemlock Leaves (*Tsuga canadensis*) | 7 | 1.5 | T | T |
| Lupine (*Lupinus sparsiflorus*) | 1 | 0.2 | T | T |
| Crownbeard (*Verbesina atternifolia*) | 1 | 0.2 | T | T |
| Vegetation (other) | 22 | 4.7 | 8.6 | 0.7 |
| ANIMAL MATTER | **97** | **36.9** | **113.0** | **8.7** |
| **Invertebrate** | **88** | **28.3** | **46.2** | **3.5** |
| Invertebrate (other) | 4 | 0.9 | 0.2 | T |
| Centipede (*Chilopoda*) | 3 | 0.6 | 0.1 | T |
| Millipede (*Diplopoda*) | 1 | 0.2 | T | T |
| Crayfish (*Procambarus* spp.) | 30 | 6.5 | 16.9 | 1.3 |
| Slug (*Limax* spp.) | 3 | 0.6 | 0.9 | 0.1 |
| Earthworm (*Helodrilus* spp.,*Limbricus* spp.) | 5 | 1.1 | 3.0 | 0.2 |
| **Insect** | **76** | **18.4** | **25.3** | **1.9** |
| Insect (other) | 47 | 10.1 | 6.3 | 0.5 |
| Coleoptera (other) | 10 | 2.2 | 5.0 | 0.4 |
| Ground Black Beetle (*Pterostichus* spp.) | 2 | 0.4 | 0.1 | T |
| Orthoptera | 6 | 1.3 | 1.3 | 0.1 |
| Odonata | 2 | 0.4 | 0.4 | T |
| Diptera (other) | 2 | 0.4 | 0.3 | T |
| Tipulidae (aquatic diptera) | 9 | 1.9 | 11.0 | 0.8 |
| Hemiptera (other) | 1 | 0.2 | 0.1 | T |
| Green Stink Bug (*Acrosternum hilare*) | 5 | 1.1 | 0.4 | T |
| Megaloptera | 1 | 0.2 | 0.1 | T |
| Hymenoptera | 1 | 0.2 | 0.1 | T |
| **Vertebrate** | **34** | **8.6** | **66.5** | **5.1** |
| Vertebrate (other) | 4 | 0.8 | 0.4 | T |
| Amphibian (other) | 4 | 0.9 | 1.7 | 0.1 |
| Frog (*Rana* spp. *Hyla* spp.) | 4 | 0.9 | 10.0 | 0.8 |
| Salamander (*Ambystomatidae, Plethodantidae*) | 7 | 1.5 | 9.3 | 0.7 |
| Bird | 4 | 0.9 | 1.6 | 0.1 |
| Mammal (other) | 14 | 3.0 | 34.0 | 2.6 |
| Mouse (*Peromyscus maniculatus*) | 3 | 0.6 | 9.4 | 0.7 |
| OTHER MATTER | **80** | **33.4** | **53.2** | **4.1** |
| Nematode (parasitic) | 79 | 17.0 | 3.6 | 0.3 |
| Unknown (animal) | 2 | 0.4 | 0.2 | T |
| Deer feces (*Odocoileus virginiana*) | 1 | 0.2 | 0.3 | T |
| Leaves,twigs,debris | 31 | 6.7 | 8.2 | 0.6 |
| Unknown | 42 | 9.1 | 41.3 | 3.2 |

T= <0.1g or <0.1%
* Numbers in bold represent subtotals.

**Table 16.** Summary of some monthly foods eaten by hunter collected raccoons in Wise, Scott, Russell, and Dickenson counties, Virginia, 1988-1990.

| Food Type | October N=43 | | November N=23 | | December N=20 | | January N=31 | |
|---|---|---|---|---|---|---|---|---|
| | % Occ | %Dry Wt | % Occ | %Dry Wt | % Occ | %Dry Wt | % Occ | %Dry Wt |
| Acorn | 11.2 | 36.2 | 7.3 | 20.1 | 12.5 | 10.9 | 5.9 | 27.6 |
| Beech | 3.4 | 12.4 | 13.0 | 57.8 | 3.6 | 19.3 | 1.0 | 1.4 |
| Corn | 3.4 | 18.9 | 1.4 | 1.6 | 7.1 | 33.3 | 1.0 | 1.3 |
| Grape | 0.0 | 0.0 | 0.0 | 0.0 | 8.9 | 23.7 | 10.9 | 24.6 |
| Pokeberry | 9.5 | 19.6 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 2.5 |
| Plant(other) | 9.5 | 6.1 | 11.6 | 9.9 | 3.6 | 0.4 | 10.9 | 18.9 |
| Diptera | 0.9 | T | 1.4 | 0.6 | 3.6 | 1.3 | 4.9 | 3.2 |
| Crayfish | 12.1 | 1.8 | 8.7 | 1.1 | 7.1 | 0.9 | 4.0 | 1.4 |
| Invert(other) | 21.6 | 1.5 | 29.0 | 0.9 | 17.9 | 0.7 | 23.8 | 3.4 |
| Vertebrate | 10.3 | 1.8 | 8.7 | 6.0 | 7.1 | 3.4 | 11.9 | 5.2 |
| Debris | 7.8 | T | 11.6 | 0.9 | 7.1 | 0.5 | 12.9 | 2.0 |
| Unknown | 10.3 | 1.6 | 7.2 | 1.1 | 21.4 | 5.6 | 11.9 | 8.5 |

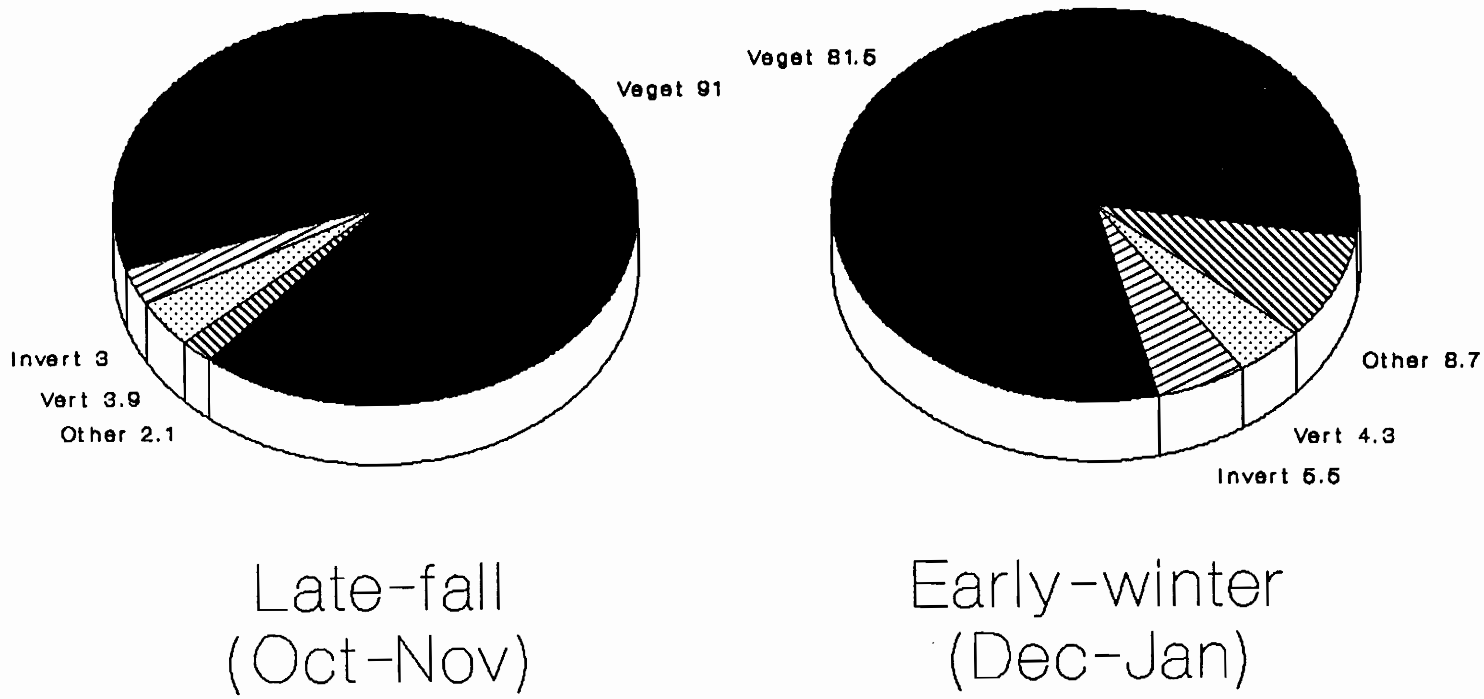


**Figure 8.** General food types eaten by hunter collected raccoons from Wise, Scott, Dickenson, and Russell counties, Virginia, 1989-1990.

Boulanger and White (1990) examined several home range estimators and concluded that they are only general measures of animal activity. All home range estimators are affected by sample size. As sample size increases so does precision or repeatability of similar estimates. The convex polygon method has biases that are a function of sample size. Bias measures how close the home range estimate is to the actual home range size. Boulanger and White (1990) found the harmonic means estimate to be the least biased estimator, but also one of the least precise. In other words harmonic means estimates came closest to the actual home range sizes, but repeatability of similar estimates lacked consistency.

## Home Range Size

A home range may be defined as the area an animal uses during its normal activities of mating, caring for young, and food gathering (Burt 1943). Home range was calculated using two methods: convex polygon (Hayne 1949) and harmonic mean (Dixon and Chapman 1980). The 95% contour of the harmonic mean (Table 17) gave larger home range estimates than those estimates of the convex polygon methods (Table 18). A two-way ANOVA was run on both convex polygon home ranges and 95% harmonic means home ranges. The results of both tests showed differences in home range size among sexes ($P < 0.003$) and seasons ($P < 0.05$), but no interaction effect (sex*season) ($P = 1.00$) was found. Further testing used Duncan's multiple range test on main effects. Males (Figure 9) had larger home ranges ($P < 0.005$, $df = 33$) than females (Figure 10) for both convex polygon and 95% harmonic means home ranges. Convex polygon summer home ranges were larger ($P < 0.05$) than those of the fall and winter. Fall and winter convex polygon home range sizes were not different ($P > 0.05$). Similarly, fall and winter 95% harmonic means home range sizes and summer and fall home ranges were not different ($P > 0.05$). But, summer 95% harmonic means home ranges were larger ($P < 0.05$) than those of the winter.

**Table 17.** Annual and seasonal 95% harmonic means home range size (ha) of male and female raccoons in High Knob Recreation Area, Virginia, 1989-1990.

| Sample[a] | N | Mean | SE | Range | Locations per raccoon |
|---|---|---|---|---|---|
| Summer (1 June to 31 August) | | | | | |
| Male | 7 | 485.0 | 120.8 | 101.7-954.1 | 23-30 |
| Female | 3 | 248.7 | 90.8 | 118.0-423.1 | 23-31 |
| Fall (1 September to 30 November) | | | | | |
| Male | 10 | 397.1 | 69.4 | 137.3-775.6 | 23-32 |
| Female | 6 | 157.2 | 38.8 | 33.7-303.3 | 24-35 |
| Winter (1 December to 28 February) | | | | | |
| Male | 6 | 284.8 | 82.2 | 49.2-610.5 | 23-39 |
| Female | 7 | 108.4 | 15.5 | 65.6-159.8 | 24-39 |
| Total (10 May to 27 April) | | | | | |
| Male | 11 | 814.3 | 215.7 | 358.8-2909.2 | 38-102 |
| Female | 8 | 277.4 | 45.0 | 125.6-512.1 | 47-112 |

[a] Only raccoons monitored at least 67% of the season are included in samples.

**Table 18.** Annual and seasonal convex polygon home range size (ha) of male and female raccoons in High Knob Recreation Area, Virginia, 1989-1990.

| Sample[a] | N | Mean | SE | Range | Locations per raccoon |
|---|---|---|---|---|---|
| Summer (1 June to 31 August) | | | | | |
| Male | 7 | 426.0 | 115.2 | 69.3-1022.3 | 23-30 |
| Female | 3 | 192.2 | 74.1 | 81.2-332.8 | 23-31 |
| Fall (1 September to 30 November) | | | | | |
| Male | 10 | 266.5 | 46.4 | 76.7-502.9 | 23-32 |
| Female | 6 | 108.7 | 25.8 | 32.7-215.3 | 24-35 |
| Winter (1 December to 28 February) | | | | | |
| Male | 6 | 183.7 | 62.0 | 30.3-408.8 | 23-39 |
| Female | 7 | 82.3 | 14.1 | 48.3-148.8 | 24-39 |
| Total (10 May to 27 April) | | | | | |
| Male | 11 | 649.1 | 112.6 | 306.4-1409.7 | 38-102 |
| Female | 8 | 239.0 | 40.0 | 112.6-446.9 | 47-112 |

[a] Only raccoons monitored at least 67% of the season are included in samples.

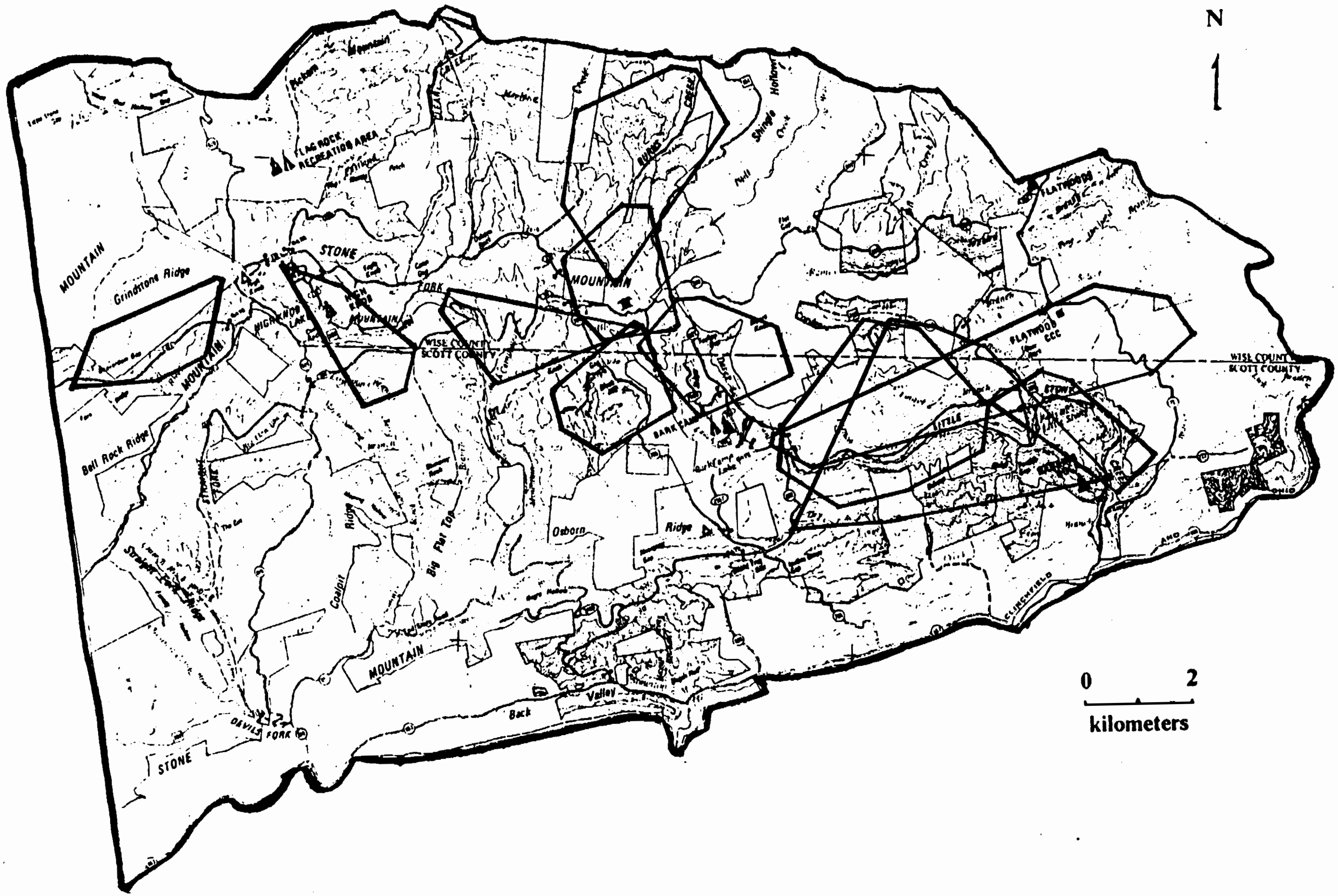


Figure 9. Convex polygon home ranges for 11 male raccoons monitored for ≥6 months in High Knob Recreation Area, Virginia, 1989-1990.

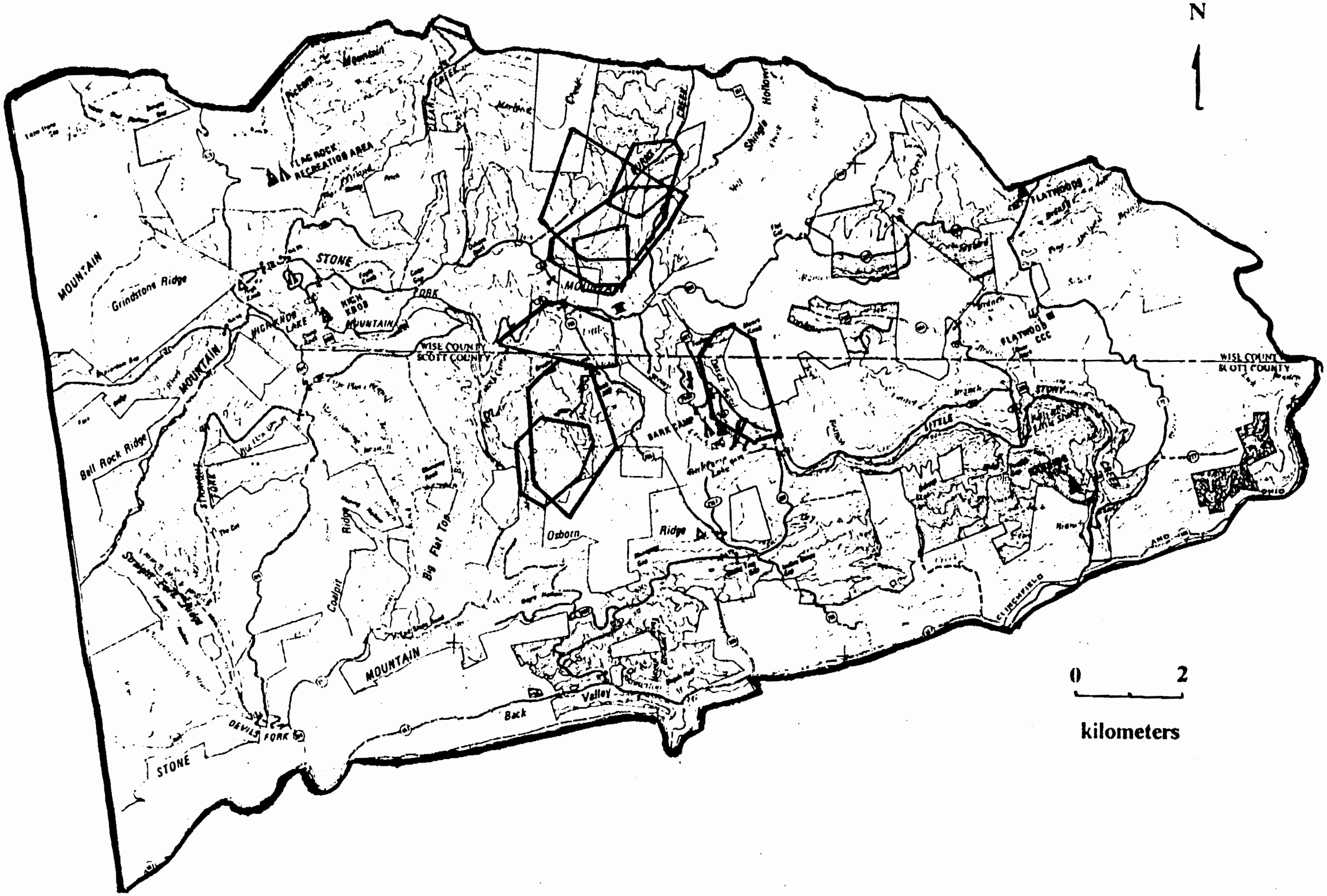


**Figure 10.** Convex polygon home ranges for 8 female raccoons monitored for ≥6 months in High Knob Recreation Area, Virginia, 1989-1990.

## Activity Centers

Activity centers (also called core areas) as determined by the 50% harmonic means (Table 19) are defined as the area of intense use in the home range (Figure 11-12). The results of a two-way ANOVA showed no sex ($P = 0.087$), season ($P = 0.065$), or interaction (sex*season) ($P = 1.00$) effects on activity center size. Thus, according to this test no differences in activity center size are apparent ($P > 0.05$, $df = 33$) among sexes or seasons. Annual activity centers were found to represent seasonal activity centers both in terms of size and location. No seasonal activity center shifts were noted.

## Home Range Overlap

Males (Figure 9) and females (Figure 10) had extensive total home range overlap. Percent overlapping range was used to measure seasonal overlap. Percent overlapping range size (according to Kruskal-Wallace tests) was not different for males ($P = 0.06$) or females ($P = 0.56$) between seasons (Figures 13-15). Percent overlapping range was greatest during summer ($47.7 \pm 9.5\%$, $N = 10$) and least during fall ($37.6 \pm 9.1\%$, $N = 16$) and winter ($31.6 \pm 9.5\%$, $N = 13$). The number of seasonal home ranges that overlapped varied between 0 and 5, but was on average 2 overlaps/ home range. Annual home range overlap ($67.2 \pm 6.8\%$, $N = 19$) was greater than the overlap of any of the seasonal home ranges. Also, a greater number of annual home ranges ($3.6 \pm 0.5$, $N = 19$) overlapped each other than seasonal home ranges.

Male-female home range overlap was most common on annual home ranges (Table 20). Male-male and female-female overlaps were less common. Summer overlap was dominated by male-male overlaps, whereas fall overlap was mostly between sexes. Female-female overlaps and overlaps between sexes were common in the winter. However, no significant differences (raw chi-square = 7.83, $P = 0.10$) were found between the different gender overlaps among seasons.

**Table 19.** Annual and seasonal activity centers (50% harmonic means) (ha) of male and female raccoons in High Knob Recreation Area, Virginia, 1989-1990.

| Sample[a] | N | Mean | SE | Range | Locations per raccoon |
|---|---|---|---|---|---|
| Summer (1 June to 31 August) | | | | | |
| Male | 7 | 87.4 | 26.6 | 5.7-204.5 | 23-30 |
| Female | 3 | 47.7 | 15.4 | 17.2-67.3 | 23-31 |
| Fall (1 September to 30 November) | | | | | |
| Male | 10 | 48.1 | 15.9 | 9.4-175.9 | 23-32 |
| Female | 6 | 31.6 | 11.6 | 6.9-83.6 | 24-35 |
| Winter (1 December to 28 February) | | | | | |
| Male | 6 | 35.8 | 23.0 | 6.7-150.3 | 23-39 |
| Female | 7 | 20.1 | 4.9 | 2.8-38.4 | 24-39 |
| Total (10 May to 27 April) | | | | | |
| Male | 11 | 75.4 | 19.8 | 16.1-199.2 | 38-102 |
| Female | 8 | 39.0 | 8.6 | 14.9-77.11 | 47-112 |

[a] Only raccoons monitored at least 67% of the season are included in samples.

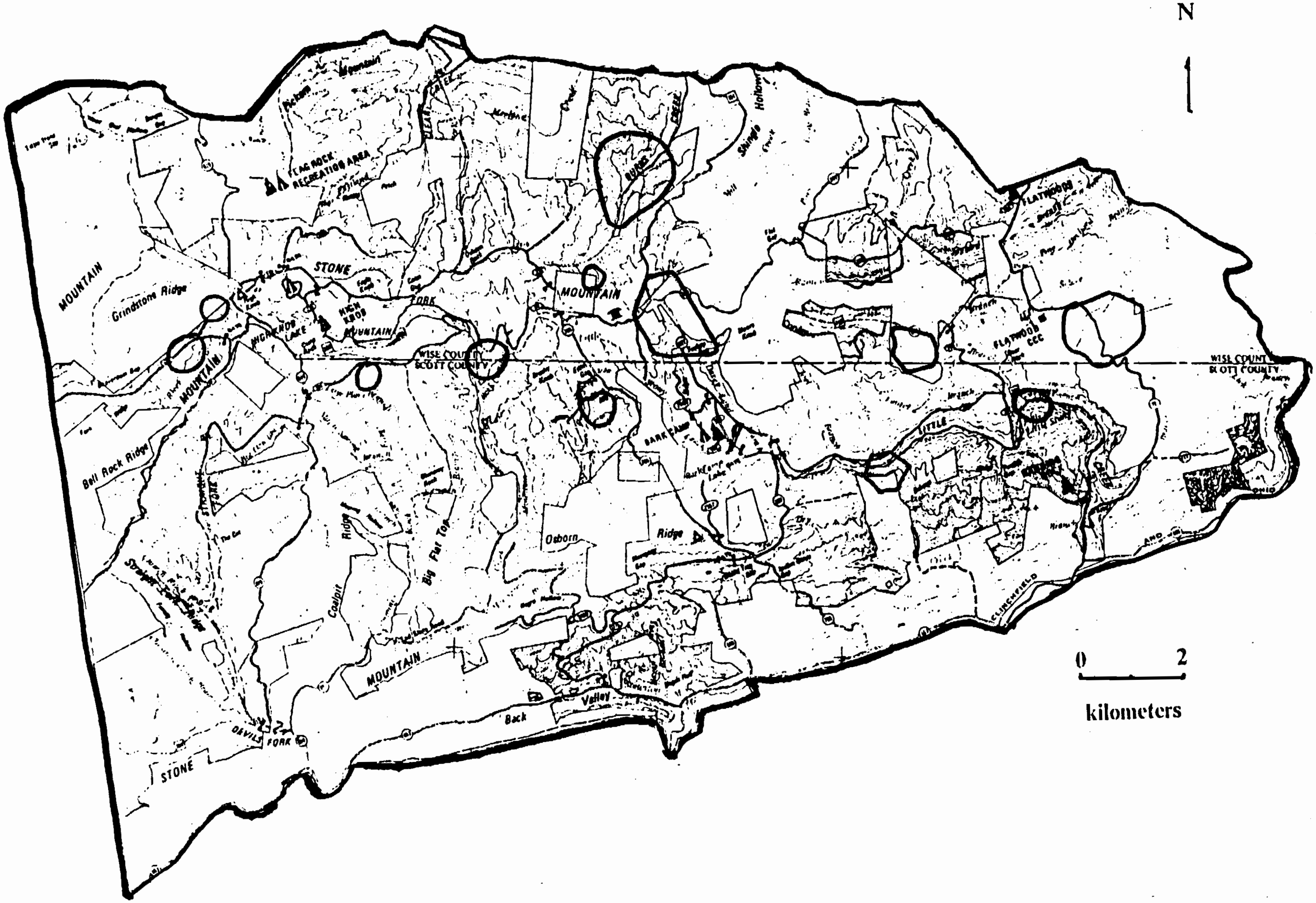


Figure 11. Activity centers (50% harmonic means) for 11 male raccoons monitored for ≥6 months in High Knob Recreation Area, Virginia, 1989-1990.

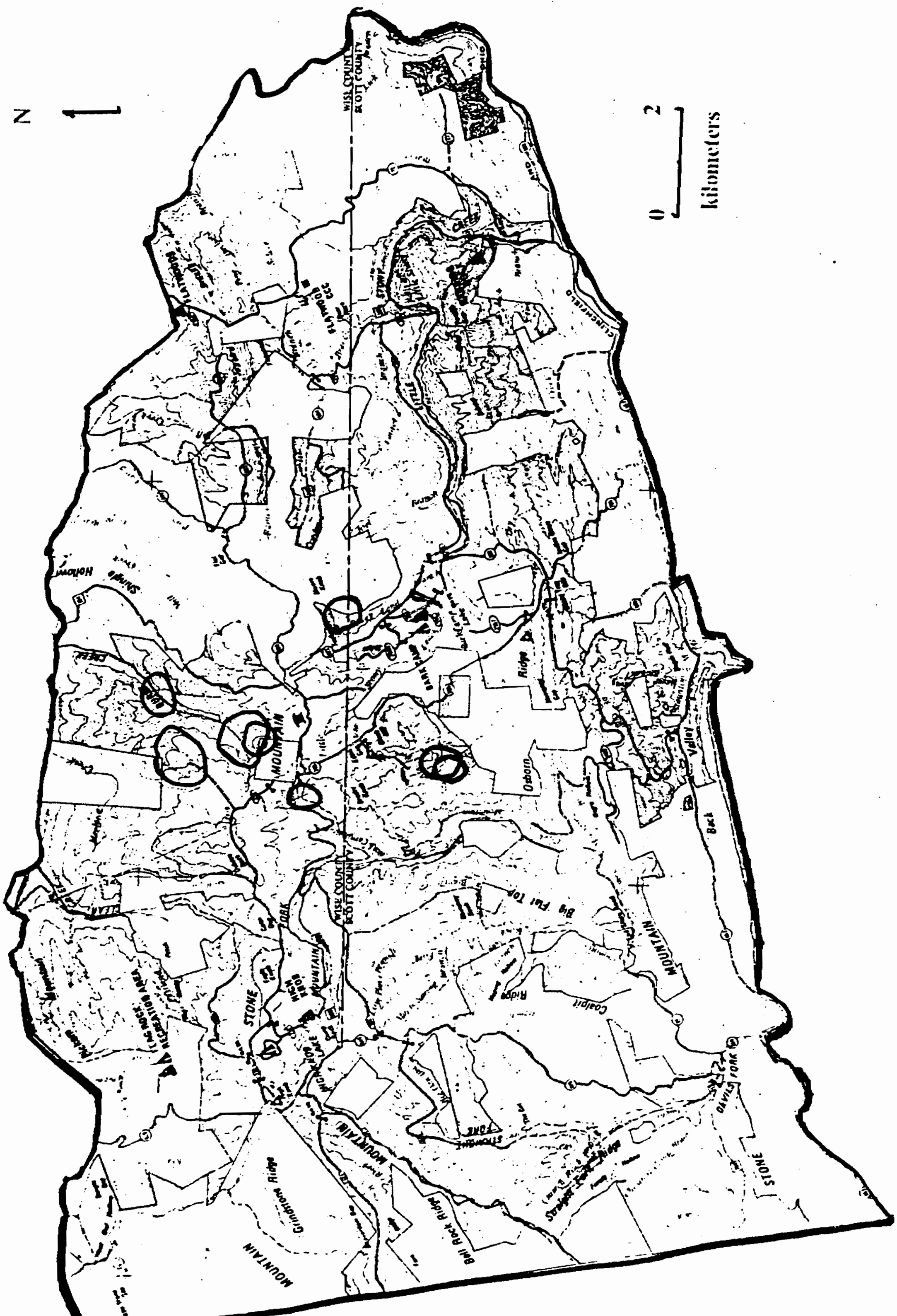


Figure 12. Activity centers (50% harmonic means) for 8 female raccoons monitored for ≥6 months in High Knob Recreation Area, Virginia, 1989-1990.

Similarly, no differences were found ($P > 0.05$) between the size (ha) of overlap between the sexes for annual and seasonal overlaps according to Kruskal-Wallace tests.

## Home Range Shift

One raccoon is believed to have exhibited a home range shift. This male raccoon was monitored from 7 June 1989 until 20 August 1989 and was subsequently lost. After checking a wide area for the signal over September and October 1989, nothing was found. On 27 March 1990 the raccoon was relocated and monitored for one month until 24 April 1990 after establishing what seemed to be a new home range. The difference in distance between the center of the 'original' home range and that established in March and April was 4,346 meters.

# *Movements and Activity*

## Activity

Activity was grouped into two times: day (sunrise-sunset) and night (sunset-sunrise). Sunrise and sunset were calculated from Virginia Game Commission (1989-1990) calendars for each season. The following sunrise-sunset times were used for each season: spring (0634-1929), summer (0618-2038), fall (0710-1814), and winter (0729-1731). Monitoring of raccoons from 0100-0900 hours was not done due to logistical concerns. Raccoon activity was low (≤25% during any one hour interval) for the 11 hours following sunrise (according to activity sensors within each radio collar) (Table 21). However, after 11 hours following sunrise activity increased. At least 50% of raccoons monitored were active during each half hour interval from 0 to 7 hours after sunset (Table

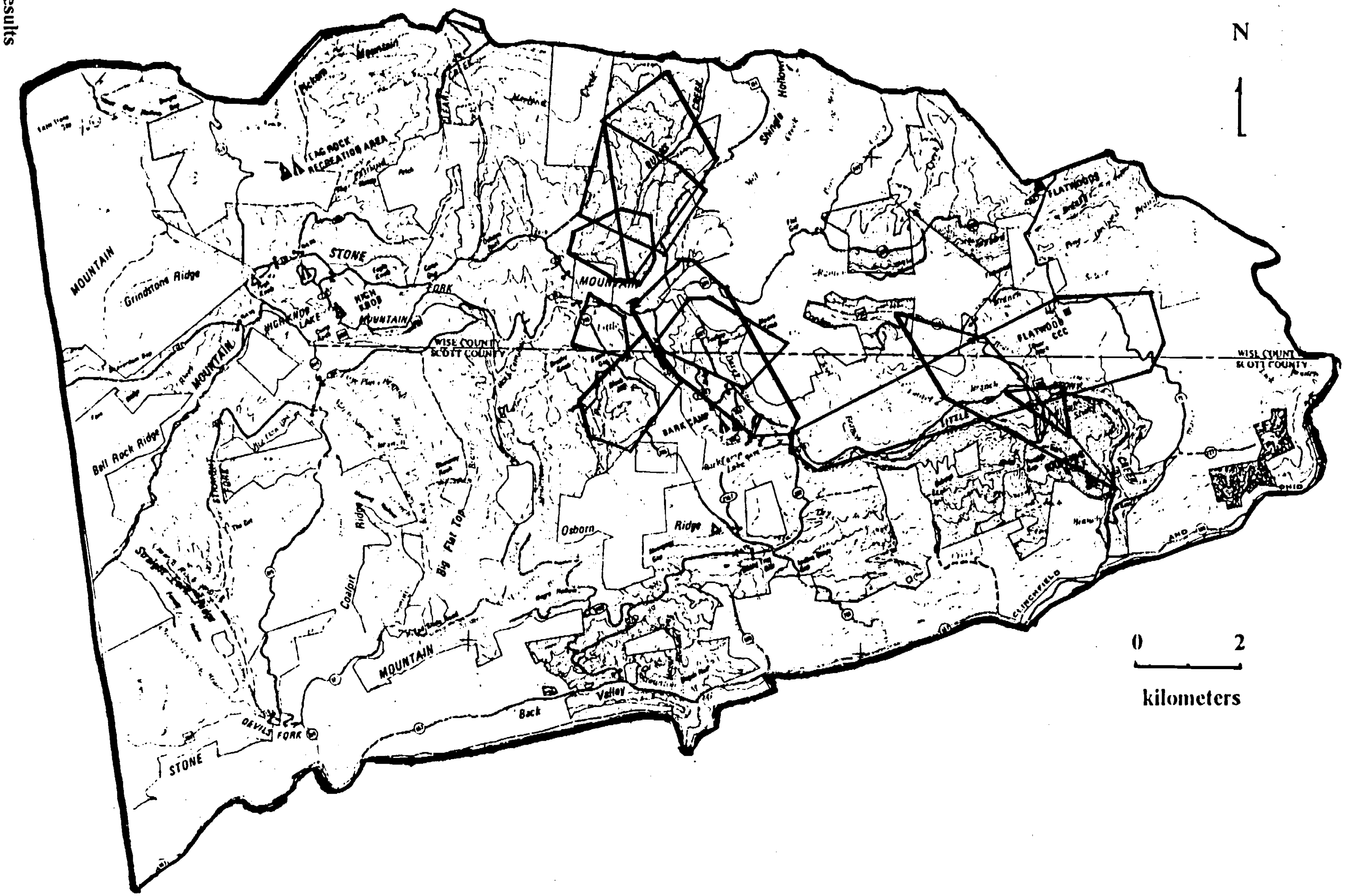


Figure 13. Convex polygon home ranges for 10 raccoons monitored during the summer (June-August) of 1989 in High Knob Recreation Area, Virginia.

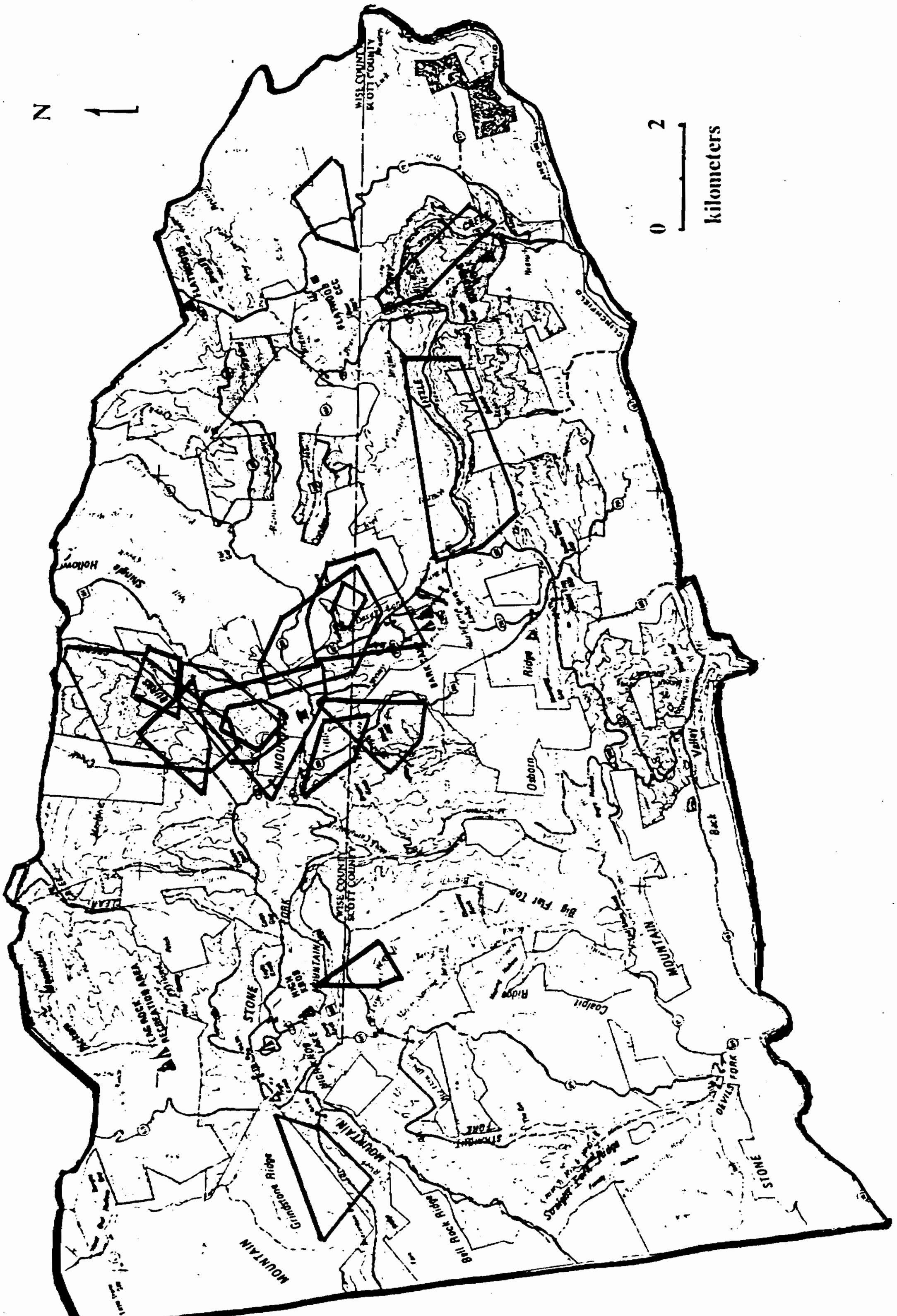


Figure 14. Convex polygon home ranges for 16 raccoons monitored during the fall (September-November) of 1989 in High Knob Recreation Area, Virginia.

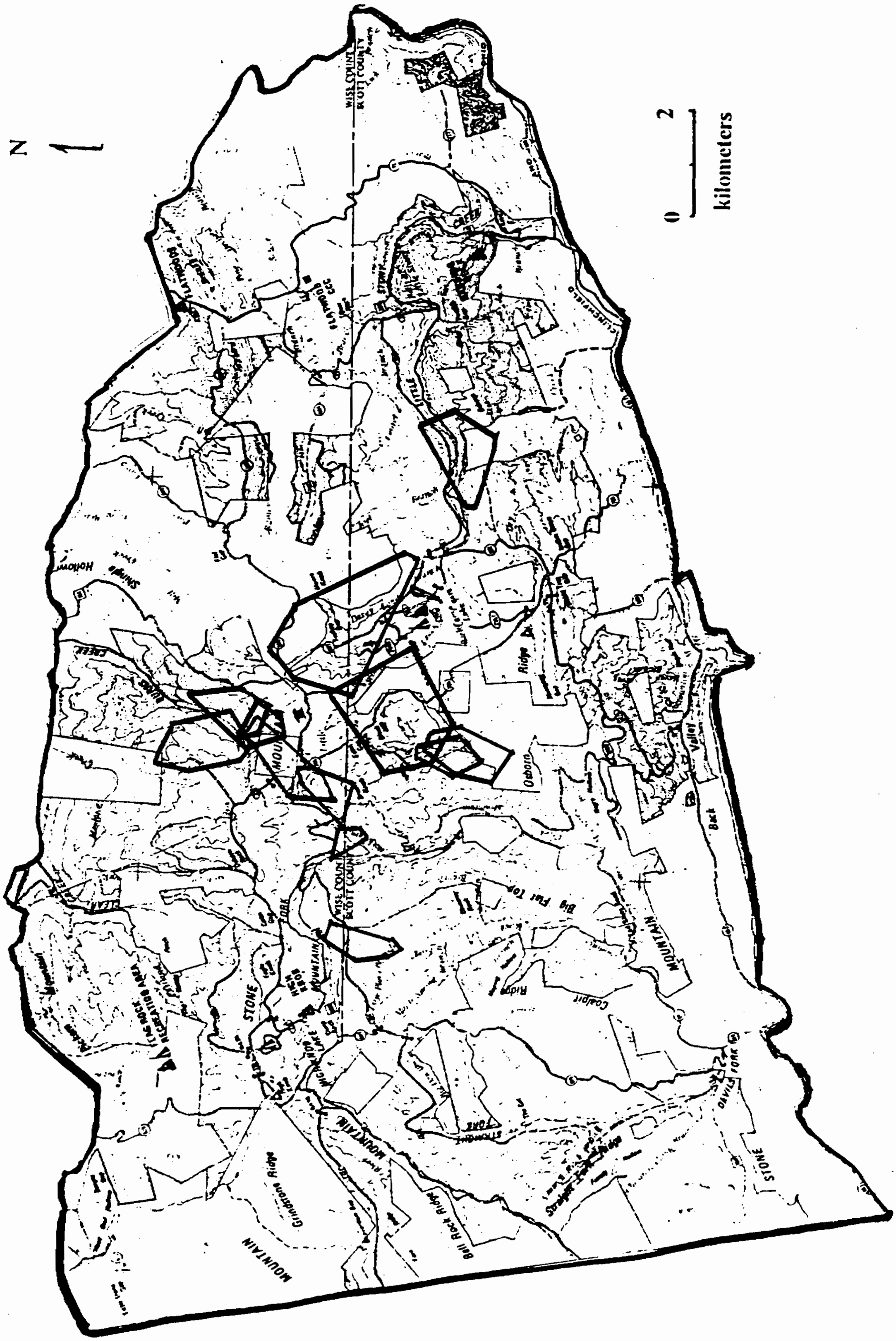


**Figure 15.** Convex polygon home ranges for 13 raccoons monitored during the winter (December-February) of 1989-1990 in High Knob Recreation Area, Virginia.

**Table 20.** Annual and seasonal home range overlap frequency between male and female raccoons of High Knob Recreation Area, Virginia, 1989-1990.

| Sample | ♀ and ♀ | ♂ and ♀ | ♂ and ♂ |
|---|---|---|---|
| Summer | 1 | 3 | 6 |
| Fall | 4 | 9 | 5 |
| Winter | 5 | 5 | 1 |
| Annual | 7 | 16 | 13 |

22). Nightly activity was fairly constant during the 7 hours after sunset that I collected data. Daytime activity was under 41% from 2 to 8 hours after sunrise, for all seasons (Figure 16). After 8 hours following sunrise, the percent of raccoons that are active increases. Nightly activity was between 70% and 80% from 0.5 to 7.0 hours after sunset, for all seasons except during the winter (Figure 17).

Differences in levels of activity existed between seasons (raw chi-square = 40.0, $P < 0.001$). Activity was greatest during the fall (Sept-Nov) with 62.4% ($N = 679$) of observations recorded in active mode. Winter (Dec-Feb) was the period of lowest activity with 36.3% ($N = 408$) of observations recorded in active mode. Raccoons were more active at night than during the day ($P < 0.001$, raw chi-square = 87.7) in all seasons (Table 23). The greatest activity (92%) occurred during fall nights followed by summer and spring nights. Activity of raccoons was least during winter nights. Differences in nightly activity were found among seasons (raw chi-square = 113.2, $P < 0.001$, $df = 3$) using chi-square analysis. Daytime activity was similar among seasons and chi-square analysis found no differences.

Monthly activity (Table 24) between March and April was different ($P = 0.016$) according to chi-square. Activity among summer months (June, July, August) and fall months (Sept., Oct., Nov.) were not different ($P > 0.05$). Raccoons were less active ($P = 0.001$) in December than in January and February. However, no differences in activity between January and February were detected with chi-square. Males and females were equally active during most months ($P > 0.05$, $N = 1557$) according to chi-square. However, during January males became more active ($P = 0.033$, $N = 178$) than females.

## Movements

Distances raccoons moved were recorded as distance between one daytime location and one nighttime location or vice versa. The time between these subsequent observations ranged from 3.6 to 14.3 hours. Raccoon movement was calculated as distance moved (meters) divided by time

**Table 21.** Activity of raccoons of High Knob Recreation Area, Virginia between sunrise and sunset, 1989-1990.

| Hrs.after sunrise | N | % Active |
|---|---|---|
| < 2.0 | 1 | 0 |
| 2.0-3.0 | 8 | 25 |
| 3.0-4.0 | 49 | 20 |
| 4.0-5.0 | 126 | 20 |
| 5.0-6.0 | 236 | 17 |
| 6.0-7.0 | 149 | 19 |
| 7.0-8.0 | 99 | 9 |
| 8.0-9.0 | 62 | 10 |
| 9.0-10.0 | 44 | 18 |
| 10.0-11.0 | 12 | 0 |
| 11.0-12.0 | 3 | 33 |
| 12.0-13.0 | 8 | 63 |
| 13.0-14.0 | 3 | 100 |
| 14.0-15.0 | 21 | 81 |

[a] Spring: sunrise = 0634, sunset = 1929.
Summer: sunrise = 0618, sunset = 2038.
Fall: sunrise = 0710, sunset = 1814.
Winter: sunrise = 0729, sunset = 1731.

**Table 22.** Activity of raccoons of High Knob Recreation Area, Virginia between sunset and sunrise, 1989-1990.

| Hrs.after sunset | N | % Active |
|---|---|---|
| 0.0-0.5 | 36 | 83 |
| 0.5-1.0 | 42 | 86 |
| 1.0-1.5 | 70 | 84 |
| 1.5-2.0 | 94 | 84 |
| 2.0-2.5 | 148 | 80 |
| 2.5-3.0 | 104 | 83 |
| 3.0-3.5 | 114 | 81 |
| 3.5-4.0 | 88 | 76 |
| 4.0-4.5 | 55 | 75 |
| 4.5-5.0 | 27 | 78 |
| 5.0-5.5 | 8 | 88 |
| 5.5-6.0 | 10 | 80 |
| 6.0-6.5 | 2 | 50 |
| 6.5-7.0 | 1 | 100 |

[a] Spring: sunrise = 0634, sunset = 1929.
Summer: sunrise = 0618, sunset = 2038.
Fall: sunrise = 0710, sunset = 1814.
Winter: sunrise = 0729, sunset = 1731.

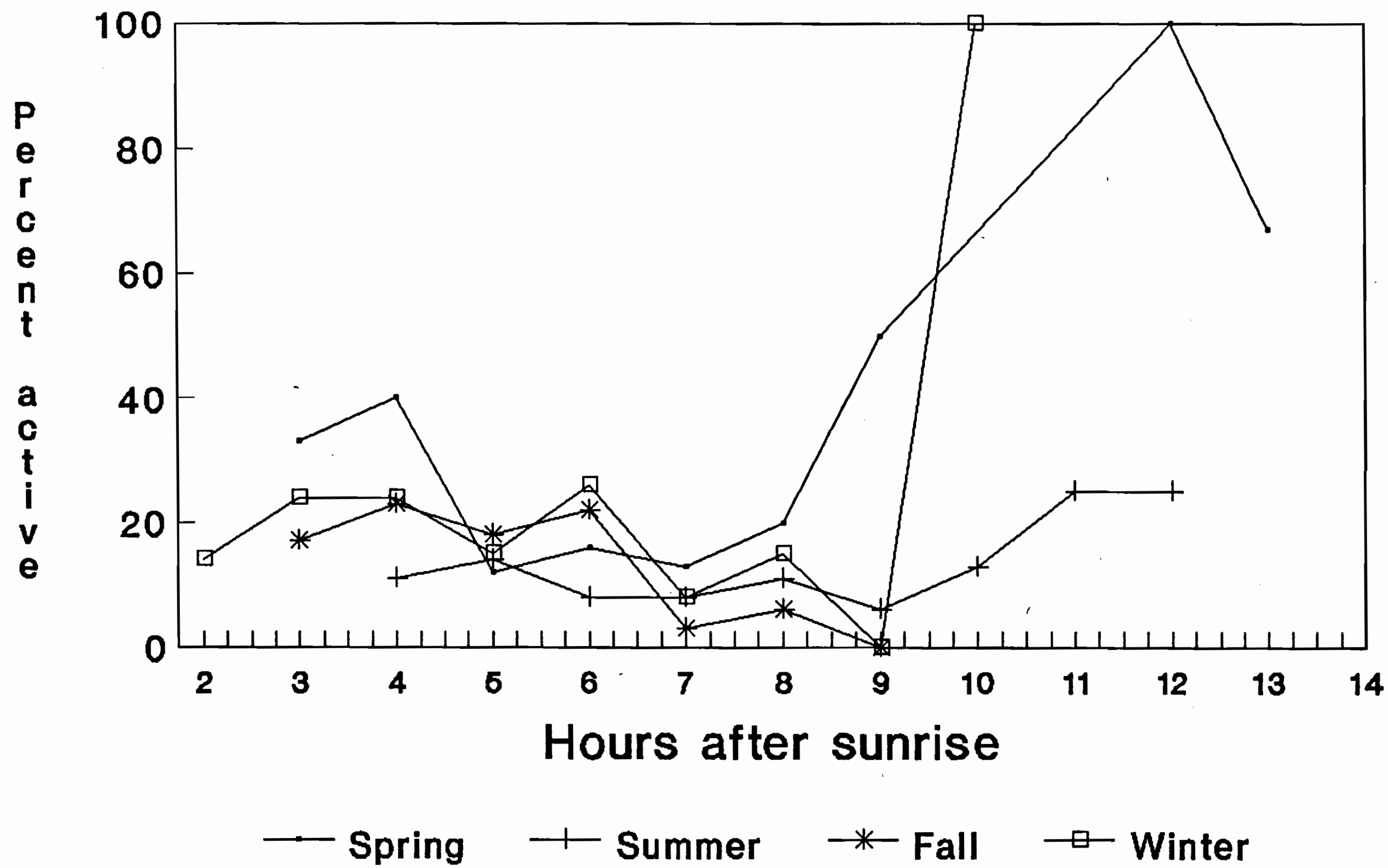


Figure 16. Activity of raccoons during the day (sunrise - sunset) at High Knob Recreation Area, Virginia during different seasons, 1989-1990.

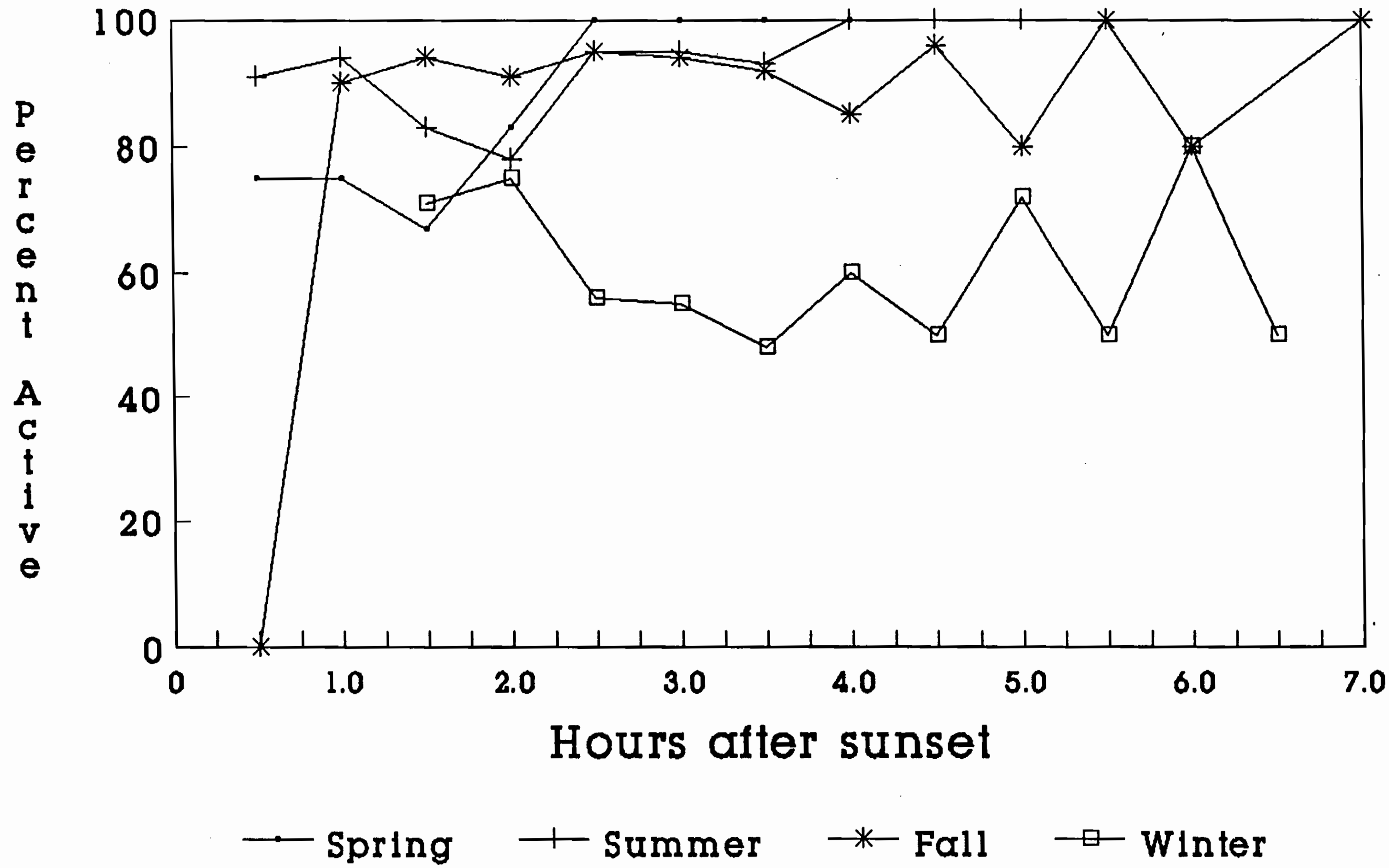


Figure 17. Activity of raccoons during the night (sunset - sunrise) at High Knob Recreation Area, Virginia during different seasons, 1989-1990.

**Table 23.** Daytime (sunrise-sunset) and nightime (sunset-sunrise) activity of raccoons at High Knob Recreation Area, Virginia, 1989-1990.

| Period[a] | N | % Active |
|---|---|---|
| Spring day | 78 | 23 |
| Spring night | 71 | 83 |
| Summer day | 227 | 18 |
| Summer night | 147 | 91 |
| Fall day | 283 | 18 |
| Fall night | 342 | 92 |
| Winter day | 236 | 19 |
| Winter night | 240 | 59 |

[a] Spring = March-May
Summer = June-August
Fall = September-November
Winter = December-February

**Table 24.** Monthly activity of raccoons at High Knob Recreation Area, Virginia, 1989-1990.

| Month | N | % Active |
|---|---|---|
| May 1989 | 0 | . |
| June | 71 | 44 |
| July | 194 | 47 |
| August | 109 | 51 |
| September | 208 | 60 |
| October | 262 | 61 |
| November | 155 | 51 |
| December | 148 | 28 |
| January 1990 | 178 | 40 |
| February | 149 | 49 |
| March | 92 | 59 |
| April | 57 | 39 |

(hours), between each subsequent observation. Raccoon movements over the monitoring period averaged (± SE) 49.4 (± 1.7) m/hr (N = 811). Movements were similar from day locations to night locations and vice versa.

Raccoon movements were different among sexes (F-value = 13.63, $P < 0.001$) and months (F-value = 6.10, $P < 0.001$), but no sex*month interaction effect ($P = 0.745$) was found according to a two-way ANOVA. Mean (± SE) male movements (55.3 ± 2.7 m/hr) were larger ($P < 0.001$) than mean (± SE) female movements (43.3 ± 1.9 m/hr). June movements (Table 24) were most extensive (83.3 ± 13.8 m/hr). December movements were the lowest (34.7 ± 4.1 m/hr). Duncan's multiple range test ($\alpha = 0.05$) found June movements greater ($P < 0.05$) than all other months. Movements during the months of July through September were greater ($P < 0.05$) than the movements during the months of November through April.

Raccoon movements (± SE) were greatest in the summer (66.7 ± 4.5m/hr) and lowest in the winter (37.5 ± 2.4m/hr). Fall (49.4 ± 2.5m/hr) and spring (41.4 ± 3.5m/hr) movements were not as large as those in the summer. Differences ($P < 0.001$) in movement existed between seasons based on a one-way ANOVA (F-value = 15.03, df = 3). Duncan's multiple range test specified these differences ($P < 0.05$) as follows: summer > fall > winter, spring = fall, and spring = winter, where '>' indicates a difference ($P < 0.05$).

# *Habitat Use*

## Forest Stand Use

Criteria for inclusion of observations used for home range analysis (mentioned in the Materials and Methods section) were the same criteria used for habitat use versus availability analysis. Totals of 719 observations from 17 males and 689 observations from 13 females were used

**Table 25.** Raccoon movements (meters/hour) in different months at High Knob Recreation Area, Virginia, 1989-1990.

| Month | N | $\bar{X}$[a] | SE |
|---|---|---|---|
| June 1989 | 45 | 83.3 a | 13.8 |
| July | 99 | 60.7 b | 5.8 |
| August | 59 | 63.9 b | 5.8 |
| September | 89 | 59.7 b | 5.4 |
| October | 123 | 46.7 bc | 3.1 |
| November | 75 | 41.9 c | 4.8 |
| December | 74 | 34.7 c | 4.1 |
| January 1990 | 79 | 37.1 c | 4.3 |
| February | 81 | 40.4 c | 4.2 |
| March | 56 | 41.2 c | 4.4 |
| April | 31 | 41.8 c | 5.7 |

[a] Means within the same column that share the same letter are not different ($P > 0.05$) according to Duncan's multiple range test.

to test habitat use versus availability. Habitat use was determined by the frequency of observations of radio collared raccoons in the various habitat types. Habitat availability was determined three ways. (1) Habitat availability for analysis on all raccoons monitored was determined by using composite home range. Composite home range is a convex polygon home range encompassing all observed locations for all 30 raccoons. The entire study area was not considered available because raccoon ranges were not found to cover the entire study area. (2) Habitat availability for males was determined by combining the 17 male home ranges. Habitat availability for females was determined by combining the 13 female home ranges. (3) Finally, habitat availability on an individual basis was determined by these habitat types within an individuals' home range.

Two methods were used to determine habitat use versus availability. Neu et al.'s (1974) method was used as well as Johnson's preference assessment (1980). Neu et al. (1974) is commonly used but is often incorrectly applied. One of the critical assumptions in this method is that all observations are independent. However, in using repeated observations in various habitat types from one individual, one may argue that those observations are not independent, but rather dependent as they came from the same raccoon. Thus, a critical assumption of Neu et al. (1974) is commonly discarded. Neu et al.'s (1974) results were included for comparison to other studies and because no articles that I have reviewed discuss whether it is the experimental unit (raccoons) that needs to be independent or the observations (of the raccoons) that needs to be independent. Johnson's (1980) preference assessment is a much more conservative test and considers the raccoon as the experimental unit.

Six habitat types were categorized as available (Table 26). According to Neu et al. (1974) average expected observations for each habitat should be six or more, in order to use the approximation that the test statistic of the comparison of observed raccoon occurrences and "expected" occurrence of raccoons for each habitat category is chi-square distributed. A minimum sample size of $N = 36$ (6 habitats $\times$ 6 observations/habitat) was used to fit the assumption, therefore excluding 10 raccoons from habitat preference analysis. Overall (Table 26) raccoons preferred ($P < 0.05$) yellow poplar--white oak--northern red oak (*Liriodendron tulipifera--Quercus alba--Quercus rubrum*) (YPWONRO) that was greater than 50 years old (Neu et al. 1974). Overall, raccoons also used white oak--northern red oak--hickory (*Carya* spp.) (WONROH) over 50 years old less ($P < 0.05$) than their availability. Male raccoons seemed to prefer ($P < 0.05$) YPWONRO stands greater than 50 year stands as well as sugar maple--beech--yellow birch (*Acer saccharum--Fagus grandifolia--Betula alleghaniensis*) (SMBYB) stands while using WONROH ($\leq$ 50 yrs) and YPWONRO ( > 50 yrs) less ($P < 0.05$) than available. Females were found in all habitats in similar ($P > 0.05$) proportions as was available.

Individual raccoon habitat use versus availability also was analyzed using Neu et al. (1974) methods. Totals of 17 raccoons met the minimum sample size requirements ($N = 36$) to be tested. Only 5 of 17 (29.4%) showed differences between use and availability (Table 27). WONROH stands older than 50 years were used less than available ($P < 0.05$) for raccoon 05 but the rest did not use the habitat in proportions different to available. YPWONRO stands older than 50 years were only preferred ($P < 0.05$) by one female (19) while 2 other raccoons used the habitat less ($P < 0.05$) than available. YPWONRO stands greater than 50 years also were preferred by one raccoon, but were used less ($P < 0.05$) than available by three. Male raccoons seemed to prefer ($P < 0.05$) SMBYB stands while females used them less ($P < 0.05$) than available.

Johnson's preference assessment (1980) works well with a large number of habitat types. Six habitats were used for Johnson's analysis. Johnson's test is less sensitive to subjective inclusion or exclusion of resources, but has been criticized (Alldredge and Ratti 1986) for its inability to detect even large differences between use and availability. However, it is a very robust test. Johnson's assessment was applied to all raccoons and males and females separately. The result was no significant difference ($P > 0.05$) between use and availability of habitat for all groups analyzed.

**Table 26.** Habitat use versus habitat availability for raccoons in High Knob Recreation Area, Virginia, 1989-1990. (Neu et al, 1974).

| Habitat | Male (N=12) | | | Female (N=8) | | | Total (N=20) | | |
|---|---|---|---|---|---|---|---|---|---|
| Type | %Avail | %Used | Pref[a] | %Avail | %Used | Pref | %Avail | %Used | Pref |
| W.Oak-N.Red Oak-Hickory | | | | | | | | | |
| > 50yrs | 45.5 | 34.5 | - | 39.5 | 37.5 | 0 | 47.2 | 36.0 | - |
| ≤50yrs | 7.9 | 9.3 | 0 | 19.0 | 18.7 | 0 | 11.4 | 13.8 | 0 |
| Y.Poplar-W.Oak-N.Red Oak | | | | | | | | | |
| > 50yrs | 34.1 | 45.3 | + | 32.4 | 37.1 | 0 | 31.7 | 41.3 | + |
| ≤50yrs | 10.9 | 7.2 | - | 6.9 | 5.4 | 0 | 7.8 | 6.3 | 0 |
| S.Maple-Beech-Y.Birch | | | | | | | | | |
| All yrs | 0.4 | 3.3 | + | 0.4 | 0.1 | 0 | 1.3 | 1.8 | 0 |
| Scarlet Oak | | | | | | | | | |
| All yrs | 1.2 | 0.3 | - | 1.8 | 1.2 | 0 | 0.9 | 0.7 | 0 |
| N locations | | 719 | | | 669 | | | 1388 | |
| $\chi^2$ | | 191.0 | | | 9.9 | | | 94.3 | |
| d.f. | | 5 | | | 5 | | | 5 | |
| P-value | | P < 0.001 | | | P > 0.05 | | | P < 0.001 | |

[a] + = used more (P < 0.05) than available, - = used less (P < 0.05) than available.

**Table 27.** Habitat use versus habitat availability for individual raccoons in High Knob Recreation Area, Virginia, 1989-1990. (Neu et al, 1974).

| Habitat | Raccoon 03 | | | Raccoon 05 | | | Raccoon 20 | | | Raccoon 16 | | | Raccoon 19 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | % Avail | % Used | Pref[a] | % Avail | % Used | Pref | % Avail | % Used | Pref | % Avail | % Used | Pref | % Avail | % Used | Pref |
| W.Oak-N.Red Oak-Hickory | | | | | | | | | | | | | | | |
| > 50yrs | 37.1 | 27.3 | 0 | 52.1 | 32.6 | - | 29.6 | 18.3 | 0 | 44.2 | 44.3 | 0 | 42.4 | 35.1 | 0 |
| ≤50yrs | 16.6 | 4.5 | - | 5.9 | 4.3 | 0 | 5.3 | 21.1 | + | 29.0 | 43.4 | + | 15.2 | 9.0 | 0 |
| Y.Poplar-W.Oak-N.Red Oak | | | | | | | | | | | | | | | |
| > 50yrs | 36.0 | 31.8 | 0 | 16.3 | 6.5 | - | 44.6 | 53.5 | 0 | 19.8 | 10.4 | - | 30.8 | 50.5 | + |
| ≤50yrs | 0.0 | 0.0 | 0 | 25.3 | 56.5 | + | 20.5 | 7.0 | - | 7.0 | 1.9 | - | 0.2 | 0.0 | - |
| S.Maple-Beech-Y.Birch | | | | | | | | | | | | | | | |
| All yrs | 7.9 | 36.4 | + | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0 | 4.3 | 0.9 | - |
| Scarlet Oak | | | | | | | | | | | | | | | |
| All yrs | 2.3 | 0.0 | - | 0.4 | 0.0 | - | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0 | 7.2 | 4.5 | 0 |
| N locations | | 66 | | | 46 | | | 71 | | | 106 | | | 111 | |
| $\chi^2$ | | 76.80 | | | 24.1 | | | 43.8 | | | 16.3 | | | 22.4 | |
| d.f. | | 4 | | | 4 | | | 3 | | | 3 | | | 5 | |
| P-value | | $P < 0.001$ | | | $P < 0.001$ | | | $P < 0.001$ | | | $P < 0.01$ | | | $P < 0.001$ | |

[a] + = used more ($P < 0.05$) than available, - = used less ($P < 0.05$) than available.

# Discussion

## *Population Dynamics*

### Survival and Mortality Rates

Survival was fairly constant throughout the year except during hunting season. The annual mortality rate during the study period for radio monitored raccoons (all adults) was calculated as 0.46 according to a method described by Pollock et al. (1989). Hunting was the leading cause (77%) of mortality (N = 13). Approximately 45.5% of raccoon carcasses collected from hunters were under the age of one year. Considering almost half of raccoons killed during the season are juveniles and adult mortality is 0.46 (largely due to hunting), juvenile mortality during the hunting season is probably quite high. Stuewer (1943a) theorized that approximately 50% of the fall population could be killed and still maintain an adequate breeding reserve, because of high juvenile survival and low mortality due to other causes. Kellner (1953) reported that hunting is the only factor that has any appreciable effect on populations of southwestern Virginia raccoons. Minser and Pelton (1982) found raccoon populations high in mountainous Tennessee in an area where hunting or chasing raccoons was prohibited or strictly controlled. However, in an area of similar habitat where hunting was open, raccoons were reported as being scarce. Cunningham (1962) found that the raccoon population more than doubled after a 10 year closure of the hunting season on the Savannah River Plant in Georgia, suggesting the effectiveness hunting has on reducing raccoon populations. Hunting is the popular method of harvesting raccoons throughout much of the country. Garner (1989) found that 33% of all raccoon mortality in eastern Maryland and Delaware was caused by hunting and only 12% because of trappers. Hunters in Michigan (Stuewer 1943a) and Alabama (Johnson 1970) accounted for 93 and 87% of the harvest. At High Knob all (10 of 10) harvested raccoons were taken by hunters. Clark et al.(1989) found 78% of deaths (N = 206) in Iowa due to harvest mortality, and 10% because of automobiles, the primary cause of nonharvest mortality. Clark et al.(1989) went on to suggest that because of the low nonharvest mortality, mortality due to harvest may act in an additive fashion and not in a compensatory manner.

Nonharvest mortality was small with poaching (suspected), automobile trauma, and unknown as the three causes. No predation was found on any monitored raccoon. In Tennessee, Rabinowitz (1981) found only 4% mortality (N = 135) due to natural causes. Reports from others also conclude that natural mortality in hunted populations is small to negligible (Stuewer 1943a; Johnson 1970; Garner 1989). Mech et al.(1968) found 54% of annual mortality in an unexploited population the result of anesthesia, live-trapping, disease, or parasitism all of which were likely the result of predisposing malnutrition. High Knob raccoons were in fair to good condition suggesting that malnutrition may not be a problem in High Knob during high mast crop years, such as was found in 1988-1989 (Figure 18). However, during low mast crop years, such as 1982-1984, the High Knob raccoons primary fall food source may fail to provide the needed winter fat reserves and the mast failure may cause malnutrition related mortality. Johnson (1970) showed a strong relationship between acorn crop failure, which occurs every 7 to 8 years, and survivorship, especially with juveniles. Juvenile natural mortality would likely be higher than adult mortality during the winter because they have less body fat to lose. Juvenile mortality between birth and the opening of hunting season was not calculated because no juveniles were radio marked.

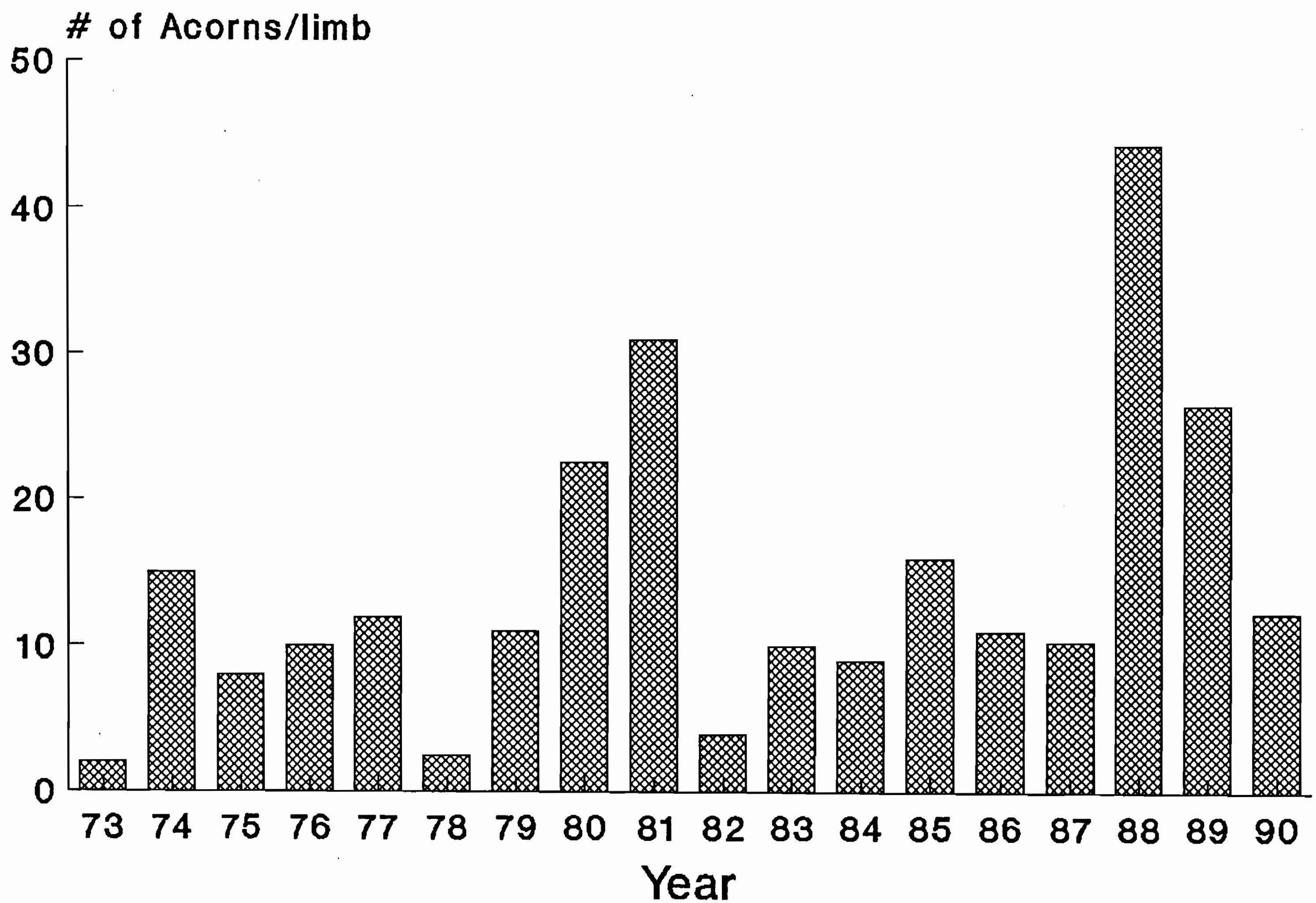


**Figure 18.** The VDGIF oak mast indices for High Knob Recreation Area, Virginia from 1973-1990.

*This index is based on information collected from 40 white oak and 40 red oak trees on various elevation gradients. The elevation gradients include low, medium-south exposure, medium-north exposure, and high elevation (adapted from Dutton 1987).

According to life table analysis, the estimate of the finite rate of increase indicated a decrease in the population by 7%. This estimate is based on the general survivorship of a "composite" of cohorts found in the life table (Table 5). Thus, this slight decrease in the High Knob raccoon population is the general population trend based on cohorts over the last nine years. Although High Knob had excellent and good mast crops in 1988 and 1989 (Figure 18), respectively, the slight population decrease of the High Knob raccoon population was more likely in part the result of the poor acorn crops of 1982 through 1987 (the period represented by the raccoon cohorts). Stability or slight decrease in the population suggests the poor habitat productivity of the High Knob region for raccoons as evidenced by low mast crops. Dutton (1987) suggested evidence based on the VDGIF oak mast survey indicating a lowered potential to produce "excellent" mast crops at High Knob relative to a Stony Creek study area in Giles county. In addition to lowered regional productivity, periodic failures in acorn yield may result in additional stresses on the population. According to Dutton (1987) mast crops at High Knob show relatively low yield, except for periodic peaks in yield every 7 to 8 years. Hunting also has an impact on the stability of raccoon populations of High Knob.

## Sex and Age Ratios

Sex ratios found in this study were not different from the expected (1:1) even ratio for both live-trapped and harvested raccoons. Adult sex ratios in many studies do not differ from expected (Stuewer 1943b; Sanderson 1951; Mech et al. 1968; Olsen 1983). Age ratios between hunter collected and live-trapped raccoons were quite different. Hunter collected raccoons were 45% (N = 121) juveniles, where live-trapped raccoons were only 3% (N = 31) juveniles. Low juvenile bias in live-trapping can easily be explained by examining the time of trapping. Trapping began in May and ended in September (with most trapping ending by mid-August). Juveniles will not travel with their mother until mid to late July and probably stay close to the den until mid-August.

Therefore, because trapping and the initiation of juvenile movements did not coincide, only one juvenile was trapped.

Johnson (1970) reported that harvests are often biased in favor of juveniles, because old, experienced raccoons are less susceptible to hunting pressure because of learning and memory. However, according to information from hunter collected raccoons, the harvest at High Knob had more (9%, N = 11) adults than juveniles. Olsen (1983) found ratios of juveniles and adults similar to those of High Knob among a harvested Massachusetts population. According to Smith (1980) "the ratio of young to adults in a relatively stable population is approximately 2:1 in most populations of game animals". Thus, if we assume the harvested raccoons represent a sample of the population in Wise and Scott county, the raccoon population has poor production (83 juveniles:100 adults). However, Downing (1980) suggests that age ratios are not very good measures of productivity or population growth. The annual finite rate of increase ($\lambda$ = 0.929) indicates a slightly declining population. This decrease is not as great as might be suggested by the juvenile:adult age ratio however, the annual finite rate of increase is probably a more reliable index of population growth.

In this study, only 4% of the harvested raccoons were over the age of 6. Olsen (1983) reported only 0.4% made it to 11 years of age. Long lives are not common in raccoons. However, females seem to live longer than males past the age of 5. Three times as many females as males were greater than 4 years of age (2 males: 4 females) in this study. Johnson's (1970) data had twice as many females in the older age classes ( > 6 years) as compared to males (N = 37).

## Physical Characteristics

Male and female raccoons at High Knob were found to have significantly different lengths and weights. Sexual dimorphism in weight classes is common among raccoons (Stuewer 1943a; Johnson 1970; Rabinowitz 1981; Garner 1989) although this difference is not always marked. A difference in length is less commonly found among sexes. Olsen (1983) found significant pelt length differences among specified age-sex groups. But many studies (Johnson 1970; Rabinowitz 1981) found only slight differences in length among the sexes (males being slightly larger).

Age of collected carcasses was determined using cementum annuli techniques rather than length and weight as these criteria are unreliable due to variations in both length and weight because of habitat, season, and geographic differences. Kellner (1953) noted little correlation between age and weight of raccoons of southwestern Virginia. Sanderson (1950) found errors of 10% and more when aging raccoons of Missouri using weight criteria. Cementum annuli provides slightly less error and allows one to determine age to year class whereas weight and length only permits two classifications, juvenile and adult (Grau et al. 1970).

Garner (1989) found 85.9% of raccoons in eastern Maryland and Delaware in good to fair condition, based on a subjective condition index similar to the one used in this project. Similarly, 82% to 97% of High Knob raccoons (hunter collected and live-trapped, respectively) were also in good to fair condition. Conditional differences in raccoons from eastern Maryland-Delaware and southwestern Virginia were not apparent during the years we compared these two populations. Both populations were sampled from the summer through the first months of winter.

Weight of High Knob raccoon carcasses collected in the late fall-early winter represented maximum weights of raccoons at High Knob as this is the period of maximum fat deposition. Live-trapped raccoon weights were not as heavy because they were captured from mid-May to September, a period of progressive weight gain, but not peak weight. Although no monthly variations in weight were recorded among the four months of hunting season, there was a sex*month interaction ($P = 0.002$) because male weights were greatest in December (among the four months examined) whereas females reached their maximum weight in January. Lowest weights for both sexes were recorded in the month immediately prior to the month that had the greatest weight (November for males, December for females). Stuewer (1943a) reported weight increases throughout the summer with a peak in the late fall-early winter. Similarly, Rabinowitz (1981) recorded seasonal weight gains from the beginning of spring to the end of summer. Summer weights were 65% and 48% heavier than early spring weights for males and females, respectively (Rabinowitz 1981).

Body condition results from High Knob raccoons indicate that a seasonal rhythm may be occurring. However, this rhythm may not be as dynamic as one might expect from a more dormant winter species, such as the bear (*Ursus* spp.). Raccoons are not known to be true hibernators; thus winter fat stores may not be as heavy as for true hibernators. Winter is a critical period, and requires fat reserves and weight gains in order for raccoons to survive periods of short-term dormancy when ambient temperatures are low and food is scarce. Poorest condition was found in in raccoons killed in October ($P < 0.05$), among the four months from which raccoons were collected. There was an age*month interaction for KFI because adults reached their peak condition in November, where juveniles reached their maximum condition in December. This increase in perirenal fat from October to November or December may indicate the presence of a seasonal rhythm which includes fall and early winter fat deposition. The large hard mast crops of 1988 and 1989 (Figure 18) probably were responsible for the body condition improvements of the raccoons through the fall and early winter. High Knob raccoons likely would lose body condition in the late winter-early spring as food resources began to diminish as seen by Mech et al. (1968) in Minnesota and Johnson (1970) in Alabama. This loss of body condition, may lead to emaciation especially with juveniles who have low fat reserves.

## Reproduction

Many researchers agree that raccoons mate in January, February, and March in Virginia (Kellner 1953; McKeever 1958; Clements 1972). According to telemetry data collected in the present study, there was no difference in activity between males and females during this period at High Knob. However, 59% of males and females (combined) were active in March which is more activity than observed in January or February.

Annual variations in percent of females breeding and number of placental scars/female do occur. However, data in the present study were combined from 2 years of carcass collections, because sample size was too small to compare years. Possible factors affecting annual variation in percent parous females include: nutrition, population density, and weather.

Age clearly affects pregnancy (Clark et al. 1989). Only 16.7% of High Knob females aged 13-24 months had placental scars, which is less ($P < 0.05$) than the 80% of adults > 24 months that had placental scars. In most studies, fewer females ≤24 months than females > 24 months became pregnant (Junge and Sanderson 1982; Olsen 1983; Clark et al. 1989). Stuewer (1943b) in Michigan, Junge and Sanderson (1982) in Illinois, Olsen (1983) in Massachusetts, and Clark et al. (1989) in Iowa reported pregnancy rates of 54% (N = 28), 59% (N = 131), 64% (N = 155), and 73% (N = 37), respectively in females ≤24 months. However, Johnson (1970) and Fritzell (1978b) found lower pregnancy rates in females ≤24 months from Alabama (6%, N = 35) and North Dakota (14%, N = 14), respectively. Pregnancy rates of females >24 months are quite high, varying between 81% (Olsen 1983) and 100% (Junge and Sanderson 1982) with many reports around 90% (Fritzell 1978b; Clark et al. 1989). Pregnancy rate remains consistent for most adults > 24 months. Clark et al. (1989) suggested that pregnancy rates decline for older females, but the results from our study do not support Clark et al.'s observation. Only 80% of High Knob hunter collected adult ( > 24 months) female raccoons were pregnant and 76.9% of live trapped adult ( > 24 months) female raccoons were lactating, which is lower than any adult ( > 24 months) pregnancy rate reported in the literature I reviewed. The low percent of High Knob females breeding indicates low productivity in the High Knob raccoon population. One possible explanation for low productivity at High Knob may be that High Knob has poorer quality habitat than that of other study areas. Bissonnette and Csech (1938) found raccoons on a low protein diet had fewer (23% less) pregnancies (as demonstrated by presence or absence of a litter) than raccoons on a 'normal' diet. If protein were limited in the raccoon food supply at High Knob it may have an effect on productivity in that area.

Mean litter size of High Knob raccoons was 3.53 (range 2 to 5). Litter sizes were not different among age groups ($P > 0.05$). Litter size is commonly reported to be around 3 or 4. McKeever (1958) in Georgia and Florida, Olsen (1983) in Massachusetts, Clark et al. (1989) in Iowa, and McLaughlin (1953) in Virginia reported mean litter sizes of 3.6, 3.6, 3.2, and 3.3, respectively. Clark et al. (1989) reported that litters from females >24 months were significantly larger (3.8) than those from females ≤24 months (3.1). The present study and Johnson's (1970) work does not support this result.

There was no difference in weight between parous and nulliparous females ≤24 months. Similarly, no difference in weight between parous and nulliparous females >24 months was found. However, nulliparous females were in better condition than parous females. This deficiency in fat reserves of parous females may be caused by the energy costs of lactation.

## Parasites and Diseases

Raccoons are the host of at least 97 species of endoparasite and 37 species of ectoparasite as well as being a reservoir for many diseases (Frederick et al. 1986). But despite the variety of parasites that use the raccoon as a host, few are pathogenic enough to cause death (Stuewer 1943a; Kellner 1953). Most studies, like this one, found parasites present, but pathogenicity negligible. However, parasitism may influence mortality rates in years with extreme winter conditions (Frederick et al. 1986). Poor nutrition and weather extremes permit parasites to accelerate the raccoons decline toward cachexia and death. Starvation and extreme parasitism was the most important mortality factor in an unexploited raccoon population in Minnesota, especially among juveniles (Mech et al. 1968). Introduced parasites and diseases from activities such as stocking may have a considerable negative effect on native populations by introducing pathogenic exotic parasite or disease causing organisms to a previously unexposed population.

The present study found ticks on 33% of the raccoons checked. Kellner (1953) found all live-trapped raccoons (N = 9) infested with fleas, and 33% had *Dermacentor* spp. Rabinowitz (1981) found about 50% of 153 raccoons harboring ticks of two genuses: *Dermacentor* and *Ixodes*. These ectoparasites normally cause no severe infection (Johnson 1970). However, *Dermacentor variabilis* is a primary vector of Rocky Mountain Spotted Fever (*Rickettsia rickettsi*) in the eastern United States and uses the raccoon as a host.

Most endoparasites of the raccoon have low pathogenicity causing only some inflammation and necrosis. However, extreme or acute parasitism may lead to ulceration and/or perforation of the intestinal wall in some types. In this study, 75% of the carcasses had intestinal parasites. Nematodes were common. *Physaloptera* spp. occurred in 33% of the raccoons examined in this project. Johnson (1970) found infestation of *Physaloptera* spp up to 47%. Mech et al. (1968) noted *Physaloptera* spp. causing severe gastritis. However, according to Chandler (1942) and Johnson (1970) *Gnathostoma procyonis* is considered to be the most harmful parasite of raccoons. But, *Gnathostoma* spp. was only found in 4.1% (N = 123) of raccoons at High Knob.

Ascarids in this study, found in 11% of the carcasses, were found in more females than males, and more juveniles than adults. Parasite loads and frequency may be correlated to condition of the host. Ascarids were found in more raccoons in poor condition than those in good condition. Since juveniles are generally in poorer condition heading into the winter than adults, one may expect the frequency or quantity of parasitism to be higher in juveniles as was seen. Ascarids are quite pathogenic as their larvae migrate to areas such as the liver and lungs, which may result in extensive damage. *Baylisascaris procyonis*, an ascarid, is an important cause of fatal nervous system disease and eye disease in wild and domestic animals (Garner 1989). Jacobson et al. (1976) reported an epizootic of cerebrospinal nematodiasis in cottontail rabbits (*Sylvilagus floridanus*) and woodchucks (*Marmota monax*) as a result of *Baylisascaris procyonis*. Raccoons show 50 to 80% prevalence of *Baylisascaris procyonis* in local populations, but this worm causes few problems in raccoons unless worm populations are high enough to cause intestinal blockage (Kazacos 1983). Stone (1983) found *B. procyonis* causing intestinal blockage and death in several raccoons in New York.

No signs in the field or upon necropsy showed evidence of disease in High Knob raccoons. Kellner (1953) and Rabinowitz (1981) found no evidence of rabies or distemper in southwestern Virginia and Tennessee. Rabies and distemper are the only diseases known to cause significant reductions in raccoon numbers. Johnson (1970) suggested distemper is the only important disease in the population ecology of the species.

I did not specifically test for rabies in High Knob raccoon carcasses, but no signs of rabies were observed in the field or necropsy. Also, no cases of rabies in raccoons have been reported in extreme southwestern Virginia (Lee, Wise, Scott, Dickenson, and Russell counties). However, rabies in skunks (*Mephitis mephitis*) has been reported in these areas (Suzanne Jenkins 1991, pers. commun.). Most authors suggest rabies is related to high population densities. Frederick et al. (1986) calculated that only 10% of the raccoon population dies from exposure to rabies at any density, because raccoons frequently survive exposure to the rabies virus (McLean 1975). Johnson (1970) reported rabies as being insignificant in Alabama, but cites an epizootic in Florida and Georgia that began in the late 1950's. Currently, the raccoon is the primary vector of a continuing epizootic in the mid-Atlantic region of the United States. Raccoons made up 77% of reported animal rabies cases from Virginia, Maryland, and Pennsylvania in 1987 (Center For Disease Control 1988). Raccoons were formerly thought to be a rabies reservoir only in the southeastern U.S. The first rabid raccoons of the current rabies epizootic were reported in northern Virginia and West Virginia in the late 1970's (Jenkins and Winkler 1987). Transmission of the disease is believed to be from raccoon to raccoon. Work continues to create an oral vaccine for raccoons against rabies (Rupprecht et al. 1989).

## *Food Habits*

Raccoons are an omnivorous, opportunistic feeder. The raccoon's seemingly unlimited variety of foods is very important in the extraordinary adaptability, survival, and distribution of the species in North America (Stuewer 1943a). However, raccoons have strong vegetarian tendencies during most of the year which may be most related to availability. Johnson (1970) reported that Alabama raccoons take plant foods most of the time in all seasons, making up 74 to 90% of total volume and 53 to 90% of percent occurrence. Schneider et al. (1971) suggested that aquatic animals are preferred foods when available. Raccoons tend to eat more invertebrates than vertebrates as animal food. Perhaps the most important invertebrates are crayfish and insects.

This study only examined raccoon diet in the fall and early winter because our stomach samples were from raccoons killed during the fall hunting seasons of 1988 and 1989. Fall diets of High Knob raccoons had a high representation of hard mast. Acorns and beech (*Fagus grandifolia*) were eaten in considerable proportions. This is believed to be the result of the two excellent mast years of 1988 and 1989 (Figure 18). Corn, grape (*Vitis aestivalis*), and pokeberry (*Phytolacca americana*) were secondarily important. Animal matter made up only 8.2% of dry weight in the diet and this was probably related to the lack of abundance. Kellner (1953) found raccoons of southwestern Virginia ate primarily wild grape in the fall with crayfish and acorns being secondarily important. Kellner also suggested that a shift occurs from late fall to early spring from vegetable to animal matter. This change he believed was due to the scarcity of vegetable foods during the period. Many other studies continue to see fruit as the predominant food item in diets (Stuewer 1943a; Baker et al. 1945; Johnson 1970; Garner 1989).

During the early part of the winter, raccoons of High Knob continued to feed on plant material, primarily acorns, grape, corn, and beech nuts. These plant foods are important in building the fat reserves seen in High Knob raccoons. Stuewer (1943a) reported Michigan raccoons ate acorns and corn in considerable quantities in the winter. Baker et al. (1945) in Texas also noted a heavy reliance on acorns (67% volume) with only 10% of the diet consisting of crayfish. Garner (1989) discussed the aquatic related food habits of eastern Maryland and Delaware raccoons during the winter, and found a variety of aquatic related food items in scats (amphibians, fish, crayfish, crabs, muskrats, and waterfowl).

In many studies raccoons eat animal matter primarily in the spring, as it is usually available, and may be important for females for litter production. Bissonnette and Csech (1938) demonstrated the importance of protein on pregnancy rates. Garner (1989) found raccoons of eastern Maryland and Delaware in the spring primarily ate winter-killed mammals, emerging amphibians, minnows, and later in the spring bird eggs. Johnson (1970) in Alabama found invertebrates taken throughout the year but noted that they were most important in the late winter and early spring, making up 17% of total volume. Johnson went on to suggest that the true importance of insects to raccoons is not reflected in quantitative food habits data. Plant foods that are eaten are commonly high in carbohydrates and fats, but low in protein, whereas insects provide a much needed and rich source of protein. Baker et al. (1945) found animal food (72% volume) in higher representation than vegetation (28%) in spring diets of Texas raccoons. Stuewer (1943a) found spring to be the only season when animal matter (56.8% volume) was greater than vegetation matter by volume.

Spring-to-summer is a period of transition from animal foods to plant foods for raccoons. Sonenshine and Winslow (1972) found raccoons of eastern Virginia eating 98% plant food during this time, mostly corn (*Zea mays*). Kellner (1953) reported many fruits such as huckleberry (*Vaccinium* spp.), blackberry (*Rubus* spp.), and cherry (*Prunus* spp.) as being important summer foods. Giles (1940), Stuewer (1943a), Johnson (1970), and Garner (1989) all found summer to be a period of significant fruit eating by raccoons. Fruits that were consumed included mulberry (*Morus* spp.), raspberry and blackberry (*Rubus* spp.), wild grape, wild plum (*Prunus* spp.), persimmon (*Diospyrous virginiana*), and a variety of others.

Obviously raccoon diet has considerable regional variations depending on what foods are available. Johnson (1970) found fruits to be a very important component of the Alabama raccoon diet. Corn and other planted crops are important in the Midwest, where they are abundantly available. Planted crops are also important locally when natural foods are not readily available. Yeager and Elder (1945) found crayfish of little importance in diets, but found raccoons strongly favoring hunter crippled or killed waterfowl. Generally, raccoons eat vegetation and only switch to animal matter when its abundant or during the late winter-early spring when vegetation is scarce.

In the High Knob area, food may be a limiting factor on the raccoon population. At High Knob there is a scarcity of aquatic foods based on field observations and stomach contents analysis. Weather conditions at High Knob such as early frosts may cause frequent fruit and mast failures (Figure 18) (Kellner 1953). In eastern Virginia, where population levels of raccoons are rather high, there is a heavy reliance on water-associated foods, especially in the spring. Without this critical resource at High Knob, in a season where caloric intake is rather low, malnutrition related mortality may result. Populations also may be suppressed because of food limitations of a poor mast crop. Raccoons of High Knob used mast in considerable amounts during our 1988 and 1989 study to build fat reserves to survive the winter. Mast crop failures which occur every 7 to 8 years (Figure

18) (Dutton 1987) may result in significant malnutrition and condition related mortality by predisposing raccoons to disease, parasites, and predation.

## *Home Range*

Home ranges at High Knob were affected by several factors including sex and age of individual raccoons and season. Adult males in this study had seasonal and annual home ranges twice as large as adult females. Stuewer (1943a), Fritzell (1978a), and Rabinowitz (1981) all found adult male home ranges significantly larger than adult female home ranges. Stuewer (1943a) suggests that males have larger home ranges because they are free from parental care and are thus "free to wander about by themselves most of the year". Rabinowitz (1981) suggested males have large spring ranges to enhance breeding potential during the mating season. However, High Knob raccoons showed no significant sex*season ($P = 1.00$) interaction in home range (convex polygon and 95% harmonic means) size. Ellis (1964) and Fritzell (1978a) explained that female raccoons with nestling young had restricted postpartum movements, thus decreasing home range size following parturition. However, I believe female movements are restricted only for a short time just after parturition, before normal movements are resumed and 'normal' spring-summer home ranges are reestablished. I base this conclusion on the fact that no sex*season interaction in home range size was found.

Seasonal changes in raccoon home range size are common. In this study summer ranges were the largest followed by fall and winter home ranges in decreasing size. Summer ranges were significantly ($P < 0.05$) larger than winter ranges. Glueck et al. (1988) found Iowa raccoons significantly ($P < 0.05$) reduced their home ranges from 103 ha at the beginning of November to 37 ha at the end of November. They theorized originally that this was due to human disturbance during the fur harvest season, but concluded that prevailing weather (cold ambient temperatures, and snowfall) was the cause of home range reductions. Johnson (1970) reported that use of an area depends on shifts in food availability over seasons. I believe that home ranges are reduced from summer to winter because of changing weather conditions and food availability, limiting raccoon movement. Moen (1978) found similar seasonal reductions in activity as well as heart rate and metabolism from summer to winter in white-tailed deer (*Odocoileus virginianus*) and related these seasonal rhythms to resource availability, specifically forage consumption and digestibility. These rhythms are simply a means of conserving energy. During the winter when caloric intake is low and low ambient temperatures cause heat loss, raccoons restrict movements which includes reducing home range size to save energy.

Differences in sex and age of individuals as well as population level, season, habitat quality, method of collection and analysis of data, and length of study all cause great variation in home range size reports in raccoons. Stuewer (1943a), Urban (1970), Johnson (1970), Olsen (1983), and Glueck et al. (1988) all reported home range sizes considerably smaller than home ranges found during this study. Rabinowitz (1981) reported similar sized home ranges and Fritzell (1978a) reported larger home range sizes for prairie raccoons than those of High Knob (Table 28). Food availability and habitat differences may be one explanation for the larger size of home ranges calculated in this study as compared to other studies. Comparisons (Table 28) shows that all of the studies except Glueck et al. (1988), recording smaller home ranges than those of High Knob occurred in habitats with bottomland hardwood forest or other aquatic related habitats. However, studies recording home ranges of similar or larger sizes, except Glueck et al. (1988) than those of High Knob were observed on open fields, or cultivated lands, all of which are generally considered fair to poor raccoon habitat especially in the late winter-early spring.

Although home ranges were larger for males than females and larger in the summer than in the winter the activity center size remained unchanged between sexes or between seasons in this study. This indicates that males may be 'roaming' around more than females and raccoons 'roam' more in the summer than in the winter, but the general area of primary use remains the same among sexes and seasons. Rabinowitz (1981) found that activity centers shifted among seasons. This was not apparent at High Knob.

**Table 28.** Comparison of annual convex polygon home range sizes (ha) of adult raccoons in different habitat types.

| Reference | N | Home Range | Habitat | State |
|---|---|---|---|---|
| Urban (1970) | | | | |
| Combined sex | 9 | 48.4 | Marsh | OH |
| Johnson (1970) | | | | |
| Male | 1 | 99.1 | Bottomland hardwoood surrounded by upland pine | AL |
| Glueck et al. (1988) | | | | |
| Male | 3 | 177.0 | Cultivated land surrounded | IA |
| Female | 8 | 91.0 | by upland/lowland hardwood | |
| Olsen (1983) | | | | |
| Male | 3 | 185.6 | Flood plain surrounded | MA |
| Female | 5 | 134.6 | by oak-pine uplands | |
| Stuewer (1943a) | | | | |
| Male | 19 | 203.6 | Bottomland | MI |
| Female | 17 | 108.4 | hardwood | |
| High Knob | | | | |
| Male | 11 | 649.1 | Upland hardwood | VA |
| Female | 8 | 239.0 | forest | |
| Rabinowitz (1981) | | | | |
| Male | 4 | 750.0 | Open field surrounded | TN |
| Female | 7 | 300.0 | by lowland hardwood | |
| Fritzell (1978a) | | | | |
| Male | 9 | 2560.0 | Cultivated land with | ND |
| Female | 7 | 806.0 | some wetlands | |

Home range overlap during the present study was considered extensive between the sexes. On average, 67.2% of each home range was overlapped by 3 to 4 other home ranges. Overlap was greatest in the fall and winter. Overlap was least during the summer. Rabinowitz (1981) found spring overlap greatest for both sexes.

Although raccoons are generally solitary animals, Stuewer (1943a) suggested that raccoons have no exclusive "home areas", as many of his raccoons had overlapping ranges, particularly adult males. In the present study, annual male-male overlap was twice as common as female-female overlap, but intersexual overlap was the most common. Fritzell (1978b) regarded exclusive occupancy by two or more adult females of one adult male home range as suggesting a polygynous mating system. He went on to suggest that the adult male maintains (competes for) this exclusive area "within which one or more sexually mature females reside". Rabinowitz (1981) found intersexual overlap extensive during the spring as it is the mating season. This study, however, found intersexual overlap greatest in the fall and least in the summer among adults. One possible explanation for low intersexual overlap during the summer is that females may remain close to their den following parturition to care for their young. Thus reducing their summer home range size temporarily and reducing the number of home range overlaps of their range. Female-female overlap also was uncommon among High Knob raccoons in the summer, but was common in the winter. This difference also may be related to parturition, in that females may tend to remain close to their kits for a period following birth.

Male-male overlap was most common in the summer, and rare in the winter. Fritzell (1978b) suggested a form of territoriality exhibited by male raccoons competing for access to females. This territoriality may explain the low male-male overlap in the winter as mating occurs in the late winter-early spring. One adult male may enhance his total fitness by increasing the probability of mating by maintaining exclusive areas in which several females reside during the mating season. Fritzell (1978b) saw little overlap among adult males during this period. Adult males that occupied adjacent home ranges were seldom near each other and Fritzell concluded that territorial defense or advertisement among males was probable. Rabinowitz (1981) supported this by suggesting males maintain a distance between each other during breeding and parturition, but not during the rest of the year. Raccoons the rest of the year appear to only exhibit mutual avoidance, except in the case of communal denning.

One home range shift in an adult male was recorded at High Knob. Fritzell (1978b) suggests that the death of one adult male caused a shift in the home range of another adult male, but the home ranges of these two adult males overlapped prior to the death. The reason for the shift observed in this study is unknown, but it may be due to availability of preferable habitat, access to females or the male may have been driven from its former range.

## *Activity and Movements*

Raccoons usually are active from sunset to sunrise. Activity was low (<26% were active during any one hour interval) among High Knob raccoons during the first 11 hours of the day (sunrise-sunset). Urban (1970) noted that raccoons spent day periods at or near their dens. Most of the literature supports low day time activity except Ellis (1964) who found 74% of raccoons active during the day in an Illinois marsh. Activity was higher at night (sunset-sunrise) and remained constant throughout the first 7 hours after sunset. During the spring and summer, 13.1-15.0 hours after sunrise (Figure 16) may be a transition period for raccoons from inactivity to activity. Raccoons show 81-100% activity from 13.1-15.0 hours which is higher than other day (sunrise-sunset) activity estimates. Rabinowitz (1981) suggested times around sunset as transitional periods between inactivity and activity.

Activity of raccoons differed among seasons and months. Activity of High Knob raccoons in the spring was moderate compared to other seasons. Activity of raccoons was higher in February and March than in months preceding or following. High activity during February and March may be because of mating activities. Urban (1970) found activity in the spring more evenly distributed throughout the night and related activity all night to the breeding season. Activity was greatest in the fall months among High Knob raccoons, which is believed to be related to food gathering activities associated with creating sufficient fat reserves necessary to survive the winter. Rabinowitz (1981) and Olsen (1983) also reported high activity during the fall. Rabinowitz went on to report high proportions of raccoons active during the entire night in the fall than in all other seasons. Activity was lowest during the winter, particularly December, in High Knob raccoons (Table 24). This halt in activity appears to be related to weather and/or food availability as raccoons spent more nights at rest, instead of moving and feeding. Moen (1978) saw similar restrictions of deer in activity during the winter due to poor forage digestibility and availability. Activity during the winter was low for all hours following sunset compared to other seasons (Figure 17). Summer activity was also low during the day when compared to other seasonal days. Low day activity in the summer appears to be weather related as raccoons may be avoiding thermal stress by resting in dens. However, activity during summer nights was high (Table 23).

Daily movements of High Knob raccoons were approximately 49.4 meters/hour. Ellis (1964) recorded greater average movements of males (175 m/hr) than females (100 m/hr) in Illinois. Urban (1970) found similar rates of travel (161 m/hr) and noted that long distance movements occurred over short periods, followed by long periods of time spent in small areas of shallow water (when animals were presumably feeding). Ellis' (1964) and Urban's (1970) movement estimates are larger than movement estimates recorded at High Knob. However, the methods used by Ellis and Urban to estimate movement were different from those used at High Knob. High Knob raccoon movement was estimated by using the distance and time difference between two consecutive observations (one day and one night) which were on average (± SE) 7.8 hours (± 0.4) apart. However, Ellis (1964) and Urban (1970) estimated movement obtaining successive radio fixes at night (sunset-sunrise) every two and one hours, respectively. Therefore the difference in rate of movement could be due to the methodology applied, but other factors affecting movement such as habitat differences can not be discounted. Butterfield (1944) suggested the importance of waterways as travel corridors recording movements concentrated along waterways. Johnson (1970) correlated large daily movements to food scarcity. High Knob male raccoons moved at greater rates than females in all seasons. Rabinowitz (1981) examined movements between day bed locations on subsequent days in Tennessee and found males averaging more distance (600 m) than females (190 m). Females were suggested as having limited movements because of parental responsibilities.

Fritzell (1978a) showed higher consecutive day bed use by females than by males. Females use the same den more than males because of parental responsibilities (returning to the den to nurse, energetic or risk reasons involved in moving young). Use of the same shelter from one day to the next was uncommon in High Knob raccoons, other than during the winter. Movements were often made to different locations indicating infrequent use of the same den on subsequent days. Mech et al. (1966) and Shirer and Fitch (1970) noted animals shifting resting sites almost every day and suggested that raccoons made no predictable pattern in making shifts. Shirer and Fitch found Kansas raccoons shifting den sites from the den previously occupied 78% of the time. They also reported that only 13% of raccoons remained in the same dens for two days, and 3% stayed in dens three and four days in a row. Apparently, raccoons find a convenient den wherever their nocturnal activity leads them, if den sites are abundant. Thus, since a variety of dens were used by raccoons of High Knob, den sites are assumed to be abundant and not a limiting factor. Schneider et al. (1971) found long-term use of dens only during certain periods: winter denning and natal dens. They noted that raccoons use short-term dens most of the time, rarely using the same den two successive days.

Raccoon movements in different seasons, like activity, were also variable. High Knob raccoons moved most during the summer, particularly in June. Fall movements were second longest perhaps for the same reason (building of fat reserves) that activity was high in the fall. December movements in High Knob raccoons were shortest possibly in response to weather; however, other causative factors can not be discounted. Reduction in activity and movement during the winter is commonly seen (Sharp and Sharp 1956; Rabinowitz 1981; Glueck et al. 1988). At High Knob, December had the lowest temperatures (15.6° C), the greatest snowfall (37.3 cm) (Table 1), and the least raccoon activity and movement of all other months. Stuewer (1943a) and Sharp and Sharp (1956) noted reductions in activity because of low temperatures (below 0° C). Rabinowitz (1981) considers temperature the controlling factor in winter dormancy.

Difficulty in studying raccoons in the winter has led researchers to unanswered questions concerning hibernation. At High Knob raccoons do enter short periods of dormancy. Sharp and Sharp (1956) described raccoons entering periods of semihibernation, but did not explain the term. Raccoons do not enter a state of torpor during dormancy according to Stuewer (1943a). Dormancy may be described as a period of deep sleep to conserve energy. However, Morrison (1960) claims that fat reserves of mammals the size range of badgers would not be sufficient to sustain these animals during a winter period, without a considerable reduction in metabolism. Brocke (1970) reported that opossums (*Didelphis marsupialis*) exhibit signs of torpor. However, work done by Folk et al. (1968) in Iowa showed no drop in body temperature or heart rate of raccoons sleeping outside on cold winter nights. Similarly, Thorkelson and Maxwell (1974) found dormant raccoons easily roused and maintaining body temperatures above 35° C. Normal body temperature of raccoons is around 38° C. With this information it appears that raccoons do not hibernate.

## *Habitat Use*

Forested areas are important to raccoons for shelter and food. Hard mast and large, older trees provide necessary food and shelter. However, according to literature reviewed, raccoons are scarce in pine forests, dry upland woodlands, and large open fields (Kaufmann 1982). McKeever (1958) and Leberg and Kennedy (1988) found only 'intermediate' populations in upland deciduous forests. McKeever also found low population densities in pine-hardwood and pine stands. In general, in the southeastern U.S., mixed pine-deciduous and pine forests support lowest densities and bottomland deciduous and aquatic-associated habitats sustain the greatest abundance of raccoons. In one case densities were 13 to 23 times higher in bottomland forest than upland forest (Leberg and Kennedy 1988). Olsen (1983) found forest habitat types not used differently than available or used significantly less than available.

Forest stand habitat analysis in the present study was difficult to interpret as stands were very similar. Most habitat studies compare agricultural land, wetlands, upland forest, and bottomland forest, which are much broader categories than the relatively homogeneous habitat of High Knob. In a broader category, all of High Knob could be placed into the upland deciduous forest category. Because of this similarity in cover types, it is easy to see why Johnson's preference assessment found no significant differences among forest stand types. Neu et al.'s (1974) method found variations in use of different stand types, but the results are difficult to interpret and lack consistency. Therefore, I concluded that because of the homogeneity of stand types, no preferences are significant. However, it is important to realize that this upland deciduous forest habitat, according to other studies, has been able to support only intermediate populations of raccoons, unlike those of bottomland hardwood or aquatic-associated habitats which support much larger densities. Glueck et al. (1988) found timbered areas (both upland and lowland) used more than expected, but the habitats analyzed did not include aquatic-associated habitats, only timberland, fencerows, and crop land. McLaughlin (1953) pointed out that although oak mast was found in much larger quantities in mountainous Virginia, the aquatic foods of eastern Virginia more than compensated for the lack of oak mast. The carrying capacity of upland forest habitat obviously depends largely on hard mast. Kellner (1953) and Minser and Pelton (1982) suggested that extensive logging activity and clearcuts may be a cause of reduced raccoon populations. However, at High Knob, logging has been minimal and I believe its effect on populations may even have been beneficial by creating diversity and allowing soft mast production.

Because corn was so often found in stomach contents of hunter killed raccoons, it appears use of small agricultural areas is common in the High Knob area (Wise and Scott counties). Urban (1970) in Ohio and Glueck et al. (1988) in Iowa found raccoons using agricultural habitats less than available. Olsen (1983), however, found hunted Massachusetts raccoons using intensive agricultural areas (mostly cornfields) in proportions higher than available. Olsen suggests that agricultural lands with crops such as corn become very important, particularly in the summer and fall.

## *Management Considerations*

Raccoon populations at High Knob are stable or slightly decreasing as evidenced by the finite rate of increase. However, poor trap success and large home range size indicate that the population size at High Knob may be relatively small. Low raccoon populations at High Knob may be due to the region's generally poor habitat suitability for raccoons. The estimated finite rate of increase indicates that no population growth is occuring at High Knob. Low acorn yields from 1982 through 1987 may be partially responsible for this lack of growth. The High Knob region is dominated by upland hardwood forest, which can support only intermediate to low raccoon populations even under good conditions. Upland hardwoods generally are considered less productive than bottomland forest areas in terms of habitat required by raccoons (primarily food production). Low food availability over many years at High Knob with only occasional swells (peaks in the acorn cycle) in food availability may result in low raccoon production and population densities. During this study raccoons were found in good condition in part because of the high acorn yield during the years the study was conducted. This may indicate the potential for population growth at least during years when food production is high.

Hunting was the primary cause of mortality in High Knob raccoons monitored in this study. Hunting is an important influence on the High Knob raccoon populations and provides sport and recreation to thousands of hunters. Clark et al. (1989) suggested that low nonharvest mortality is an indication that hunting acts in an additive rather than a compensatory manner. Additive mortality means that hunting does not replace some other (natural) form of mortality, but instead adds to that mortality. Low nonharvest mortality at High Knob suggests that hunting may have an additive effect on the population and this additive mortality may be pronounced under poor habitat conditions (especially with mast failures) as seen at High Knob. Additive hunting mortality probably inhibits population growth, and in some years when habitat conditions are particularly poor, additive hunting mortality may cause population declines. Since productivity of raccoons at High Knob is low, as evidenced by low reproduction rates (particularly yearling females) and low juvenile:adult ratios in the hunter harvest, it is unlikely that the additive impact of hunting is compensated for with increased recruitment.

The habitat limitations at High Knob in conjunction with hunter harvest are the most likely causes of a low raccoon population. Poor recruitment due to low raccoon productivity makes recovery from population declines (whether they are due to habitat limitations or hunting) slow.

Given the high demand for raccoon hunting and its popularity in southwestern Virginia, it would seem desirable to increase raccoon population size in southwestern Virginia. A number of alternatives exist to accomplish this goal. In order to maintain a larger standing crop, harvest pressure may be reduced by raccoon hunters voluntarily reducing their take by limiting their harvest to even less than that allowed by regulations (currently two per party per night west of the Blue Ridge). Raccoon hunters should also be encouraged to leave family groups (mother and offspring) as they are critical to the health of the population. I have received entire family groups (mother and 1-4 young) during my carcass collection from hunters, suggesting that family groups in the High Knob region are still intact when the hunting season begins. By leaving these groups intact or at least not taking the entire group (which may exceed bag limits anyhow), hunters can ensure a good breeding population during the mating season.

A less desirable alternative may be to delay the opening of harvest season by 2 weeks to a month, from its present opening date (October 15). This would guarantee raccoon young more time to disperse and become self-sufficient, increasing the potential for young raccoons to survive the harvest season. The chase season could be extended from its current opening date (August 1) to the delayed opening date of hunting season. This substitution of harvest opportunity for chase season would allow raccoon hunters to train their dogs and enjoy their sport while potentially ensuring increased survival of young raccoons.

Habitat enhancement is perhaps the most effective and most promising management tool to encourage a larger and healthier raccoon population at High Knob. However habitat enhancement may be limited by general landuse practices of the High Knob region (lack of substantial farming, and timber interests). Habitat deficiencies are a major limiting factor in many areas in the Southwest, despite the raccoon's adaptability and opportunistic behavior. Many habitat manipulations that benefit the raccoon also benefit other forest game species such as wild turkeys, gray squirrels, and deer. Although den sites do not appear to be a limitation at High Knob, older hardwood stands are important not only for dens, but also for hard mast production. The abundance of secure den sites at High Knob provides temporary refuges for raccoons from weather conditions and hunters.

Mature oak and beech stands are critical for raccoon den sites and fall food. At High Knob, food supply may be limited in some years as hard mast crops fail. Although no evidence of malnutrition was found (in fact, High Knob raccoons were in fair to good condition), the mast crop was excellent to good for both years (1988-1989) of my study. Food availability in other years (1982-1987) was not as good as was seen during this study (Figure 18). Adequate food supply is crucial during the late fall and early spring to sustain raccoons throughout the late winter-early spring. Acorns and other hard mast are an important fall food and nut-trees such as oaks and beech should be encouraged. However, during mast crop failures, alternative food supplies also should be abundant to maintain a stable population. Promoting fruit-producing species such as wild grape, pokeberry, russian olive, and persimmon creates a buffer for mast crop failures. Planting game food patches also provides emergency winter food for raccoons and other species. Johnson (1970) suggests that grassy openings promote high insect populations, an important food source of raccoons in the spring. Raccoon clubs interested in enhancing local raccoon populations could create food patches on private or public land providing an additional source of food for raccoons.

Protection of stream quality and the areas adjacent to these water areas also may be important at High Knob. Extensive use of wetland areas by raccoons has been recorded by a variety of authors (Stuewer 1943a; Sonenshine and Winslow 1972; Kaufmann 1982; Minser and Pelton 1982; Olsen 1983; Leberg and Kennedy 1988). Permanent water areas provide food, particularly during the critical early spring period. Leberg and Kennedy (1988) found western Tennessee raccoon densities 2 to 11 times higher in sites close to permanent water. Creating woodland buffers around streams may be one method of preserving raccoon habitat. Constructing ponds and marshes near woodlands may create a productive aquatic food supply. Similarly, beaver activity is usually very beneficial to raccoons, producing aquatic food and dead trees used as den sites.

Stocking of raccoons from other areas should be discouraged at High Knob for three simple reasons. (1) Stocking is ineffective in creating a larger population because of other limiting factors. Translocated raccoons suffer high mortality rates and tend to disperse long distances from the site of release (Wright 1977; Nettles and Martin 1978; Allen 1980). (2) Stocking is expensive. Money spent on stocking could easily be spent more effectively on habitat improvements. Also most stocking programs yield low return rates (Tayor and Pelton 1979). (3) Stocking is dangerous. Stocking raccoons spreads parasites and diseases which may threaten the native population with parasites such as *Baylisascaris procyonis* (Jacobson et al. 1976) and diseases such as rabies and distemper (Johnson 1970; Schaffer et al. 1978; Nettles et al. 1980).

In conclusion, it is unlikely that raccoon populations will ever be as high at High Knob as in lowland areas because of the poor productivity of upland hardwood forests in relation to bottomland hardwood forests, lack of highly productive aquatic areas, and periodic mast crop failures. The most promising approach to population enhancement and better raccoon hunting at High Knob is through habitat enhancement and voluntary reduction in hunter harvest.

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# Appendix A. Data collected at High Knob

Appendix Table 1. Data collected from live-trapped raccoons of High Knob Recreation Area, Virginia. 1989-1990.

| Radio No. | Sex | Age[a] | Condition[b] | Total Length[c] | Tail Length | Body Length | Rear Ft Length | Ear Length | Girth | Neck Circ. | Head Circ. | Weight (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 151.421 | F | A | 3 | 86.0 | 25.5 | 56.3 | 10.5 | 5.3 | 33.7 | 20.1 | 23.8 | 4.65 |
| 151.110 | F | A | 2 | 73.8 | 23.1 | 51.4 | 9.2 | 5.7 | 34.5 | 19.8 | 23.9 | 3.40 |
| 151.140 | M | A | 3 | 78.1 | 22.9 | 52.8 | 10.2 | 5.2 | 30.5 | 21.4 | 24.4 | 3.80 |
| 151.740 | F | A | 2 | 78.6 | 25.3 | 50.9 | 9.9 | 5.0 | 29.4 | 19.6 | 22.5 | 3.70 |
| 151.820 | F | A | 2 | 81.9 | 25.3 | 55.4 | 9.9 | 5.6 | 31.2 | 20.0 | 23.1 | 4.62 |
| 151.270 | M | A | 2 | 79.3 | 22.9 | 54.7 | 9.8 | 5.4 | 30.0 | 20.7 | 23.8 | 3.70 |
| 151.160 | M | A | 2 | 77.1 | 21.6 | 56.0 | 9.8 | 5.1 | 30.8 | 21.3 | 23.6 | 4.00 |
| 151.941 | M | A | 3 | 82.4 | 24.8 | 55.7 | 10.1 | 5.1 | 31.2 | 20.8 | 24.0 | 3.87 |
| 151.650 | F | A | 3 | 79.8 | 25.8 | 52.9 | 9.4 | 5.1 | 30.1 | 19.2 | 22.6 | 3.30 |
| 151.232 | M | A | 3 | 84.2 | 26.5 | 53.8 | 9.8 | 5.8 | 30.2 | 20.1 | 23.8 | 3.75 |
| 151.480 | M | A | 2 | 82.1 | 22.0 | 56.7 | 10.0 | 4.9 | 34.0 | 21.9 | 25.1 | 4.90 |
| 151.923 | M | A | 4 | 84.9 | 27.6 | 54.8 | 9.9 | 5.5 | 29.0 | 20.3 | 24.4 | 3.43 |
| 151.380 | F | A | 3 | 75.6 | 24.0 | 51.5 | 9.2 | 5.3 | 29.3 | 20.3 | 22.6 | 3.25 |
| 151.880 | M | A | 3 | 78.6 | 23.9 | 54.5 | 10.9 | 5.0 | 33.0 | 23.4 | 26.8 | 3.90 |
| 151.570 | F | A | 3 | 82.4 | 25.8 | 53.5 | 10.1 | 4.8 | 29.0 | 19.6 | 22.7 | 3.35 |
| 151.710 | F | A | 3 | 77.8 | 24.9 | 51.7 | 10.1 | 4.9 | 28.6 | 18.9 | 21.7 | 3.45 |
| 151.548 | M | A | 3 | 82.2 | 26.2 | 53.7 | 10.2 | 5.0 | 28.5 | 18.7 | 23.1 | 3.45 |
| 151.610 | M | A | 2 | 84.3 | 24.3 | 58.8 | 10.4 | 5.7 | 31.6 | 21.5 | 24.5 | 4.58 |
| 151.290 | F | A | 3 | 79.7 | 24.4 | 53.8 | 9.8 | 4.9 | 27.1 | 19.1 | 22.1 | 3.50 |
| 151.500 | M | A | 1 | 82.2 | 23.5 | 57.1 | 9.8 | 5.0 | 33.6 | 22.6 | 25.7 | 5.05 |
| 151.190 | M | A | 2 | 82.2 | 26.5 | 54.2 | 10.1 | 5.0 | 29.5 | 18.9 | 23.6 | 3.50 |
| 151.810 | M | A | 1 | 83.5 | 25.0 | 57.5 | 10.5 | 4.7 | 35.1 | 22.8 | 25.9 | 4.60 |
| 151.530 | M | A | 2 | 84.3 | 24.7 | 57.3 | 9.9 | 5.0 | 33.6 | 22.7 | 25.3 | 4.65 |
| 151.980 | M | A | 2 | 84.3 | 25.1 | 57.3 | 10.0 | 5.7 | 33.7 | 23.3 | 25.1 | 4.10 |
| 151.900 | M | A | 2 | 81.2 | 24.5 | 55.1 | 9.9 | 4.7 | 31.5 | 21.6 | 24.6 | 3.70 |
| 151.850 | F | A | 3 | 80.6 | 23.3 | 55.3 | 9.7 | 5.2 | 32.7 | 19.7 | 24.0 | 3.80 |
| 151.211 | M | A | 2 | 82.3 | 26.2 | 56.4 | 9.8 | 5.5 | 30.6 | 20.9 | 23.8 | 3.92 |
| 151.398 | F | A | 2 | 74.7 | 20.5 | 53.3 | 9.9 | 5.0 | 30.8 | 19.2 | 22.7 | 3.90 |
| 151.330 | F | A | 3 | 79.1 | 24.0 | 53.6 | 9.5 | 5.0 | 33.0 | 19.6 | 23.8 | 3.91 |
| 151.630 | F | A | 3 | 75.8 | 24.5 | 50.2 | 9.1 | 4.5 | 27.3 | 18.1 | 22.3 | 2.90 |
| 151.001[d] | F | A | 1 | 79.6 | 21.3 | 53.4 | 8.9 | 5.3 | 40.6 | 23.5 | 25.2 | 6.95 |
| 151.002[d] | F | J | 2 | 53.9 | 15.2 | 33.8 | 7.7 | 4.1 | 22.5 | 14.8 | 17.8 | 1.07 |

[a] A = Adult (> 12months), J = Juvenile (≤12 months).
[b] 1 = Excellent, 2 = Good, 3 = Fair, 4 = Poor.
[c] All lengths are in centimeters.
[d] Not included in analysis.

**Appendix Table 2.** Data collected from live-trapped raccoons of High Knob Recreation Area, Virginia. 1989-1990.

| Radio No. | Date Capture | Date Death | Cause[a] Death | No. Ticks | Up. Canine[b] Length | Low Canine Length | Tooth[c] Wear | Tartar[d] | No. Broken Canines |
|---|---|---|---|---|---|---|---|---|---|
| 151.421 | 060789 | 070389 | 2 | 1 | 0.9 | 0.8 | 1 | 0 | 1 |
| 151.110 | 052089 | 110689 | 5 | 3 | 0.9 | 0.8 | 1 | 0 | 0 |
| 151.140 | 091389 | 101789 | 5 | 0 | 1.1 | 1.2 | 1 | 1 | 0 |
| 151.740 | 072789 | 102889 | 5 | 0 | 0.1 | 0.7 | 2 | 0 | 3 |
| 151.820 | 070789 | 102889 | 5 | 0 | 0.8 | 0.8 | 2 | 1 | 3 |
| 151.270 | 052689 | 110489 | 5 | 0 | 1.2 | 1.2 | 0 | 0 | 1 |
| 151.160 | 072789 | 102389 | 5 | 0 | 1.1 | 1.2 | 0 | 0 | 0 |
| 151.941 | 062489 | 110489 | 5 | 1 | 0.9 | 1.0 | 0 | 0 | 1 |
| 151.650 | 072489 | 102589 | 5 | 0 | 0.6 | 0.3 | 3 | 0 | 4 |
| 151.232 | 081989 | 102189 | 5 | 0 | 1.1 | 1.0 | 1 | 1 | 1 |
| 151.480 | 091589 | 101889 | 5 | 0 | 1.1 | 1.1 | 2 | 1 | 2 |
| 151.923 | 060789 | . | . | 5 | 1.1 | 1.2 | 0 | 0 | 0 |
| 151.380 | 091689 | . | . | 0 | 1.0 | 1.0 | 1 | 0 | 0 |
| 151.880 | 051089 | 072189 | 7 | 1 | 1.1 | 0.9 | 1 | 0 | 0 |
| 151.570 | 052589 | . | . | 0 | 0.9 | 0.6 | 2 | 0 | 1 |
| 151.710 | 072689 | . | . | 0 | 1.0 | 0.9 | 0 | 0 | 0 |
| 151.548 | 072489 | . | . | 1 | 1.1 | 1.1 | 0 | 1 | 0 |
| 151.610 | 070689 | . | . | 0 | 0.7 | 0.9 | 2 | 1 | 2 |
| 151.290 | 062989 | . | . | 0 | 1.0 | 0.9 | 1 | 0 | 0 |
| 151.500 | 060789 | . | . | 3 | 0.3 | 0.1 | 3 | 0 | 1 |
| 151.190 | 052689 | . | . | 0 | 1.1 | 1.1 | 0 | 0 | 0 |
| 151.810 | 052089 | . | . | 0 | 0.5 | 0.7 | 2 | 1 | 3 |
| 151.530 | 052489 | . | . | 0 | 1.0 | 0.9 | 0 | 0 | 1 |
| 151.980 | 051989 | 03??90 | 7 | 1 | 1.0 | 1.1 | 1 | 0 | 1 |
| 151.900 | 051789 | . | . | 1 | 0.4 | 0.1 | 3 | 0 | 1 |
| 151.850 | 060489 | . | . | 2 | 0.5 | 0.6 | 3 | 2 | |
| 151.211 | 060389 | . | . | 0 | 1.2 | 1.0 | 1 | 1 | 3 |
| 151.398 | 060789 | . | . | 0 | 0.3 | 0.3 | 2 | 0 | 3 |
| 151.330 | 061589 | . | . | 0 | 0.4 | 0.6 | 3 | 1 | 1 |
| 151.630 | 061589 | . | . | 0 | 0.9 | 0.9 | 0 | 0 | 0 |
| 151.001[e] | 071989 | . | . | 0 | 0.9 | 0.8 | 2 | 1 | 3 |
| 151.002[e] | 071089 | 110989 | 5 | 0 | 0.4 | 0.2 | 0 | 2 | 0 |

[a] 2 = Roadkill, 5 = Hunter kill - with dogs, 7 = Other
[b] All lengths are in centimeters
[c] 0 = None, 1 = Slight, 2 = Moderate, 3 = Extensive.
[d] 0 = None or little, 1 = Moderate, 2 = Heavy.
[e] Not included in analysis.

**Appendix Table 3.** Data collected from hunter killed raccoons of High Knob Recreation Area, Virginia. 1989-1990.

| Raccoon No. | Date of Death | Cause of[a] Death | Sex | Age (yrs) | Condition[b] | Total[c] Length | Tail Length | Body Length | Rear Ft Length | Girth |
|---|---|---|---|---|---|---|---|---|---|---|
| 001.000 | 122188 | 5 | M | 1 | 1 | 80.0 | 26.7 | 53.0 | 9.6 | 31.7 |
| 002.000 | 010689 | 5 | F | 2 | 2 | 77.5 | 23.3 | 53.8 | 10.0 | 32.7 |
| 003.000 | 010789 | 5 | F | 1 | 2 | 75.6 | 22.1 | 53.5 | 9.5 | 37.8 |
| 004.000 | 010789 | 5 | F | 0 | 1 | 75.1 | 24.3 | 50.7 | 9.6 | 29.2 |
| 005.000 | 011189 | 5 | M | 1 | 2 | 74.4 | 23.9 | 52.5 | 9.7 | 32.1 |
| 006.000 | 011189 | 5 | F | 0 | 1 | 73.1 | 26.2 | 48.2 | 10.4 | 29.6 |
| 007.000 | . | 5 | F | 0 | 3 | 74.3 | 25.5 | 47.9 | 10.0 | 22.9 |
| 008.000 | 011689 | 5 | M | 1 | 1 | 85.5 | 26.2 | 58.4 | 11.0 | 33.7 |
| 009.000 | 121088 | 5 | F | 0 | 4 | 72.9 | 24.1 | 47.6 | . | 31.3 |
| 010.000 | 012689 | 5 | M | 0 | 2 | 73.6 | 28.6 | 45.7 | 9.9 | 25.8 |
| 011.000 | 011889 | 5 | F | 0 | 2 | 73.0 | 24.7 | 49.7 | 9.6 | 27.5 |
| 012.000 | 011889 | 5 | F | 5 | 1 | 70.5 | 23.9 | 45.8 | 9.4 | 26.9 |
| 013.000 | 012889 | 5 | M | 3 | 2 | 80.7 | 27.7 | 53.8 | 10.2 | 36.8 |
| 014.000 | 122688 | 5 | M | 4 | 1 | 80.6 | 27.7 | 56.6 | 10.3 | 36.4 |
| 015.000 | 011389 | 5 | F | 0 | 3 | 62.1 | 19.6 | 44.2 | 9.5 | 25.6 |
| 016.000 | 011389 | 5 | F | 1 | 1 | 77.2 | 26.4 | 53.2 | 9.9 | 31.7 |
| 017.000 | 010089 | 5 | M | 2 | 2 | 78.8 | 23.8 | 55.6 | 10.3 | 36.1 |
| 018.000 | 010089 | 5 | M | . | 2 | 72.1 | 23.1 | 50.1 | 10.0 | 28.3 |
| 019.000 | 122788 | 5 | M | 3 | 2 | 86.4 | 27.9 | 58.6 | 9.9 | 32.4 |
| 020.000 | 122788 | 5 | M | 5 | 1 | 80.6 | 27.1 | 55.4 | 10.0 | 34.3 |
| 021.000 | . | 5 | F | 0 | 1 | 75.2 | 22.0 | 55.5 | 9.2 | 43.0 |
| 022.000 | 122388 | 5 | M | 1 | 2 | 76.8 | 27.2 | 52.4 | 9.4 | 32.2 |
| 023.000 | 010289 | 5 | M | 1 | 2 | 75.4 | 24.8 | 51.6 | 9.5 | 32.2 |
| 024.000 | 010389 | 5 | M | 0 | 3 | 68.7 | 21.9 | 47.3 | 8.9 | 26.2 |
| 025.000 | 121488 | 5 | M | 0 | 2 | 70.1 | 23.2 | 48.1 | 9.3 | 30.2 |
| 026.000 | 010389 | 5 | M | 0 | 3 | 71.4 | 23.4 | 47.7 | 9.2 | 29.8 |
| 027.000 | 102188 | . | M | 1 | 3 | . | . | 52.6 | . | 35.0 |
| 028.000 | 121588 | 5 | M | 0 | 1 | 78.4 | 26.7 | 54.4 | 10.1 | 35.5 |
| 029.000 | 121588 | 5 | M | 0 | 2 | 76.9 | 21.2 | 56.4 | 10.2 | 36.5 |
| 030.000 | 122188 | 5 | M | 1 | 3 | 73.9 | 27.2 | 48.5 | 10.1 | 26.7 |
| 031.000 | 122188 | 5 | F | 0 | 2 | 71.2 | 24.7 | 45.7 | 9.2 | 32.3 |
| 032.000 | 122188 | 5 | M | 2 | 1 | 83.3 | 27.3 | 59.6 | 10.4 | 43.3 |
| 033.000 | 010089 | 5 | M | 3 | 1 | 84.9 | 27.4 | 60.4 | 10.6 | 36.1 |
| 034.000 | 012689 | 5 | F | 2 | 1 | 78.8 | 28.2 | 51.7 | 8.5 | 28.5 |
| 035.000 | 012589 | 5 | M | 0 | 1 | 65.5 | 22.1 | 46.6 | 8.9 | 32.6 |
| 036.000 | 012589 | 5 | F | 0 | 2 | 69.2 | 25.4 | 48.2 | 8.4 | 32.5 |
| 037.000 | 012389 | 5 | F | 1 | 2 | 72.8 | 25.5 | 50.7 | 9.6 | 36.0 |

Appendix Table 3. (continued)

| Raccoon No. | Date of Death | Cause of[a] Death | Sex | Age (yrs) | Condition[b] | Total[c] Length | Tail Length | Body Length | Rear Ft Length | Girth |
|---|---|---|---|---|---|---|---|---|---|---|
| 038.000 | 012389 | 5 | F | 1 | 1 | 83.1 | 25.7 | 58.2 | 10.2 | 39.7 |
| 039.000 | 012389 | 5 | F | 1 | 1 | 75.1 | 24.5 | 52.8 | 9.9 | 36.3 |
| 040.000 | 012389 | 5 | M | 7 | 2 | 80.6 | 27.2 | 57.3 | 9.3 | 36.4 |
| 041.000 | 012689 | 5 | F | 0 | 3 | . | . | . | 7.2 | . |
| 042.000 | 102189 | 5 | F | 0 | 4 | 66.5 | 22.8 | 42.9 | 8.7 | 22.0 |
| 043.000 | 112989 | 5 | F | 0 | 3 | 67.9 | 22.6 | 45.0 | 8.3 | 25.0 |
| 044.000 | 112689 | 5 | F | 0 | 3 | 69.6 | 24.1 | 45.4 | 9.2 | 28.0 |
| 045.000 | 112589 | 5 | F | 7 | 2 | 74.3 | 23.8 | 50.5 | 9.1 | 29.0 |
| 046.000 | 120789 | 5 | F | 0 | 2 | . | . | . | 8.5 | . |
| 047.000 | 112889 | 5 | M | 0 | 4 | 68.6 | 23.3 | 45.2 | 9.7 | 26.7 |
| 048.000 | 101789 | 5 | F | 1 | 2 | . | . | . | 9.0 | . |
| 049.000 | 102189 | 5 | F | 6 | 2 | . | . | . | 8.9 | . |
| 050.000 | 103189 | 5 | M | 0 | 2 | . | . | . | 8.6 | . |
| 051.000 | 112489 | 5 | M | 2 | 2 | 77.5 | 23.9 | 53.4 | . | 32.2 |
| 052.000 | 111489 | 5 | M | 1 | 2 | 78.8 | . | 53.9 | 9.5 | 24.0 |
| 053.000 | 112189 | 5 | F | 1 | 1 | 78.0 | 23.5 | 54.5 | 9.5 | 31.4 |
| 054.000 | 120289 | 5 | F | 2 | 2 | 79.4 | 26.6 | 53.2 | . | 32.4 |
| 055.000 | . | 5 | M | 1 | 3 | 80.5 | 25.3 | 55.3 | . | 32.0 |
| 056.000 | 120589 | 5 | F | 0 | 4 | 63.6 | 21.3 | 43.3 | 8.7 | 23.0 |
| 057.000 | 120989 | 5 | F | 0 | 2 | 67.0 | 23.2 | 44.3 | 8.7 | 28.2 |
| 058.000 | 120989 | 5 | F | 0 | 4 | 71.2 | 24.2 | 45.9 | 9.3 | 24.2 |
| 059.000 | 010390 | 5 | M | 1 | 3 | 79.5 | 25.6 | 56.0 | 9.9 | 29.7 |
| 060.000 | . | 5 | M | 0 | 4 | 68.2 | 23.8 | 45.4 | 9.1 | 25.1 |
| 061.000 | 120089 | 5 | M | 0 | 2 | 72.5 | 22.4 | 49.4 | 9.7 | 28.8 |
| 062.000 | 110289 | 5 | F | 0 | 3 | 73.9 | 24.3 | 48.8 | 8.7 | 29.6 |
| 063.000 | 011390 | 5 | F | 1 | 2 | 78.3 | 26.1 | 53.5 | 9.1 | 29.0 |
| 064.000 | 112889 | 5 | M | 0 | 3 | 73.8 | 25.8 | 48.5 | 10.4 | 27.1 |
| 065.000 | 100089 | 5 | M | 1 | 3 | 77.4 | 25.5 | 53.3 | 9.5 | 31.5 |
| 066.000 | 100089 | 5 | M | 0 | 3 | 68.0 | 24.3 | 43.4 | 8.9 | 25.7 |
| 067.000 | 102589 | 5 | F | 0 | 4 | 61.0 | 19.5 | 40.6 | 8.4 | 20.6 |
| 068.000 | 011389 | 5 | F | 4 | 1 | 80.2 | 26.6 | 53.5 | 8.4 | 33.7 |
| 069.000 | 110289 | 5 | M | 0 | 4 | 68.3 | 25.3 | 43.9 | 9.8 | 22.0 |
| 070.000 | 112989 | 5 | F | 0 | 3 | 70.3 | 23.6 | 46.8 | 9.3 | 23.6 |
| 071.000 | 012689 | 5 | M | 0 | 3 | 69.0 | 24.2 | 46.4 | 9.1 | 23.6 |
| 072.000 | 102489 | 5 | F | 0 | 4 | 71.1 | 25.2 | 45.4 | 9.5 | 24.5 |
| 073.000 | 012689 | 5 | F | 0 | 2 | 66.8 | 23.5 | 44.0 | 9.0 | 26.6 |
| 074.000 | 102689 | 5 | F | 1 | 3 | 75.9 | 25.7 | 50.4 | 9.7 | 29.3 |

Appendix Table 3. (continued)

| Raccoon No. | Date of Death | Cause of[a] Death | Sex | Age (yrs) | Condition[b] | Total[c] Length | Tail Length | Body Length | Rear Ft Length | Girth |
|---|---|---|---|---|---|---|---|---|---|---|
| 075.000 | 010089 | 5 | M | . | 3 | 81.1 | 25.4 | 55.7 | 9.9 | 35.3 |
| 076.000 | 010089 | 5 | F | 0 | 3 | 73.5 | 25.7 | 48.7 | 9.2 | 29.4 |
| 077.000 | 102589 | 5 | F | 1 | 1 | 72.7 | 24.3 | 49.0 | 8.1 | 26.7 |
| 078.000 | 102589 | 5 | F | 0 | 3 | . | 22.3 | . | 9.6 | 26.7 |
| 079.000 | 102589 | 5 | F | 3 | 3 | 71.9 | 23.8 | 49.8 | 8.9 | 28.5 |
| 080.000 | 110388 | 5 | M | 0 | 4 | 65.9 | 22.0 | 43.7 | 8.8 | 25.7 |
| 081.000 | 102588 | 5 | M | 2 | 2 | 77.2 | 25.3 | 53.3 | 10.1 | 31.4 |
| 082.000 | 102188 | 5 | F | 0 | 3 | 64.5 | 19.7 | 45.5 | 9.1 | 28.0 |
| 083.000 | 102188 | 5 | M | 1 | 4 | 83.6 | 26.9 | 57.4 | 10.7 | 33.2 |
| 084.000 | 012690 | 5 | M | 1 | 2 | 79.6 | 25.5 | 50.0 | 10.5 | 34.0 |
| 085.000 | 012690 | 5 | M | 2 | 3 | 80.6 | 27.9 | 53.7 | 10.3 | 31.4 |
| 086.000 | 881210 | 5 | F | 0 | 4 | 49.7 | 14.0 | 35.5 | 5.4 | 25.3 |
| 087.000 | 062089 | 7 | M | 1 | 4 | 72.0 | 24.0 | 47.0 | 10.5 | 25.5 |
| 088.000 | 110389 | 5 | F | 2 | 2 | 79.4 | 25.5 | 55.0 | 9.5 | 29.9 |
| 089.000 | 110389 | 5 | F | 1 | 2 | 74.2 | 24.2 | 50.4 | 8.5 | 30.6 |
| 090.000 | 110389 | 5 | F | 0 | 4 | 67.8 | 22.3 | 45.9 | 8.8 | 23.6 |
| 091.000 | 103089 | 5 | M | 0 | 4 | 72.7 | 24.8 | 47.7 | 10.2 | 28.8 |
| 092.000 | 102889 | 5 | M | 2 | 2 | 76.9 | 24.0 | 52.3 | 9.8 | 32.1 |
| 093.000 | 102189 | 5 | F | 1 | 3 | 75.3 | 21.6 | 53.4 | 9.8 | 33.8 |
| 094.000 | 101789 | 5 | M | 0 | 4 | 65.9 | 21.3 | 43.7 | 9.2 | 22.3 |
| 095.000 | 101989 | 5 | M | 3 | 2 | 76.5 | 22.5 | 55.2 | 9.9 | 31.0 |
| 096.000 | 112789 | 5 | M | 1 | 1 | 83.7 | 29.1 | 54.4 | 9.9 | 34.4 |
| 101.000 | 101989 | 5 | F | 0 | 3 | . | . | . | 7.7 | . |
| 102.000 | 102189 | 5 | F | 0 | 4 | . | . | . | 8.3 | . |
| 103.000 | 102589 | 5 | M | 0 | 3 | . | . | . | 8.2 | . |
| 104.000 | 101789 | 5 | F | 0 | 2 | . | . | . | 8.5 | . |
| 105.000 | 103189 | 5 | F | 4 | 2 | . | . | . | 9.4 | . |
| 106.000 | 101789 | 5 | M | 1 | 2 | 83.3 | 28.8 | 55.2 | 9.7 | 32.0 |
| 107.000 | 101789 | 5 | M | 0 | 4 | 72.1 | 25.5 | 47.1 | 10.1 | 23.3 |
| 108.000 | 101789 | 5 | F | 0 | 4 | 71.6 | 26.3 | 45.7 | 9.5 | 24.0 |
| 109.000 | 012689 | 5 | M | 1 | 4 | . | . | . | 8.1 | . |
| 110.000 | 102589 | 5 | F | 2 | 3 | 72.4 | 25.0 | 47.9 | 9.1 | 27.1 |
| 111.000 | 012289 | 5 | F | 1 | 2 | 74.8 | 23.4 | 51.0 | 9.1 | 28.4 |
| 112.000 | 012289 | 5 | M | 1 | 3 | 78.1 | 23.7 | 53.9 | 9.7 | 29.8 |
| 113.000 | 120289 | 5 | M | 1 | 1 | 84.3 | 27.0 | 56.8 | 9.2 | 31.8 |
| 114.000 | 112689 | 5 | M | 0 | 3 | 62.3 | 18.8 | 43.0 | 8.5 | 22.8 |

Appendix Table 3. (continued)

| Raccoon No. | Date of Death | Cause of[a] Death | Sex | Age (yrs) | Condition[b] | Total[c] Length | Tail Length | Body Length | Rear Ft Length | Girth |
|---|---|---|---|---|---|---|---|---|---|---|
| 115.000 | 112589 | 5 | M | 0 | 3 | 67.9 | 22.3 | 45.8 | 9.4 | 25.5 |
| 116.000 | 120789 | 5 | M | 0 | 2 | 74.4 | 24.4 | 50.4 | 8.7 | 34.9 |
| 117.000 | 110489 | 5 | M | 3 | 2 | 82.3 | 27.2 | 56.2 | 10.0 | 31.2 |
| 118.000 | 102189 | 5 | M | 0 | 4 | 76.0 | 25.7 | 49.5 | 10.5 | 26.3 |
| 151.270 | 110489 | 5 | M | 2 | 1 | . | . | . | 9.1 | . |
| 151.110 | 110689 | 5 | F | 5 | 1 | 72.4 | . | 49.7 | 8.5 | 27.8 |
| 151.650 | 102589 | 5 | F | 9 | 1 | . | . | . | 9.1 | . |
| 151.940 | 110489 | 5 | M | 2 | 2 | . | . | . | 10.0 | . |
| 151.480 | 101889 | 5 | M | 4 | 1 | 78.6 | 23.6 | 56.5 | 9.6 | 37.5 |
| 151.740 | 102889 | 5 | F | 8 | 3 | 69.2 | 18.9 | 51.0 | 9.6 | 30.1 |
| 151.421 | 070289 | 2 | F | 3 | 3 | 81.9 | 25.6 | 54.7 | 10.3 | 28.8 |
| 151.232 | 102189 | 5 | M | 1 | 4 | 69.5 | 20.0 | 50.0 | 9.6 | 27.0 |
| 151.140 | 101789 | 5 | M | 1 | 3 | 73.3 | 18.9 | 47.9 | 10.2 | 30.2 |

[a] 2 = Roadkill, 5 = Hunter kill - with dogs, 7 = Other
[b] 1 = Excellent, 2 = Good, 3 = Fair, 4 = Poor
[c] All lengths are in centimeters.

**Appendix Table 4.** Data collected from hunter killed raccoons of High Knob Recreation Area, Virginia. 1989-1990.

| Raccoon No. | Full Weight (kg) | Skinned Weight(kg) | No. of Placental Scars | Left KFI | Right KFI |
|---|---|---|---|---|---|
| 001 | . | 4.086 | . | 45.0 | 36.0 |
| 002 | . | 4.477 | 3 | 51.6 | 33.7 |
| 003 | . | 3.744 | 0 | 66.2 | 47.3 |
| 004 | . | 2.993 | 0 | 58.7 | 52.6 |
| 005 | . | 4.228 | . | 33.3 | 37.7 |
| 006 | . | 3.755 | 0 | 16.7 | 26.3 |
| 007 | . | 2.414 | 0 | 46.3 | 42.2 |
| 008 | . | 5.742 | . | 42.5 | 36.4 |
| 009 | . | 2.665 | 0 | | ... |
| 010 | 3.303 | 2.750 | . | 30.0 | 30.4 |
| 011 | . | 2.722 | 0 | 42.3 | 25.6 |
| 012 | . | 2.296 | 0 | 46.9 | 28.1 |
| 013 | . | 4.054 | . | 29.4 | 35.5 |
| 014 | . | 5.216 | . | 27.1 | 30.4 |
| 015 | . | 2.041 | . | 25.0 | 20.3 |
| 016 | . | 4.026 | 0 | 56.5 | .. |
| 017 | . | 4.678 | . | 28.9 | 25.9 |
| 018 | . | 2.637 | . | 34.4 | 32.1 |
| 019 | . | 5.571 | . | 38.0 | 44.8 |
| 020 | . | 5.330 | . | 43.2 | 36.8 |
| 021 | . | 4.763 | 0 | 83.6 | 61.1 |
| 022 | 4.876 | 4.054 | . | 46.5 | 48.5 |
| 023 | . | 2.580 | . | 36.3 | 33.0 |
| 024 | . | 2.325 | . | 42.1 | .. |
| 025 | . | 2.240 | . | 26.7 | 35.6 |
| 026 | . | 2.041 | . | . | 20.7 |
| 027 | . | 4.621 | . | 29.5 | 22.1 |
| 028 | . | 4.366 | . | 70.1 | 74.5 |
| 029 | . | 4.905 | . | 43.7 | 27.2 |
| 030 | . | 2.410 | . | 24.8 | 21.3 |
| 031 | . | 2.665 | 0 | 40.5 | 42.6 |
| 032 | . | 6.322 | . | . | 55.5 |
| 033 | . | 5.046 | . | 50.9 | 54.4 |
| 034 | 4.252 | 3.402 | 5 | 74.0 | 69.1 |
| 035 | . | 2.665 | . | 38.9 | 50.3 |
| 036 | . | 2.296 | 0 | 32.9 | 36.3 |
| 037 | . | 4.281 | 0 | 35.0 | 33.8 |

Appendix Table 4. (continued)

| Raccoon No. | Full Weight (kg) | Skinned Weight(kg) | No. of Placental Scars | Left KFI | Right KFI |
|---|---|---|---|---|---|
| 038 | . | 4.933 | 0 | 50.0 | 51.9 |
| 039 | . | 4.479 | 0 | 62.2 | 50.8 |
| 040 | . | 4.933 | . | . | 49.8 |
| 041 | . | 1.219 | 0 | 49.1 | 32.8 |
| 042 | . | 1.859 | 0 | 20.2 | 27.7 |
| 043 | . | 2.381 | 0 | 49.0 | 43.9 |
| 044 | . | 2.495 | 0 | 20.1 | 24.4 |
| 045 | . | 3.402 | 3 | 47.0 | 16.8 |
| 046 | . | 2.821 | 0 | 57.8 | 50.0 |
| 047 | . | 2.551 | . | 30.3 | 13.1 |
| 048 | . | 4.125 | 0 | 40.0 | 28.9 |
| 049 | . | 5.386 | 4 | 35.5 | 32.0 |
| 050 | . | 2.381 | . | 45.1 | 32.8 |
| 051 | . | 4.819 | . | 42.6 | 47.8 |
| 052 | . | 3.800 | . | 43.7 | 41.9 |
| 053 | . | 4.423 | 4 | 35.0 | 30.8 |
| 054 | . | 4.508 | 3 | 29.2 | 26.4 |
| 055 | . | 4.763 | . | 54.9 | 43.5 |
| 056 | . | 1.814 | 0 | 26.0 | 19.5 |
| 057 | . | 2.963 | 0 | . | . . |
| 058 | . | 2.452 | 0 | 31.1 | 34.5 |
| 059 | . | 4.607 | . | 28.5 | 32.5 |
| 060 | . | 2.041 | . | 13.0 | 20.4 |
| 061 | . | 3.501 | . | 49.6 | 46.3 |
| 062 | . | 2.835 | 0 | 24.4 | 23.7 |
| 063 | 5.457 | 4.493 | 0 | 39.1 | 46.7 |
| 064 | . | 3.189 | . | 24.1 | 25.8 |
| 065 | . | 4.224 | . | 36.5 | 31.2 |
| 066 | . | 2.381 | . | 18.5 | 27.0 |
| 067 | 2.310 | 1.899 | 0 | 18.1 | 19.1 |
| 068 | 5.160 | 4.267 | 0 | . | 51.0 |
| 069 | 2.551 | 2.055 | . | 13.4 | 13.7 |
| 070 | . | 2.155 | 0 | 23.4 | 25.7 |
| 071 | 3.161 | 2.679 | . | 28.4 | 25.6 |
| 072 | . | 2.466 | 0 | 16.1 | 14.5 |
| 073 | 3.005 | 2.523 | 0 | 25.5 | 36.8 |
| 074 | . | 3.062 | 3 | 31.9 | 27.7 |

Appendix Table 4. (continued)

| Raccoon No. | Full Weight (kg) | Skinned Weight(kg) | No. of Placental Scars | Left KFI | Right KFI |
|---|---|---|---|---|---|
| 075 | . | 5.160 | . | 38.1 | 44.9 |
| 076 | . | 3.203 | 0 | 39.1 | 35.1 |
| 077 | . | 3.118 | 0 | 60.0 | 52.7 |
| 078 | . | 2.679 | 0 | 46.2 | . |
| 079 | . | 3.104 | 2 | 17.2 | 14.2 |
| 080 | . | 1.829 | . | 19.6 | 23.2 |
| 081 | . | 4.111 | . | 42.7 | 35.9 |
| 082 | . | 2.580 | 0 | 25.0 | 14.6 |
| 083 | . | 5.216 | . | 28.9 | 24.0 |
| 084 | 5.769 | 4.337 | . | 40.2 | 34.7 |
| 085 | 5.273 | . | . | 24.8 | 30.5 |
| 086 | . | 0.709 | 0 | 12.0 | 13.0 |
| 087 | 2.948 | 2.395 | . | 13.5 | 34.1 |
| 088 | . | 4.025 | 0 | 39.1 | 39.4 |
| 089 | . | 3.317 | 0 | 64.8 | 84.3 |
| 090 | . | 2.126 | 0 | 17.8 | 21.4 |
| 091 | . | 2.679 | . | 13.2 | 15.6 |
| 092 | . | 4.593 | . | 17.6 | 22.3 |
| 093 | . | 4.805 | . | 12.0 | 11.4 |
| 094 | . | 2.140 | . | 20.7 | 14.0 |
| 095 | . | 4.550 | . | 34.8 | . |
| 096 | 6.535 | 5.131 | . | 30.0 | . |
| 101 | . | 2.665 | 0 | 38.4 | 17.9 |
| 102 | . | 2.367 | 0 | 29.5 | 21.5 |
| 103 | . | 2.155 | . | 18.8 | 24.8 |
| 104 | . | 2.807 | 0 | 41.9 | 25.3 |
| 105 | . | 5.953 | 3 | 78.4 | 14.5 |
| 106 | . | 4.749 | . | 20.0 | 19.8 |
| 107 | . | 2.509 | . | 21.5 | 23.0 |
| 108 | . | 2.381 | 0 | 16.8 | 11.0 |
| 109 | . | 1.247 | . | . | . |
| 110 | . | 3.260 | 4 | 24.5 | 28.5 |
| 111 | . | 3.898 | 0 | 52.3 | 34.3 |
| 112 | . | 4.366 | . | 15.5 | 20.0 |
| 113 | . | 5.698 | . | 41.6 | 32.4 |
| 114 | . | 2.169 | . | 34.2 | 37.9 |

Appendix Table 4. (continued)

| Raccoon No. | Full Weight (kg) | Skinned Weight(kg) | No. of Placental Scars | Left KFI | Right KFI |
|---|---|---|---|---|---|
| 115 | . | 2.693 | . | 26.8 | 33.5 |
| 116 | 4.380 | 3.728 | . | 48.2 | 42.3 |
| 117 | . | 4.904 | . | 63.2 | 47.8 |
| 118 | . | 2.920 | . | 20.2 | 21.8 |
| 151.110 | 5.528 | 3.827 | 4 | 64.7 | 49.8 |
| 151.140 | 4.508 | 3.586 | . | 15.8 | 17.2 |
| 151.232 | 4.040 | 3.118 | . | 13.6 | 10.1 |
| 151.270 | 5.358 | 4.423 | . | 36.7 | 49.6 |
| 151.421 | 4.607 | 3.586 | 3 | . | 14.9 |
| 151.480 | 6.308 | 5.202 | . | 53.1 | 30.2 |
| 151.650 | 4.593 | . | 4 | 22.1 | 19.9 |
| 151.740 | 4.522 | 3.586 | 4 | 33.4 | 42.9 |
| 151.940 | 5.018 | . | . | 34.6 | 35.4 |

# Vita

Eric Paul Schrading was born in Princeton, New Jersey on June 18, 1966. His family settled in Pittsburgh, Pennsylvania in 1969 where Eric attended elementary and middle school. Eric graduated from Taylor Allderdice High School in June 1984. He then attended University of Maine at Orono, Maine for 2 years. Eric continued one year's education at University of Edinburgh in Scotland studying an ecology cirriculum. He graduated with a Bachelor's of Science in Wildlife Management with honors from the University of Maine in May 1988. Eric worked the summers of 1986 and 1988 at Moosehorn National Wildlife Refuge in Maine as an SCA volunteer and a YCC leader. In the fall of 1990, he also completed the small mammal survey for the Fort Eustis Military Base Environmental Impact Statement as a contractor for International Science and Technology, Inc. His Master's work in Wildlife Science at Virginia Polytechnic Institute and State University was completed in January 1991.

Eric is a member of Xi Sigma Pi and a member of the Wildlife Society, where he is presently publicity chairman of the student chapter. He is also a certified forest fire fighter.