ECOLOGY OF RACCOONS IN CENTRAL ALABAMA: A STUDY OF SURVIVAL, SPACE USE, AND HABITAT SELECTION

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ECOLOGY OF RACCOONS IN CENTRAL ALABAMA: A STUDY OF SURVIVAL, SPACE USE, AND HABITAT SELECTION

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ECOLOGY OF RACCOONS IN CENTRAL ALABAMA: A STUDY OF SURVIVAL, SPACE USE, AND HABITAT SELECTION

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Christine Elizabeth Fisher, daughter of William Earl and Melinda (Carkner) Fisher, was born June 28, 1980, in Potsdam, New York. She graduated from Madrid-Waddington Central High School as Valedictorian in 1998. She attended Elmira College in Elmira, New York, for one year, then entered Clarkson University in Potsdam, New York, in September, 1999, and graduated with High Honors with a Bachelor of Science degree in Biology in May, 2002. After working as a Wildlife Technician for the United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services Agency of New York for two years, she entered Graduate School, Auburn University in September, 2004.

THESIS ABSTRACT

ECOLOGY OF RACCOONS IN CENTRAL ALABAMA: A STUDY OF SURVIVAL, SPACE USE, AND HABITAT SELECTION

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Population characteristics of raccoons (*Procyon lotor*) vary across time and geographic regions; biological information acquired in one region, at one time, may not be pertinent to other regions in other times. In Alabama, demographic studies of raccoon populations date back several decades and little knowledge of current ecological trends exists. Increasing urban populations and alterations in the southeastern landscape affect the availability and distribution of favorable habitat and resources; however, raccoon abundance in the Southeast has increased because of its ability to adapt to such alterations. Stable or increasing populations of raccoons have ecological importance for wildlife, domestic animals, and humans, by increasing the opportunity for competition and conflict over resources, nuisance problems, and disease transmission. The management of wildlife in Alabama, specifically of raccoons, must also be able to continuously adapt to the ever-changing environment.

Over 60 raccoons were monitored at 3 study sites, representative of several distinct habitat types, in central Alabama from 2004-2005 in order to monitor survivorship, static interactions, home range characteristics, and preferred habitat use. Survivorship of adult raccoons was high in all study areas and differed little between genders. Raccoons exhibited extensive static overlap of home ranges, but static interactions at the level of core use areas appeared less common. Habitat use was examined at three orders of selection and did not differ between genders. Compositional analyses for habitat use at each study site illustrated that used differed from random; at levels of intense activity (*i.e.*, core use areas), animals selected proportionately more hardwood and riparian habitat than other habitat types available in their home ranges. Habitat selection at the level of home range composition showed that pine forest, grassy openings, and areas of human development were preferred by raccoons over hardwoods and riparian areas, dependent on resource availability. Results from this study will aid management of raccoons in Alabama by contributing to current knowledge of population characteristics that allow this species to adapt to, and thrive in, altered landscapes.

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CALHOME (Kie et al. 1996)

MICROMORT (Heisey and Fuller 1985)

SAS (SAS Institute, Inc., 2004)

Heisey, D. M., and T. K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. The Journal of Wildlife Management 49:668-674.

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CHAPTER ONE

Survival of Adult Raccoons (*Procyon lotor*) in Agricultural, Bottomland Hardwood, and Pine Forest Habitats in Central Alabama.

INTRODUCTION

In the United States, human population growth and urban development rates have increased dramatically in recent decades, particularly in the Southeast. Habitat fragmentation and degradation result from land development, which in turn negatively affects wildlife populations (U.S. Environmental Protection Agency 2001). Regardless of the rapid increase in urbanization rates throughout this region, populations of raccoons (*Procyon lotor*) steadily grow larger (Gehrt et al. 2002). Throughout their North American range, raccoons are adept at establishing a mesocarnivore niche in a variety of habitats due to their ability to utilize temporary and unpredictable resources.

Historically, harvesting raccoons for fur has been an important part of the North American economy (Sanderson 1987). In recent years, however, demand for raccoon pelts and decrease in price of fur has lessened the economic status of raccoons. Yet raccoon hunting remains an important tradition in the Southeast and management is needed to maintain healthy population levels without increasing the potential for conflict with other wildlife, humans, or domestic animals. Zoonotic diseases such as canine distemper and rabies affect raccoon survivorship and population demography (Brown et al. 1990, Roscoe 1993), as well as pose threats of disease transmission to domestic animals and humans. Raccoons commonly are reported as nuisance animals in areas where they coexist with humans and as efficient predators of other wildlife (Urban 1970, Ratnaswamy et al. 1987). Management of raccoons (*Procyon lotor)* as disease vectors, nuisance animals, and predators requires information concerning population demography. Population characteristics, such as survivorship, of raccoons vary throughout North America (Johnson 1970, Lynch 1974, Dunn and Chapman 1983, Riley et al. 1998, Chamberlain et al. 2000) and biological information acquired in one area may not be accurate for other areas (Allsbrooks and Kennedy 1987).

Raccoon mortality most often is attributed to human activities such as hunting, recreational trapping, removal of nuisance animals, and vehicle collision (Mech et al. 1968, Fritzell and Greenwood 1984, Chamberlain et al. 1999). In absence of human-related mortalities, disease and starvation are primary sources of death, as *P. lotor* has few natural predators (Gehrt et al. 1990, Roscoe 1993, Riley et al. 1998, Rosatte 1998). In Alabama, survival rates are lowest for raccoons within the first two years of life and rates of population turnover have been previously estimated to be slower than those in northern regions of its range (Stuewer 1943, Johnson 1970, Bigler et al. 1981). Demographic characteristics of wildlife populations vary due to different age distributions (Williams et al. 2002) and are important predictors of population trends. Survivorship influences population growth and while research on survival and mortality is abundant in the North and Midwest regions of the United States (Clarke et al. 1989, Hasbrouck et al. 1992, Gehrt and Fritzell 1996), little has been done recently in the Southeast. Chamberlain et al. (1999) conducted a study of cause-specific mortality and survival in Mississippi; however, Alabama is lacking such information for state-specific management practices.

The objective of this study was to establish current estimates of adult survival and population age distribution for raccoons in three habitat types in central Alabama. Information from this study may be combined with knowledge of raccoon ecology including spatial distribution, movement patterns, habitat use, and disease transmission, to better shape management practices.

STUDY AREAS

Fieldwork was conducted January 2004 to December 2005 on 4 study sites in central Alabama. These areas were chosen based on distinct and observable habitat characteristics that included areas of bottomland hardwoods, managed pine forests, and agricultural land. The humid, sub-tropical climate in central Alabama has average annual precipitation of 6.6-16.2 cm. Mean monthly temperatures range from 1.9°C in January to 33.7°C in July.

Riverine hardwood habitat was represented by 2 field sites, including portions of Lowndes County Wildlife Management Area (WMA) and property owned by General Electric Plastics in Burkville, Alabama. The study area at the WMA was in northern Lowndes County (16S 529470, 3579085); the 4,200-hectare property was managed by the Division of Wildlife and Freshwater Fisheries of the Alabama Department of Conservation and Natural Resources (ALDCNR). Lowndes County WMA was available to the public for recreational use, including large and small game hunting and fishing in regulated seasons, as well as seasonal picnicking, swimming, and boating. Primarily bottomland hardwood forest, the ALDCNR provided year-round grazing for wildlife in the form of planted food plots. Early summer plots typically provided chufa (*Cyperus* sp.), millet (*Panicum* sp., *Brachiaria* sp.), cowpea (*Vigna* sp.), and occasionally corn (*Zea mais*). Autumn food plots consisted of cereal grains, including oats (*Avena* sp.), wheat (*Triticum* sp.), and rye (*Secale* sp.), as well a variety of clovers and other legumes.

The study site at the General Electric Plastics Plant in Burkville, Alabama also was located in northern Lowndes County (16S 545875, 3576758), about 30 km west of Montgomery, Alabama. General Electric's property was not available for public access; however, a portion of the property was leased by a local hunting club for large and small game hunting. Areas at General Electric and on Lowndes County WMA are referred to as "riverine sites" in this study.

Agricultural habitat was represented by privately owned property in Lowndes County (16S 534678, 3575496) and is referred to as the "agricultural site" in this study. The land consisted primarily of grass pasture for cattle farming, but also contained several barns for commercially raised chickens. Remaining land consisted of hardwood-forest patches, fence rows, ponds, streams, storage facilities, and a number of residential buildings.

The Autauga Community Hunting Area, hereafter referred to as AWMA, represented the study area for managed pine habitat and was located in Autauga County (16S 541885, 3605709). The property was owned by International Paper and leased and managed by the Division of Wildlife and Freshwater Fisheries of the ALDCNR. Portions of the 2,700-hectare property were available to the public for large and small game hunting in regulated seasons. Habitat consisted primarily of managed pine stands (*Pinus taeda* and *P. palustris*) used for timber and wood fiber harvest and habitat regeneration.

The property was intersected with streamside management zones (SMZ) along perennial and intermittent streams; Alabama's Best Management Practices for Forestry (Alabama Forestry Commission 1999) requires an SMZ to extend > 10 meters from a definable bank. No major timber harvest was conducted during the course of this study, only stand thinning. The ALDCNR managed the property with prescribed burning, herbicide application, and planted food plots. Early summer plots typically provided chufa, millet, cowpea, and occasionally corn. Autumn food plots consisted of cereal grains, including oats, wheat, and rye, as well a variety of clovers and other legumes.

METHODS

Capture and Handling

In each of the study areas, raccoons were captured in 0.8 x 0.25 x 0.30-m single-door box-traps (Tomahawk Live Trap, Tomahawk, Wisconsin) from January 2004 to September 2005. Traps were baited with sardines or anise oil and marshmallows, deployed in late morning or early afternoon, and checked daily in the early morning. Traps were placed in locations that contained evidence of presence of raccoons (*e.g.,* tracks, scat) or in areas believed to be attractive to raccoons (*e.g.,* culverts, streams) throughout the study sites to maximize trap success, with an attempt to deploy radio-collars as evenly as possible across sites. While remaining in box-traps, raccoons were immobilized with an intramuscular injection of ketamine hydrochloride and xylazine (5:1 ratio, dosage = 0.1 ml/kg of estimated body mass). Upon immobilization, ophthalmic ointment was placed in the animal's eyes to prevent eyes from drying. Captured raccoons were estimated as adults (≥12 months) or juveniles (< 12 months) by reproductive characteristics (Sanderson 1961) and tooth wear (Grau et al. 1970). Weight and body measurements also were recorded for every capture. Monel 1005-3 ear tags (National Band and Tag Company, Newport, Kentucky) were placed on the outer edges of each ear of every animal and a unique animal identification number was assigned to each captured raccoon. Additionally, an AVID® microchip was inserted subcutaneously between the shoulder blades, to aid in future identification if ear tags were missing. A lower premolar was extracted with dental elevators and submitted to Matson's Laboratory LLC (Milltown, Montana) for cementum age analysis. About 5 ml of blood was drawn from the jugular vein, which was later centrifuged and the serum was sent to the Centers for Disease Control and Cornell University to ascertain rabies and distemper titers.

Adult (≥ 12 months) raccoons were radio-collared with either a 35-g mortality-sensor VHF transmitter (Advanced Telemetry Systems, Inc., Isanti, Minnesota & Telemetry Solutions, Walnut Creek, California) or a 200-g GPS- Posrec™ transmitter (Telemetry Solutions, Walnut Creek, California). An internal drop-off mechanism was initiated with the transmitter activation; this was pre-programmed cause the release of the collar from an animal's neck at 180 days of activity or low battery power. The GPS transmitters recorded 4 locations from 19:00 – 01:00 CST, 7 days a week and a VHF beacon was scheduled to transmit 2 days a week, during 06:00 – 15:00 CST. Collars with GPS transmitters were only fitted on raccoons that weighed ≥ 3.5 kg; size and weight of the radio-collar typically resulted in a poor fit on smaller animals. Raccoons were monitored until recovery and released at point of capture. A capture and handling protocol, 2004-0707, was approved by the Institutional Animal Care and Use Committees at Auburn University, Alabama, and the National Wildlife Research Center.

Survival Analysis

Following the protocol used by Matson’s Laboratory, an annual birthday of May 1 was assumed to determine age (years) of all captured raccoons in this study. A reliability index was provided with age results, indicating either a reliable age (years) estimate or a range of ages in which the correct age was expected to be within. If an age range was reported, I calculated median age and used that estimate in analyses. Age data from 2004 and 2005 captures were pooled. A two-way analysis of variance (ANOVA, SAS Institute 2004) was used to test for differences in age among study sites and by gender of raccoon.

Radio-collared raccoons were monitored February 2004 through December 2005, with an emphasis on nocturnal activity. I acquired additional observations by walking to the day-time resting site of radio-collared animals at least once a month. In the event that a radio-collared raccoon could not be located from roadside stations, extensive searches for the individual were conducted by driving throughout the study area and surrounding areas on established roads. Three telemetry flights were conducted to locate animals that had been missing for > 1 month (Mech 1983).

I estimated annual and seasonal survival with telemetry data collected during 2004 and 2005 based on number of radio-days an animal survived, using MICROMORT (Heisey and Fuller 1985). Survival is defined as probability of a radio-collared raccoon surviving through a specified time period (*e.g.*, over the course of this study). I defined biological seasons following Chamberlain and Leopold (2002): breeding (1 February – 31 May), young rearing (1 June – 30 September), and winter (1 October – 31 January). Animal deaths that occurred within 10 days of capture and handling were assumed to be the result of capture myopathy and these individuals were excluded from analyses. All radio-transmitter collars were equipped with 8-hr mortality sensors; upon detecting the mortality signal, attempts were made to locate the collar within 2 days. Due to difficulty in determining cause of death for all raccoons, cause-specific mortality rates were not estimated. Following Heisey and Fuller (1985), I estimated a minimum estimate of survival by assuming all missing animals had died. Additionally, the bias corrected estimate of survival was used in analyses, as estimations of interval survival rates are known to become more biased with smaller samples, longer interval lengths, and lower daily survival rates (Heisey and Fuller 1985). I tested for differences in survival among years and between sexes and seasons. Z-tests were used for 2-way comparisons (Nelson and Mech 1986) and survival rates were considered to be significantly different at $P \leq 0.05$.

RESULTS

Throughout the study, 121 unique raccoons (62 males, 59 females) (Table 1.1) were captured; 61 raccoons were radio-collared (32 males, 29 females). Of the 60 raccoons (30 males, 30 females) that were not collared, 16 were juveniles and not eligible for collaring. Capture and monitoring data are presented in Appendix 1.

Teeth were submitted for age analysis from 112 of the unique captures and age estimates from cementum analysis were calculated for 99 raccoons. No differences in raccoon age was detected between sites, sexes, or an interaction of the two variables ($F_{5,93} = 0.99$, $P = 0.428$). At the agricultural site, average age of all raccoons was 1.30 ± 0.20 years and all raccoons ($n = 25$) were about 3 years or younger at time of capture. At riverine and AWMA sites, average age was 1.64 ± 0.28 and 2.19 ± 0.48 years, respectively. At the riverine site, 88% of captured animals (n = 50) were 4 years or younger and the oldest capture was about 8 years old. Similarly, the majority (92%, n = 24) of captured raccoons at the AWMA site were 4 years or younger when initially captured and the oldest animal was estimated to be 9-10 years old at initial capture. Average age data for males and females at all study sites are presented in Table 1.2. A population age pyramid was constructed using proportion of raccoons in each of 8 age-classes (Grau et al. 1970) and is presented in Figure 1.1. Nearly 81% of raccoons (n = 99) were < 2 years or younger. Ages of males and females were similarly distributed, with slightly fewer males than females in older age classes.

Annual Survival

Fifty-six adult raccoons (29 males, 27 females) were included in the survival analysis (Appendix 1); in total, 15,889 radio-days were collected from 2004-2005. During the study, 12 raccoons died (4 males, 8 females) and ultimate fates were unknown for 22 animals (11 males, 11 females). I was able to locate 12 carcasses within 2 days of detecting the mortality signal, but was unable to distinguish causes of death in the field. Climatic conditions that accelerated decomposition accounted for most difficulty in determining the cause, in addition to scavenging by birds and mammals.

Minimum estimates of annual survival are presented in Table 1.3. When sexes were pooled, annual survival did not differ between the three study sites (Table 1.4). However, survival of males at the agricultural site was higher than that of the riverine ($z = -2.84$, $P = 0.002$) and the AWMA ($z = 0.02$, $P = 0.018$) sites in 2004 and lower than that of the AWMA site ($z = -4.46$, $P < 0.001$) in 2005. Survival of males at the riverine site was also lower than males at AWMA ($z = -4.33$, $P < 0.001$) in 2005. Survival of females at riverine sites was lower than that of females at AWMA in 2004 ($z = -1.82$, $P = 0.034$) and did not differ between other sites and years.

Average annual survival decreased from 2004 to 2005 for males at the agricultural site ($z = 4.46$, $P < 0.001$, Table 1.5) and AWMA ($z = -2.11$, $P = 0.018$). Annual survival of females was lower in 2005 at the riverine site ($z = 2.16$, $P = 0.015$) and AWMA ($z = 4.12$, $P < 0.001$). At AWMA, annual survivorship of females was estimated to be higher than males in 2004 ($z = -2.11$, $P = 0.018$), but lower in 2005 ($z = 4.12$, $P < 0.001$).

Seasonal Survival

Seasonal survival estimates for all study sites in 2004-2005 are presented in Table 1.6a-c. Survival of males during the breeding season of 2004 was lower at riverine sites than agricultural ($z = -1.35$, $P = 0.035$, Table 1.7) and AWMA ($z = -1.82$, $P = 0.035$) sites. During the breeding season of 2005, survival of males at the riverine sites was also lower than that of the agricultural site ($z = -3.18$, $P < 0.001$) and AWMA ($z = -3.17$, $P < 0.001$). Survival of males at AWMA was less than that at the agricultural site during young-rearing of 2004 ($z = 2.24$, $P = 0.013$), but higher during young-rearing of 2005 ($z = -3.08$, $P = 0.001$). Survivorship at the agricultural site was also lower than that of the riverine site in the same season ($z = 1.75$, $P = 0.040$). During dispersal season of 2005, males at the agricultural site had lower survivorship than at the riverine ($z = 6.74$, $P < 0.001$) and AWMA ($z = -3.82$, $P < 0.001$) sites.

Riverine females had lower average survival rates during the dispersal season of 2004 than those at the agricultural site ($z = -2.33$, $P = 0.010$). During young-rearing of 2005, females at the agricultural sites were estimated to have higher survival than at AWMA ($z = 1.64$, $P = 0.050$).

Seasonal survival of males and females did not differ at the agricultural site during 2004-2005 (Table 1.8). However, at riverine sites, females exhibited higher survivorship than males during the breeding season of 2004 ($z = -1.82$, $P = 0.035$) and lower survivorship in the dispersal season of 2005 ($z = 2.95$, $P = 0.002$). Males at AWMA had lower seasonal survival rates than females during young rearing of 2004 ($z = -2.24$, $P = 0.013$), but higher survival throughout all seasons of 2005 (Table 1.8).

DISCUSSION

Survival, reproductive capacity, spatial distribution, and population density are factors in demography of raccoons that potentially vary with population age distribution. Populations typically consist of raccoons that are 2 years of age or younger (Mankin et al. 1999, Gehrt 2003) and longevity has been estimated to be 3.1 years in Alabama (Johnson 1970). The majority of individuals in this study were less than 2 years old (81%, n = 99) and was not consistent with reports that older age classes dominate raccoon populations in the Southeast (Cunningham 1962, Caldwell 1963, Johnson 1970). Rather, age distribution of raccoon populations in central Alabama is similar to that of populations at northern latitudes.

Johnson (1970) attributes the geographic difference in age structure to higher mortality from seasonally cold climates and greater hunting and trapping pressure in the North. At southern latitudes, weather conditions are less harsh and affect survival of raccoons differently than in northern areas (Schneider et al. 1971, Fritzell 1978), but do not necessarily improve an animal's chance of survival. The temperate climate in Alabama places fewer restrictions on seasonal raccoon movements and activities, possibly allowing for increased mortality due to vehicle collisions, hunting, predation, or transmission of disease from other animals (Glueck et al. 1988, Brown et al. 1990, Chamberlain et al. 1999).

Furthermore, temperate climatic conditions in this region may not restrict resources on a seasonal basis as in northern regions, but may alter seasonal resource distribution. Young-rearing typically occurs in raccoon populations during the time of year when food and shelter resources are abundant and widely distributed (Gehrt 2003). Physical and behavioral evidence collected during this study suggested that raccoons in central Alabama breed throughout the year, similar to observations at other southern latitudes (Kaufmann 1982, Dunn and Chapman 1983, Gehrt and Fritzell 1996). Females that breed and rear young at other times of the year may expend more energy allocating resources and sharing space with conspecifics (Fritzell 1978). This added stress may decrease adult female survivorship (Schneider et al. 1971) and lower recruitment of breeding females. Low survivorship affects productivity; the number of breeding adults is reduced and compensated for by larger litter sizes (Stuewer 1943, Johnson 1970). The mother-young relationship improves with smaller litter sizes (Tardiff et al. 2002); energy of breeding females is less taxed with smaller litters, allowing mothers to provide greater individual care to her offspring during times of pregnancy and young-rearing (Nowak et al. 2000).

At the agricultural site, all raccoons were about 3 years or younger at time of initial capture; while there was no difference in age structure between the three study sites, population turnover may have been greatest at the agricultural site. The chance of human-related mortality appeared to be greater at the agricultural site, due to its proximity to several heavily traveled roadways and higher encounter rate with human occupants and workers on the property. At AWMA, human activity was low for much of the year, except during regulated hunting seasons. Raccoons likely survived to older ages in areas with less human-raccoon interaction, but there was no unequivocal evidence of that at any study site.

Annual survival of male and female raccoons, when pooled, did not appear to differ among sites and years in this study. Estimates were consistent with recent estimates in neighboring Mississippi (Chamberlain et al. 1999). However, when considered by sex alone, there were many differences within sites and years. Average annual survival of males and females fluctuated greatly between years at AWMA and differed from previous reports of no annual difference in male and female survivorship (Gehrt and Fritzell 1999, Kamler and Gipson 2003). Difference in survival of both genders at AWMA appeared substantial in 2005; all radio-collared males (n = 7) were known to survive the monitoring period, in sharp contrast to the 2 females (n = 8) known to survive.

In calculating minimum estimate of survival, all animals that went "missing" were assumed dead, but their actual fate was unknown. During 2005, 3 females were found dead, 2 females went missing, and 1 either lost the collar or was killed - only the collar remained. It is possible that the first 2 missing females did not actually die, but moved to an area where I was unable to locate them. Telemetry flights conducted to re-locate missing animals often were successful; three raccoons were re-located north of the Alabama River in Lowndes County, in areas that were otherwise inaccessible. In several cases, at all study sites, radio-collared animals that previously had disappeared were recaptured, either without their transmitter or with a failed transmitter still attached to the collar. However, I calculated minimum estimate of survival in an attempt to depict a more realistic conservative situation; when “missing” animals were considered as alive in survival analyses, 100% survivorship was predicted for both sexes, across all sites and times.

Survivorship of males and females decreased from 2004 to 2005 in all cases except for males at AWMA in 2005; however, not all comparisons were statistically significant. Raccoon hunting appeared not to be common at any site, but one female was found with a bullet hole in her collar and, therefore, hunting could not be ruled out as a source of mortality. Raccoons are known to have few natural predators as adults (Rosatte 1998), but the possibility of death due to disease remains. Diseases such as canine distemper and rabies are cyclic in wildlife populations (Roscoe 1993); blood titer examinations will likely determine presence/absence of these diseases in the study areas of this project. The majority of animals handled or observed during this study appeared healthy, with no outward physical or behavioral signs of disease. Brainstem samples were sent to county health departments on 2 occasions when the animal handler was bitten or scratched by an aggressive raccoon; results for both submissions were negative for the rabies.

Other sources of mortality for raccoons include malnutrition and starvation, often compounded by high parasitic loads (Mech et al. 1968). Most, if not all, captured animals were heavily infested with ticks. While ticks often are not associated with cause of mortality, infestation is known to vary seasonally (Oullette et al. 1997). If high parasitic loads on the body alter foraging behaviors at times of the year when food is scarce or when behavior is altered due to breeding or young-rearing, mortality may increase due to starvation. However, this study does not seem to support a change in mortality due to time of year, as survival rates differed considerably between genders at all sites in all seasons (Table 1.7). Survival of males appeared less than that of females during the breeding seasons at riverine sites, but was either equal to or less than that of females at the other two sites during these times. There was no clear trend as to whether or not one sex consistently exhibited higher survivorship than the other during the young-rearing seasons, but males typically had higher survival rates than females during dispersal seasons, with the exception of the agriculture site. Here, dispersal survival of males was either similar to or lower than that of females.

The spatial distribution of raccoons across a landscape may influence survival rates in central Alabama. Temporal, spatial, and gender-specific differences in behavior, movements, and territory overlap of raccoons likely influence resource use and competition, interaction with humans, and disease transmission. It is therefore possible that survivorship of raccoons in this study was affected by habitat use, movement patterns, spatial overlap, and population densities. Current survivorship estimates in these areas should be examined in the context of species-specific distribution and resource use to enhance wildlife management practices in Alabama.

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Table 1.1. Number of raccoons captured at agricultural, riverine, and AWMA study sites, Alabama, 2004-2005.

		Total Captures	Radio-collared
Agricultural	Male	13	7
	Female	19	9
Riverine[1]	Male	32	15
	Female	24	11
AWMA	Male	17	10
	Female	16	9
Totals		121	61

[1] The riverine study areas consisted of captures from Lowndes WMA and General Electric.

Table 1.2. Mean age (years) of male and female raccoons at time of initial capture at agricultural, riverine, and AWMA sites, Alabama, 2004-2005.

			Age	
Study Site	Sex	n	Mean	SE
Agricultural	Males	8	1.12	0.23
	Females	17	1.38	0.28
	Both	25	1.30	0.20
Riverine	Males	30	1.78	0.34
	Females	20	1.42	0.46
	Both	50	1.64	0.28
AWMA	Males	13	1.73	0.31
	Females	11	2.73	0.99
	Both	24	2.19	0.48

Table 1.3. Minimum estimate of annual survival of radio-collared raccoons at agricultural, riverine, and AWMA sites, Alabama, 2004-2005.

		2004					2005				
Study Site	Sex	n[1]	Days[2]	Radio-days[3]	Survival Rate[4]	95% CI[5]	n	Days	Radio-days	Survival Rate	95% CI
Agricultural	Male	4	308	667	1.0	(1.0, 1.0)	6	350	1071	0.2	(0.07, 0.97)
	Female	7	308	988	0.7	(0.40, 1.0)	7	350	1470	0.3	(0.11, 0.86)
	Both	11	308	1655	0.8	(0.58, 1.0)	13	350	2541	0.3	(0.13, 0.65)
Riverine	Male	12	339	2372	0.5	(0.32, 0.99)	10	350	1589	0.3	(0.13, 0.87)
	Female	10	339	1903	0.7	(0.43, 1.0)	6	350	1179	0.2	(0.06, 0.83)
	Both	22	339	4275	0.6	(0.42, 0.91)	16	350	2768	0.3	(0.13, 0.62)
AWMA	Male	7	308	1079	0.5	(0.26, 1.0)	7	350	1774	1.0	(1.0, 1.0)
	Female	6	308	1013	1.0	(1.0, 1.0)	7	350	784	0.0	(0.01, 0.60)
	Both	13	308	2092	0.7	(0.50, 1.0)	14	350	2558	0.4	(0.23, 0.85)

[1] Number of animals used in analysis.

[2] Number of days within the annual study interval.

[3] Number of radio-days animals were collared.

[4] Mean survival rate estimate.

[5] 95% Confidence Interval (Lower, Upper).

Table 1.4. *Z*-test results of adult raccoon survivorship comparisons for (a) male, (b) female, and (c) both genders at agricultural, riverine and AWMA sites, Alabama, 2004-2005.

	2004		2005	
a) Adult Male Raccoons				
	Z-statistic	*P*-value	*Z*-statistic	*P*-value
Riverine versus Agricultural Site	-2.84	0.002*	0.33	0.371
Riverine v. Autauga WMA	0.08	0.468	-4.33	<0.001*
Autauga WMA v. Agricultural Site	0.02	0.018*	-4.46	<0.001*
b) Adult Female Raccoons				
	Z-statistic	*P*-value	*Z*-statistic	*P*-value
Riverine v. Agricultural Site	-0.06	0.474	-0.38	0.351
Riverine v. Autauga WMA	-1.82	0.034*	0.53	0.297
Autauga WMA v. Agricultural Site	-1.33	0.092	-1.44	0.075
c) All Adult Raccoons				
	Z-statistic	*P*-value	*Z*-statistic	*P*-value
Riverine v. Agricultural Site	-1.05	0.146	-0.03	0.488
Riverine v. Autauga WMA	-0.61	0.272	-0.84	0.201
Autauga WMA v. Agricultural Site	0.40	0.345	-0.79	0.214

* Indicates a significant deviation from random ($P < 0.05$).

Table 1.5. *Z*-test results of adult raccoon survivorship comparisons for (a) male, (b) female, and (c) both genders at agricultural, riverine and AWMA sites, Alabama, 2004-2005.

Study Site	Comparison	*Z*-statistic	*P*-value
Agricultural	Male 2004 versus 2005	4.46	<0.001*
	Female 2004 v. 2005	1.56	0.060
	Male v. Female 2004	1.33	0.092
	Male v. Female 2005	-0.20	0.420
Riverine	Male 2004 v. 2005	1.09	0.139
	Female 2004 v. 2005	2.16	0.015*
	Male v. Female 2004	-0.57	0.284
	Male v. Female 2005	0.27	0.394
AWMA	Male 2004 v. 2005	-2.11	0.018*
	Female 2004 v. 2005	4.12	<0.001*
	Male v. Female 2004	-2.11	0.018*
	Male v. Female 2005	4.12	<0.001*

* Indicates a significant deviation from random ($P < 0.05$).

Table 1.6a. Minimum estimate of breeding season survival of radio-collared raccoons at agricultural, riverine, and AWMA sites, Alabama, 2004-2005.

		2004					2005				
Breeding season											
Study Site	Sex	n[1]	Days[2]	Radio-days[3]	Survival Rate[4]	95% CI[5]	n	Days	Radio-days	Survival Rate	95% CI
Agricultural	Male	1	58	60	1.00	(1.00, 1.00)	5	120	585	1.00	(1.00, 1.00)
	Female	3	58	149	1.00	(1.00, 1.00)	6	120	647	0.82	(0.58, 1.00)
Riverine	Male	7	120	685	0.68	(0.43, 1.00)	8	120	637	0.44	(0.22, 0.98)
	Female	5	120	505	1.00	(1.00, 1.00)	5	120	593	0.80	(0.55, 1.00)
AWMA	Male	4	58	296	1.00	(1.00, 1.00)	6	120	677	1.00	(1.00, 1.00)
	Female	3	58	149	1.00	(1.00, 1.00)	5	120	469	0.56	(0.29, 1.00)

[1] Number of animals used in analysis.

[2] Number of days within each season interval.

[3] Number of radio-days animals were collared.

[4] Mean survival rate estimate.

[5] 95% Confidence Interval (Lower, Upper).

Table 1.6b. Minimum estimate of young-rearing season survival of radio-collared raccoons at agricultural, riverine, and AWMA sites, Alabama, 2004-2005.

		2004					2005				
Young-rearing season											
Study Site	Sex	n[1]	Days[2]	Radio-days[3]	Survival Rate[4]	95% CI[5]	n	Days	Radio-days	Survival Rate	95% CI
Agricultural	Male	1	122	122	1.00	(1.00, 1.00)	6	122	404	0.35	(0.14, 1.00)
	Female	3	122	303	0.61	(0.30, 1.00)	6	122	514	0.77	(0.49, 1.00)
Riverine	Male	6	122	628	0.81	(0.56, 1.000)	6	122	638	0.81	(0.57, 1.00)
	Female	5	122	589	1.00	(1.00, 1.00)	5	122	444	0.73	(0.44, 1.00)
AWMA	Male	4	122	369	0.46	(0.20, 1.00)	6	122	682	1.00	(1.00, 1.00)
	Female	3	122	366	1.00	(1.00, 1.00)	4	122	227	0.24	(0.07, 1.00)

[1] Number of animals used in analysis.
[2] Number of days within each season interval.
[3] Number of radio-days animals were collared.
[4] Mean survival rate estimate.
[5] 95% Confidence Interval (Lower, Upper).

Table 1.6c. Minimum estimate of dispersal season survival of radio-collared raccoons at agricultural, riverine, and AWMA sites, Alabama, 2004-2005.

Dispersal season		2004					2005				
Study Site	Sex	n[1]	Days[2]	Radio-days[3]	Survival Rate[4]	95% CI[5]	n	Days	Radio-days	Survival Rate	95% CI
Agricultural	Male	4	123	485	1.00	(1.00, 1.00)	2	77	82	0.22	(0.06, 1.00)
	Female	6	123	536	1.00	(1.00, 1.00)	5	77	309	0.43	(0.20, 1.00)
Riverine	Male	9	123	1059	0.88	(0.71, 1.00)	5	77	314	1.00	(1.00, 1.00)
	Female	8	123	809	0.61	(0.38, 1.00)	3	77	142	0.24	(0.07, 1.00)
AWMA	Male	5	123	414	1.00	(1.00, 1.00)	6	77	416	1.00	(1.00, 1.00)
	Female	6	123	498	0.76	(0.48, 1.00)	2	77	88	0.26	(0.07, 1.00)

[1] Number of animals used in analysis.
[2] Number of days within each season interval.
[3] Number of radio-days animals were collared.
[4] Mean survival rate estimate.
[5] 95% Confidence Interval (Lower, Upper).

Table 1.7. *Z*-test results for (a) riverine versus agricultural site, (b) riverine versus AWMA, and (c) AWMA versus agricultural site comparisons for male and female adult raccoons, Alabama, 2004-2005.

(a) Riverine versus Agricultural Site

	Male		Female	
Year & Season	*Z*-statistic	*P*-value	*Z*-statistic	*P*-value
2004 Breeding	-1.82	0.035*	0	> 0.5
2004 Young-rearing	-1.20	0.115	1.43	0.076
2004 Dispersal	-1.12	0.132	-2.33	0.010*
2005 Breeding	-3.18	< 0.001*	-0.88	0.188
2005 Young-rearing	1.75	0.040*	1.36	0.086
2005 Dispersal	6.74	< 0.001*	-0.58	0.281

(b) Riverine v. AWMA

Year & Season	*Z*-statistic	*P*-value	*Z*-statistic	*P*-value
2004 Breeding	-1.82	0.035*	0	> 0.5
2004 Young-rearing	1.20	0.114	0	> 0.5
2004 Dispersal	-1.11	0.132	-0.57	0.284
2005 Breeding	-3.17	< 0.001*	0.88	0.189
2005 Young-rearing	-1.20	0.116	1.47	0.071
2005 Dispersal	0	> 0.5	-0.07	0.473

(c) AWMA v. Agricultural

Year & Season	*Z*-statistic	*P*-value	*Z*-statistic	*P*-value
2004 Breeding	0	> 0.5	0	> 0.5
2004 Young-rearing	2.24	0.013*	-1.43	0.076
2004 Dispersal	0	> 0.5	1.26	0.104
2005 Breeding	0	> 0.5	-0.69	0.245
2005 Young-rearing	-3.08	< 0.001*	1.64	0.05*
2005 Dispersal	-3.82	< 0.001*	0.52	0.301

* Indicates a significant deviation from random ($P < 0.05$).

Table 1.8. *Z*-test results for comparison between seasonal survival of male and female adult raccoons at (a) agricultural, (b) riverine, and (c) AWMA sites, Alabama, 2004-2005.

(a) Agricultural

Year	Season	*Z*-statistic	*P*-value
2004	Breeding	0	> 0.5
	Young-rearing	1.43	0.076
	Dispersal	0	> 0
2005	Breeding	1.19	0.117
	Young-rearing	-1.48	0.069
	Dispersal	-0.89	0.186

(b) Riverine

Year	Season	*Z*-statistic	*P*-value
2004	Breeding	-1.82	0.035*
	Young-rearing	-1.20	0.115
	Dispersal	1.39	0.082
2005	Breeding	-1.50	0.067
	Young-rearing	0.30	0.380
	Dispersal	2.95	0.002*

(c) AWMA

Year	Season	*Z*-statistic	*P*-value
2004	Breeding	0	> 0.5
	Young-rearing	-2.24	0.013*
	Dispersal	1.26	0.104
2005	Breeding	2.03	0.021*
	Young-rearing	2.92	0.002*
	Dispersal	6.44	<0.001*

* Indicates a significant deviation from random ($P < 0.05$).

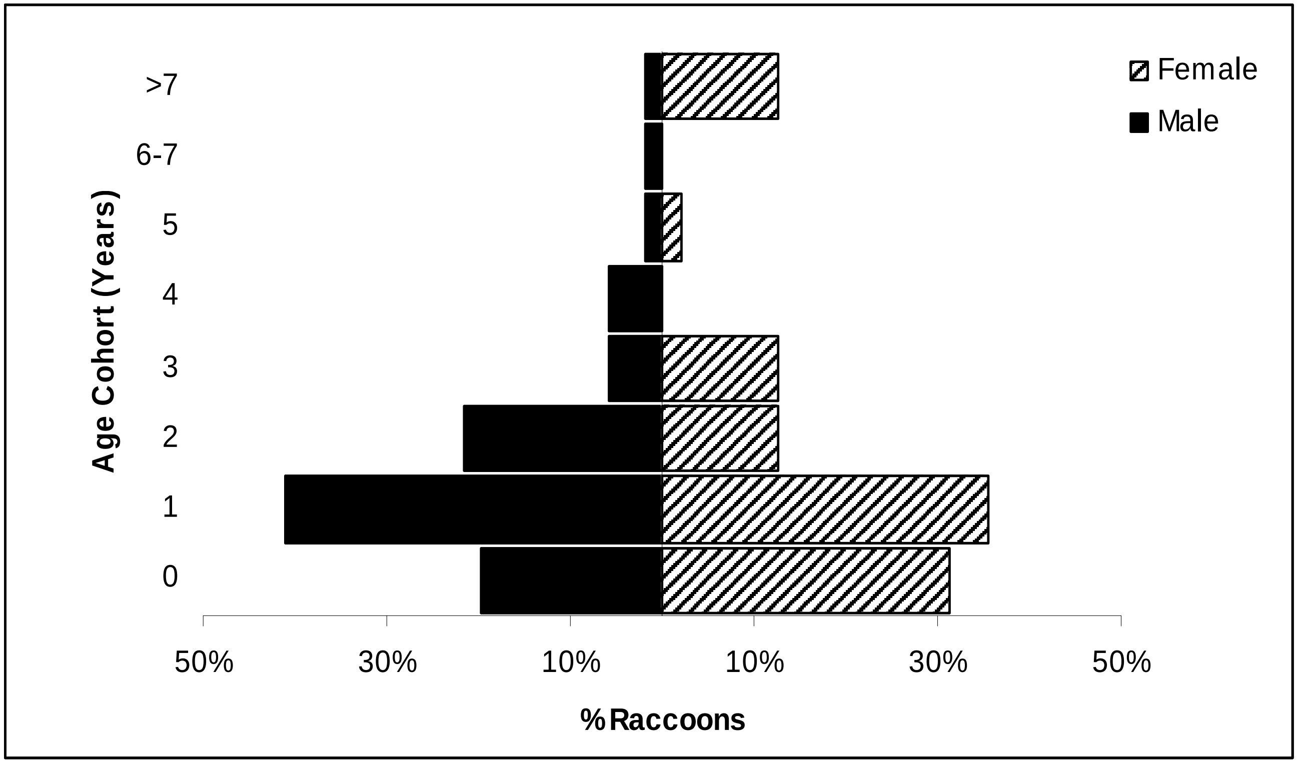

Figure 1.1. Population age distribution of raccoons captured at agricultural, riverine, and AWMA sites, Alabama, 2004-2005. Age (years) was determined by cementum analysis of premolars and calculated with an assumed birth date of 1 May. The age class of “0” represents young-of-the-year, < 1 year old.

CHAPTER TWO

Multi-scale Assessment of Spatial Patterns and Habitat Selection of Adult Raccoons (*Procyon lotor*) in Central Alabama

INTRODUCTION

The raccoon, *Procyon lotor*, is an extremely adaptable omnivore capable of living in a wide variety of habitats. This ability, as well as introductions by humans, is the primary reason for the species' extensive range across North America (Gehrt 2003). In the southeastern United States, raccoons preferentially inhabit bottomland hardwood and pine-hardwood forests, as well as forests adjacent to permanent streams and rivers (Johnson 1970). However, this species also is able to exploit resources in less favorable habitats including pine timberland and intensively managed pine plantations (Johnson 1970, Leberg and Kennedy 1988, Chamberlain et al. 2000). However, the reasons that *P. lotor* "chooses" its habitat remain largely unknown. Selective habitat use is defined as an animal choosing particular habitat components disproportionately to their availability in a landscape, i.e., components that are "preferred" (Johnson 1980). Habitat components often are ranked in order of preference, dependent on equal availability of all parts, but comparison of usage to habitat availability can be misleading. Results may vary with the researcher's definition of habitat availability as well as by the scale at which individual animals actively select components of the habitat to include in their movement patterns.

Chamberlain et al. (2002) documented that habitat selection differed at multiple scales in Mississippi and stressed the importance of considering multiple scales in future studies.

Landscape features and habitat characteristics affect spatial arrangement and sizes of home ranges (Chamberlain and Leopold 2001) and social behavior of raccoons (Urban 1970, Barash 1974, Fritzell 1978a, Glueck et al. 1988, Kamler and Gipson 2003). Distributions of females are shaped by resource availability (e.g., food, water, den sites), while spacing patterns of males largely are dependent on distribution of females (Sandell 1989, Gehrt and Fritzell 1998, Chamberlain and Leopold 2002). Habitat use, home-range characteristics, and activity patterns vary temporally (Fritzell 1978b, Endres and Smith 1993, Gehrt and Fritzell 1997) and spatially (Berner and Gysel 1967, Johnson 1970, Fritzell 1978b, Chamberlain and Leopold 2002). In the Southeast, winter conditions are less harsh than at northern latitudes and *P. lotor* exhibits dissimilar social organization and spatial patterns (Fritzell 1978a, Gehrt and Fritzell 1998). Seasonal and intersexual differences of habitat use exist (Sherfy and Chapman 1980, Endres and Smith 1993); these differences are likely dependent on geographic location.

The promiscuous mating tendencies of raccoons also alter size, shape, and location of home ranges on a seasonal basis (Johnson 1970). Expansion and contraction of home ranges throughout the year(s) may affect intra- and interspecific resource competition, interaction with humans and other animals, and disease transmission. Raccoons historically have been described as solitary and intolerant of conspecifics (Tevis 1947, Kaufmann 1982, Sanderson 1987). However, social organization of this species is complex and possibly unique to other solitary carnivores (Gehrt and Fritzell 1998). Numerous studies have investigated social structure of populations (Fritzell

1978a, Gehrt and Fritzell 1998, Chamberlain and Leopold 2002, Gehrt and Fox 2004) and have illustrated that sociality also varies by location and demographics. Little is known about behavior in Alabama, but the social diversity of *P. lotor* in other regions of North America indicates that variable management of this species on a local scale, for wildlife conservation, fur harvest, nuisance problems, and disease control, is likely necessary.

The combination of large home ranges and the ability to shift activity patterns in response to habitat and resource availability often allows large populations of *P. lotor* to have a significantly detrimental effect on prey populations (Dorney 1954, Fritzell 1978b). Their ability to easily adjust to changing landscapes allows raccoons to establish successful populations in many areas where humans reside, inevitably causing nuisance and damage problems. Management of raccoons as predators and nuisance animals is affected by habitat conditions at different scales and depends on a greater understanding of how they are spatially distributed. As the landscape of the Southeast continues to change and is increasingly dominated by pine timberland (Dickson and Wigley 2001), knowledge of interactions, presence, and preference for various habitat types is needed. The objectives of this study were to (1) estimate home range and core use areas; (2) describe seasonal, interspecific interactions; and (3) investigate and compare multiple scales of habitat selection in central Alabama, across several landscapes and biological seasons. Information detailing local habitat selection will supplement the existing knowledge pertaining to the ecology of raccoons in Alabama. An understanding of habitat preference of raccoons, in addition to knowledge of space use, interactions, and survivorship, will contribute to state-wide management practices involving harvest regulations, nuisance control, and conservation of other wildlife species.

STUDY AREAS

Refer to Chapter One for a detailed description of the study areas.

METHODS

Capture and Handling

Refer to Chapter One for the capture and handling protocol.

Spatial Patterns

Radio-collared raccoons were monitored from February 2004 through December 2005, with an emphasis on nocturnal activity. An attempt to obtain equal numbers of locations was made to reduce bias in home-range estimates. Locations were acquired using ≥ 2 locations with a hand-held 3-element Yagi antenna and portable receiver (Advanced Telemetry Systems, Inc., Isanti, Minnesota), from permanent, telemetry stations ≥ 3 times/week. Sequential locations were separated by a minimum of 2 hours to maintain sample independence. Additional observations were acquired by walking to the day-time resting site of radio-collared animals at least once a month. During the young rearing season, attempts were made to locate all female den sites at least once a week. I defined biological seasons following Chamberlain and Leopold (2002): breeding (1 February – 31 May), young rearing (1 June – 30 September), and winter (1 October – 31 January).

In the event that a radio-collared raccoon was not located from roadside stations, an extensive search was conducted by driving throughout the study area and surrounding areas on established roads. Three telemetry flights were conducted to locate animals that had been missing for ≥ 1 month (Mech 1983).

Telemetry bearing error was measured with a double-blind beacon study (White and Garrott 1990), using test transmitters in the Lowndes WMA and AWMA. Precision of bearings was 7.3° and 6.8° at Lowndes WMA and AWMA, respectively.

Locations of raccoons were estimated using program LOCATE II (Nams 1990) with ≥ 2 bearings taken ≤ 10 min apart. Bearings were maintained between 20° and 160° to reduce error (Gese et al. 1988). Annual and seasonal home range (95%) and core-area (50%) contour intervals were estimated with the adaptive kernel method (ADK) (Worton 1989) in the program CALHOME (Kie et al. 1994). The default grid cell size of 30 x 30 m was used (Kie et al. 1994). A smoothing parameter (h_{cv}) was calculated in CALHOME by least squares cross-validation and was manually altered to a value of $0.8h_{cv}$, following Kie et al. (1994) and Worton (1995), to reduce bias in the adaptive kernel density estimation of home ranges. Seasonal and annual home ranges were calculated for animals with a minimum of 20 locations and monitored for 75% of the season or year. Differences in annual home range and core area sizes were tested with a 2-way analysis of variance (ANOVA, SAS Institute 2004), blocked by year. Possible differences in seasonal home range and core area size among sites, sexes, and seasons were tested using a 3-way ANOVA, also blocked by year.

To examine overlap between neighboring raccoons, static interaction indices were constructed based on seasonal home ranges and core areas estimated by the ADK method, without reference to time (Kernohan et al. 2001). Area of overlap was delineated using ArcView (v3.3, Environmental Systems Research Institute, Inc., Redlands, California); static overlap indices were obtained as:

$$O_{i,j} = \frac{A_{i,j}}{A_i}$$

where $O_{i,j}$ is the proportion of an area occupied by raccoon *i* overlapped by raccoon *j*, $A_{i,j}$ is the area of overlap between the two areas, and A_i is the total area occupied by raccoon *i* (Kernohan et al. 2001). Amount of overlap was specific to the individual animal ($O_{i,j} \neq O_{j,i}$) and all collared animals were included in calculations, regardless of location on study sites. Interactions were sorted into gender-specific pairs (male-male, female-female, male-female) and seasonal overlap percentages were pooled across 2004 and 2005. Prior to analysis, an arcsine transformation was applied to proportional data of the indices and coefficients were combined according to season. I then used a 3-way ANOVA blocked by year to test for differences in home range and core area overlap indices within dyads, seasons, and sites. Differences in size of home ranges and core areas, as well as for amount of overlap, were considered significant at $P \leq 0.05$.

Habitat Use

I defined available habitat in similar fashion to Chamberlain et al. (2002). The area boundary was created around the outermost locations where raccoons were trapped during 2004-2005. A polygon was formed from the outermost trap points and buffered with the longest axis of the largest annual home range for each area. Available habitat within each study area was calculated by dividing total area for each habitat type by total area of the buffered polygon.

Habitat types were delineated in a geographic information system (GIS) created from 1:12,000 U.S. Geological Survey 3.75-min digital orthophoto quarter quadrangles

(DOQQ). The DOQQs were produced during 1996-2005 and provided by the Water Quality Program of the Alabama Cooperative Extension System. Habitat types were classified as field/grass, hardwood forest, pine forest, regenerating pine stands, human development areas, and water and were defined by on-screen digitizing using ArcView (v3.3 Environmental Systems Research Institute, Inc., Redlands, California). Field/grass habitat consisted of all pasture, field, and other herbaceous cover with few or no shrubs and/or trees (Kamler and Gipson 2003). Hardwood forests were defined as wooded areas containing 75% deciduous tree cover. Pine forests consisted mainly of planted pine stands or of areas with 75% mature coniferous tree cover; mature pine was classified as ≥15 years of age. Areas in which pine forest was harvested by clear-cutting composed regenerating pine stands. Additionally, I classified an area as a regenerating stand if it contained replanted pine seedlings or other immature stands (<15 years of age). Human development incorporated sections of land covered primarily by human-built structures or areas of intensive use. Water included rivers, streams, ponds, or other water bodies discernible at the digitizing scale.

Using ArcView v3.3, I intersected individual point locations and isopleths for annual home range and core areas with habitat maps for each study area. Attribute tables, including habitat type and area estimates, were then exported for each buffered study area, home-range polygon, core-use polygon, and set of point locations to dBASE IV files (dataBASED Intelligence, Inc., Vestal, New York). Habitat availability of home range and core use areas was calculated in the same manner as total study area availability. The orders of habitat selection described by Johnson (1980) were used to compare usage to availability. Two methods of second-order habitat selection (Johnson

1980) were defined as total area of each habitat type within home range and core area divided by total area of each type available in the study area and home range, respectively. Third-order habitat selection (Johnson 1980) was determined by dividing number of individual point locations found within each habitat type by total number of point locations in the home range.

I used compositional analysis (Aebischer et al. 1993) to analyze annual habitat use. A multivariate analysis of variance (MANOVA) was used to determine if raccoons selected habitats at random and to detect any differences in use of habitat between sexes and study sites. Year was not considered as an effect in the MANOVA because study area boundaries did not change from 2004 to 2005. Differences between used habitat and available habitat were compared after transforming compositional data to log-ratios. Proportion of hardwoods was used as the denominator in these comparisons. In the case that an available habitat type was not used by a particular individual, I replaced a value of 0% with 0.0001% (Aebischer et al. 1993). Nonrandom use was denoted by pair-wise differences between corresponding transformations of available and used habitats. If habitat use occurred in non-random manner, I used paired *t*-tests to develop a ranking matrix of habitat use. Separate ranking matrices were constructed for each site and/or gender, if differences between these groups were identified in the MANOVA. Differences were considered significant at $P \leq 0.05$.

RESULTS

Throughout the study, 121 individual raccoons (62 males, 59 females) (Table 1.1) were captured; 61 were radio-collared (32 males, 29 females). Of the 60 (30 males, 30 females) that were not collared, 16 were juveniles and not eligible for collaring. Capture and monitoring data are presented in Appendix 1.

Spatial Patterns

A total of 4,218 locations for 61 raccoons were collected from 17 February 2004 to 15 December 2005. I estimated 47 annual and 87 seasonal home ranges, with core areas, for 40 and 47 raccoons, respectively. Annual home ranges differed by year ($F_{1,40}$ = 6.38, $P = 0.016$), but core areas did not ($F_{1,40}$ = 2.37, $P = 0.131$). Site and sex did not interact to affect sizes of annual home range ($F_{2,40}$ = 0.78, $P = 0.467$) or core area ($F_{2,40}$ = 0.80, $P = 0.457$). No difference in size of home ranges ($F_{2,40}$ = 0.24, $P = 0.785$) and core areas ($F_{2,40}$ = 0.34, $P = 0.714$) was detected across sites. However, as a main effect, sex contributed considerably to the model. Males, on average, had larger home ranges ($F_{1,40}$ = 19.82, $P < 0.001$) and core areas ($F_{1,40}$ = 36.32, $P < 0.001$) than females, across all sites (Table 2.1).

Differences in seasonal home range size were detected by the model investigating influence of season, site, and sex ($F_{18,68}$ = 3.04, $P < 0.001$). No interactive combination of season, site, and sex contributed to the model, nor did the main effects of year ($F_{1,68}$ = 0.86, $P = 0.357$) or site ($F_{2,68}$ = 2.78, $P = 0.069$). Gender acted as the main effect in the seasonal home range model ($F_{1,68}$ = 25.07, $P < 0.001$). Seasonal core areas differed only by gender ($F_{1,68}$ = 27.82, $P < 0.001$). Males maintained larger core areas and home ranges than females, across all seasons and sites (Table 2.2).

A total of 315 seasonal overlap indices were estimated for 46 raccoons (22 males, 24 females) from 7 February 2004 to 15 December 2005. Year did not affect static home-range interactions ($F_{1,287}$ = 2.59, $P = 0.109$) or core area interactions ($F_{1,287}$ = 3.64,

$P = 0.058$). A 3-way ANOVA showed evidence that home range overlap differed among seasons, sites, and dyads (male-male, female-female, male-female) ($F_{27,287} = 2.97$, $P < 0.001$, Table 2.3). Interaction of study site and biological season influenced the model of home range overlap ($F_{4,287} = 5.504$, $P = 0.001$), as did the main effects of season ($F_{2,287} = 5.57$, $P = 0.004$) and site ($F_{2,287} = 4.10$, $P = 0.018$). Home range overlap did not differ among dyads ($F_{2,287} = 2.91$, $P = 0.056$) or for any interaction with dyads. Amount of home range overlap for all dyads was primarily greatest at the AWMA site, during breeding and dispersal seasons. Illustrations of seasonal static overlap between neighboring male and female raccoons, at each study site, are represented in Figures 2.1a-c, 2.2a-c, and 2.3a-c. A 3-way ANOVA also showed evidence for a difference in amount of core-area overlap among seasons, sites, and dyads ($F_{27,287} = 1.61$, $P = 0.031$). Differences in amount of core area overlap were not due to 2-way interactions of site, season, and dyad, nor to main effects of site, season, or dyad. Year, however, did affect the model ($F_{1,295} = 5.19$, $P = 0.024$); core area overlap was greater in 2004 ($\bar{x} = 15.3\%$, SE = 3.5%, n = 67) than in 2005 ($\bar{x} = 7.1\%$, SE = 1.2%, n = 248).

Habitat Use

Habitat selection was analyzed using 47 annual home ranges of 41 raccoons (21 males, 20 females) from 17 February 2004 to 15 December 2005. Area of available habitat in agricultural, riverine (Lowndes WMA and General Electric) and AWMA sites during this time totaled 5,411, 8,389, and 8,331 ha, respectively (Table 2.4, Figures 2.4, 2.5, 2.6, 2.7). Annual home range of one male at the Lowndes WMA was established outside the defined boundary of the study area and was not included in habitat analyses.

In comparing home-range area to available study area habitat, a site-specific difference was identified ($\lambda = 0.076$; df = 10, 78; $P < 0.001$). Overall, home-range habitat use differed from random at the agricultural ($\lambda = 0.000$; df = 4, 10; $P < 0.001$), riverine ($\lambda = 0.346$; df = 5, 14; $P = 0.006$), and AWMA ($\lambda = 0.075$; df = 5, 9; $P < 0.001$) sites. No gender specific difference was detected at the agricultural ($\lambda = 0.819$; df = 4, 9; $P = 0.738$), riverine ($\lambda = 0.602$; df = 5, 13; $P = 0.200$), or AWMA ($\lambda = 0.316$; df = 5, 8; $P = 0.058$) sites; therefore, the ranking matrices of home-range habitat use represents both sexes at all three sites. Raccoons at the agricultural site showed greatest preference for the water component of the study area, followed by hardwoods, field/grass, human development, and pine woods. At riverine sites, raccoons selected hardwoods preferentially, followed by water areas, human development, field/grass, pine woods, and regenerating pine stands. When selecting home ranges from available habitat, raccoons at AWMA preferred pine woods, then hardwoods, field/grass and regenerating pine stands, water areas, and areas of human development. Rankings for habitat preference in home range areas are presented in Table 2.5.

Comparison of habitat selection within core areas to selection within home ranges did not differ by sex ($\lambda = 0.887$; df = 5, 39; $P = 0.437$) or between sites ($\lambda = 0.670$; df = 10, 78; $P = 0.089$). Habitat use within core areas differed from random when raccoons selected habitat components available in their home ranges ($\lambda = 0.730$; df = 5, 42; $P = 0.018$) and a ranking matrix was constructed using means of habitat elements from all three sites (Table 2.6). In order of relative preference, raccoons selected hardwoods, water areas, pine woods, areas of human development, field/grass, and regenerating pine stands.

When assessing habitat components of locations relative to components available in the home range, no difference between sex ($\lambda = 0.949$; df = 5, 39; $P = 0.835$) or sites ($\lambda = 0.650$; df = 10, 78; $P = 0.062$) was detected. However, raccoons were located in habitat areas that were disproportionate to available habitat within their home ranges ($\lambda = 0.388$; df = 5, 42; $P < 0.001$). When ranked in order of preference, areas of hardwoods were selected most often, followed by pine woods, regenerating pine stands, field/grass, water areas, and areas of human development (Table 2.7).

DISCUSSION

Raccoons exhibit intersexual differences in home range sizes (Sanderson 1987, Sandell 1989) and, similar to previous research, this study found that average annual and seasonal home ranges and core areas of male raccoons were larger than those of females. Average home-range size for male raccoons ranged from a low of 152.33 ± 49.15 ha during the dispersal season at the agricultural site to a high of 300.07 ± 67.71 ha during the breeding season at the AWMA site. Male spacing patterns are likely influenced by those of females during the mating season and influenced by resource distribution outside of this season (Sandell 1989). Thus, males should be expected to increase their territories during the mating season to optimize mating success. In this study, average home ranges of males during the breeding season tended to be larger than those in other seasons, although the difference was not significant. Further, average male home ranges and core areas were smallest during autumn/winter, or the dispersal season. However, while winter home ranges are expected to decrease in northern latitudes due to colder temperatures and a decrease in available forage material (Glueck et al. 1988), studies at southern latitudes do not show similar trends (Gehrt and Fritzell 1997). This is perhaps due to a milder climate and year-round availability of forage materials. Solitary carnivores that breed seasonally often maintain constant territories throughout seasons (Sandell 1989), which was observed in this study as a lack of seasonal variation in average home range and core area sizes for males. It is possible that spatial distribution of these areas shifted seasonally, in response to space use by females and resource availability. Adult raccoons may exhibit site fidelity on a spatial scale (Gehrt 2003), if resource levels do not fluctuate greatly; I was unable to assess site fidelity of males in this study, due to the number of disappearances and mortalities of study animals.

At the AWMA, average seasonal home-range estimates for males are similar to those in what is described as analogous habitat in Mississippi (Chamberlain et al. 2000; Chamberlain and Leopold 2002). It is difficult to further compare the 95% ADK home ranges of this study with other studies at southern latitudes, because study protocols differed among sites and seasons and most calculations were conducted with minimum convex polygons (MCP) (Johnson 1970; Allsbrooks and Kennedy 1987; Gehrt and Fritzell 1997, 1998; Gehrt and Fox 2004). The MCP method is still widely used for comparative purposes with other wildlife studies of home ranges (Kie et al. 1996), but home range estimation by kernel density may provide a more useful technique for comparing space use (Worton 1995). However, the finding that male home range sizes remained consistent throughout the year in Texas (Gehrt and Fritzell 1997) is similar to the lack of difference between male seasonal home ranges in this study, regardless of method of calculating home ranges.

Average home range sizes for females ranged from 52.29 ± 18.28 ha during the young-rearing season at the riverine site to 178.72 ± 94.24 ha during mating season at the

AWMA. Similar to male home range analysis, there were no substantial differences in home range sizes between sites or seasons, but biological trends were noted. Within sites, average sizes of home range and core areas of females decreased during the young-rearing season; this is consistent with arguments of restricted female movement due to presence of a litter (Ellis 1964). However, it also is possible that food resources were abundant during this period and females were able to concentrate foraging and young-rearing activities in a smaller area (Johnson 1970; Gehrt and Fritzell 1998). Overall, this study supports other research on use of space by raccoons conducted at southern latitudes (Gehrt and Fritzell 1997, Chamberlain et al. 2003); home range and core area sizes are maintained seasonally, unlike variation in space use that is common of raccoons in northern regions (Stuewer 1943, Glueck et al. 1988).

Average home-range area of riverine females during the dispersal season may have been influenced by the substantially larger territory of one individual (C5805, Appendix 1). This female moved > 3.5 km from the capture location over 4 months. No other female moved such a distance during the study. Actual age of this individual was undetermined by cementum analysis, however C5805 was lactating at time of capture and thus considered as an adult. The large area traversed by the female while in this reproductive state is contradictory to the theory that females restrict movement during young-rearing (Ellis 1964).

Female natal philopatry appears widespread in populations of *P. lotor* (Gehrt 2003), but this is not necessarily a sign of increased tolerance of females to related neighbors (Ratnayeke et al. 2002). Local distribution of resources and relative costs of sharing those with neighbors is more likely to dictate population structure than relatedness of neighbors (Ratnayeke et al. 2002). While dispersal is predominantly male-biased, instances of female dispersal have been documented (Stuewer 1943). Perhaps the large home range of C5805 at the riverine site is indicative of female dispersal due to a negative spatial relationship between this individual, her litter, and neighboring individuals.

The promiscuous (Stuewer 1943) or polygynous (Fritzell 1978a) mating system of *P. lotor* is characterized by an increase in the home range sizes of males during breeding season in order to optimize reproductive success. In this study, males did not significantly increase size of home ranges during the breeding season, but did share more space with females and other males during this time. Amount of static overlap between core areas did not differ seasonally; core-area sizes did not fluctuate seasonally and space sharing in these areas of intense use appeared less common for individuals. Multiple raccoons shared den sites on numerous occasions; however, the majority of these were assumed to be family groups, as it appeared one adult was sharing space with 2-4 juveniles.

Space sharing also differed by site and often was greatest at the AWMA. This site was characterized by large plots of pine plantation, interspersed with hardwood corridors. The fragmented quality of habitat at this site may dictate that animals cover larger areas when moving, in order to encounter a mate. Home ranges and static interactions of all animals typically were greatest at the AWMA; it is likely that raccoons traveled further through fragmented habitat to locate resource patches and had a higher tolerance for sharing concentrated resources with conspecifics.

Amount of home range and core area overlap was similar for all dyads and it was difficult to ascertain whether or not social groups, beyond the family group, are present in Alabama. Trapping efforts throughout the study demonstrated that there were raccoons present in the study area that were not radio-collared; these observations made it difficult to make a statement about the importance of static interactions at any study site. If animals actively excluded each other, the coefficient of shared space-use was 0. However, percentage of space-use overlap was also 0 in cases where interactions were restricted due to distance between home ranges. Therefore, the actual meaning of limited or no static interactions is questionable. For example, a male (C0805) was captured within the riverine study area in July 2005. However, this male moved out of the pre-defined study area within 5 days of capture and established a home range north of the Alabama River. The animal may have been in the process of dispersing when radio-collared. While it seemed that the capture and handling process did not adversely affect behavior of raccoons in this study, it remains possible that the process spurred this male to leave the vicinity. There was no overlap of C0805's home range or core area with any other males or females at the riverine study site in 2005, but it remains unknown if interactions with other animals influenced this move. Males may form social groups in Alabama, but no conclusive evidence was found in this study to support male social groups.

Site also affected habitat selection, but only at the coarsest scale in this study. In comparing habitat use in home ranges to that available in the study area, water spots were highly preferred by raccoons at agricultural and riverine sites, but not at the AWMA. The water component included wetlands, rivers, and creeks; availability of this component seemed low at the AWMA (0.3%). Creeks and streams were present at this site, but often were hidden in aerial photographs by thick canopy of hardwood-dominated streamside management zones. Availability of water components at this landscape is likely better represented by availability of hardwood forests. More land was characterized by hardwood-dominated forests (39.3%) than pine woods (22.4%) at the AWMA; however, this component typically was present in corridors interspersed throughout pine plantations and regenerating pine stands, as well as along edges of fields and other grassy areas. Pine stands tended to occur in larger, more continuous tracts, and when home range isopleths were overlaid onto habitat maps, they often engulfed pine woods surrounding hardwood corridors. While pine habitat was less abundant on this landscape, it was still preferred above hardwoods by raccoons at the scale of choosing home-range space. Mature pine stands may provide quality habitat for raccoons, by providing soft mast forage on a seasonal basis (Johnson 1970, Chamberlain et al. 2003). Use of prescribed fire in mature pine stands was infrequent at the AWMA prior to and during the course of this study, which allowed a thick understory of vines (e.g., *Vitis* sp.), woody plants (e.g., *Callicarpa americana*), and berry thickets (e.g., *Rubus* sp.) to persist. Presence of unharvested pine snags in mature stands and along hardwood edges also provided quality denning and resting sites.

At the agricultural site, water and grassy areas were ranked above hardwood use at the home range level. Nearly 43% of this area was characterized by field/grass, which occurred in large patches intersected with wooded areas and waterways. Raccoons were observed on several occasions to be foraging in grass pastures – areas known to harbor insect populations (Johnson 1970). Only 2% of the agricultural site was classified as water; however, it was the most preferred habitat type at the home-range level. These water areas had a high ranking at the scale of core-area selection and individual locations, second only to hardwood habitat. Hardwood corridor areas typically were used for travel throughout a landscape, documented by presence of raccoon locations, and also contained resources available for successful foraging by raccoons. Both hard and soft masts were available in travel corridors, as well as prey including herpetofauna, fishes, and insects. Concentration of available den sites along wooded strips also contributed to increased use; nearly half of all documented den sites were in hardwood trees or snags at all sites. Henner et al. (2004) suggested that den selection is related to resource availability; raccoons selected areas with greater availability of water and chose hardwood patches. Resource availability across a landscape likely dictates presence in various habitats.

Raccoons maintained core areas where hardwoods were available on the landscape, similar to the findings of Chamberlain et al. (2002). Hardwoods ranked highest for male and female raccoons at all study areas at the second order level of core areas and at the third order level of individual locations. Forested habitat, both pine and hardwood, is an important component of home ranges, often providing areas of concentrated resource availability (Chamberlain et al. 2003). While *P. lotor* has been successful at exploiting a variety of habitats across North America (Ivey 1948, Cagle 1949, Johnson 1970, Glueck et al. 1988, Chamberlain et al. 2002), the species invariably incorporates resource-laden wooded and riparian areas into its home range.

A multi-scale investigation of habitat use is important because the degree to which animals select habitats is unknown (Chamberlain et al. 2002). Habitat features that are selected at a finer level, such as core-use areas, may not be reflected suitably at a coarser scale. Habitat selection did not differ between genders; males typically occupied larger home ranges than females, but both sexes selected habitat in their annual home ranges and core areas with similar preferences. Seasonal selection of habitat was not analyzed in this study, because there were fewer individual, seasonal home ranges to represent habitat use accurately. It is possible that habitat use differed between male and female raccoons throughout seasons, as energy requirements and locations of available forage changed (Kaufmann 1982). A multi-scale assessment of seasonal habitat use by raccoons in Alabama is recommended to improve management of this species in various landscapes.

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Table 2.1. Annual 95% ADK home-ranges (ha) and 50% ADK core-areas (ha) for adult male and female raccoons at agricultural, riverine, and AWMA sites, Alabama, 2004-2005. Estimates were pooled for all study sites because there was no difference in size of home ranges or core areas among sites.

			Home Range		Core Area	
		n[1]	Mean	SE	Mean	SE
Male	2004	7	201.6	26.6	34.7	3.8
	2005	16	247.2	23.8	40.1	4.8
Female	2004	11	61.4	9.4	7.7	1.1
	2005	13	151	26.5	17.4	2.8

[1] Number of individual raccoons used in estimation of annual home ranges and core areas.

Table 2.2. Seasonal 95% ADK home ranges (ha) and 50% ADK core use areas (ha) of adult male and female raccoons at agricultural, riverine, and AWMA sites, Alabama, 2004-2005.

		Male			Female		
			Home Range	Core Area		Home Range	Core Area
Study Site	Season	n	Mean ± SE	Mean ± SE	n	Mean ± SE	Mean ± SE
Agriculture	Breeding[1]	5	167.1 ± 28.7	24.4 ± 4.3	5	78.2 ± 14.0	18.8 ± 5.6
	Young-rearing[2]	5	167.4 ± 22.5	30.2 ± 6.8	5	56.8 ± 13.7	8.2 ± 1.6
	Dispersal[3]	3	152.3 ± 49.2	21.8 ± 9.4	6	117.4 ± 12.7	15.3 ± 4.0
Riverine	Breeding	8	198.7 ± 31.6	27.4 ± 2.9	8	67.2 ± 17.4	7.8 ± 1.7
	Young-rearing	8	174.3 ± 20.7	30.5 ± 4.2	7	52.3 ± 18.3	5.8 ± 1.8
	Dispersal	6	170.2 ± 45.2	30.2 ± 6.3	2	145.5 ± 63.6	22.1 ± 2.8
AWMA	Breeding	3	300.1 ± 67.7	44.3 ± 10.0	3	178.7 ± 94.2	29.9 ± 14.3
	Young-rearing	4	261.1 ± 72.8	41.8 ± 7.2	3	83.5 ± 22.8	11.7 ± 3.6
	Dispersal	7	190.3 ± 44.4	30.5 ± 9.3	2	85.5 ± 17.2	11.4 ± 1.5

[1] 1 February – 31 May
[2] 1 June – 30 September
[3] 1 October – 31 January

Table 2.3. Seasonal average (± SE) home-range and core-area overlap indices (%) for adult raccoon dyads at agricultural, riverine, and AWMA sites, Alabama, 2004-2005.

a) Breeding season

			Home Range	
Dyad	Site	n	Overlap	SE
Male-Female	Agriculture	20	25	9
	Riverine	21	45	10
	AWMA	9	59	14
Male-Male	Agriculture	12	14	7
	Riverine	14	27	10
	AWMA	6	52	12
Female-Female	Agriculture	20	5	3
	Riverine	14	21	9
	AWMA	6	63	15

b) Young-rearing season

			Home Range	
Dyad	Site	n	Overlap	SE
Male-Female	Agriculture	11	35	14
	Riverine	22	6	4
	AWMA	8	22	14
Male-Male	Agriculture	12	17	9
	Riverine	22	27	7
	AWMA	12	13	9
Female-Female	Agriculture	8	16	12
	Riverine	14	24	8
	AWMA	2	0	0

c) Dispersal season

			Home Range	
Dyad	Site	n	Overlap	SE
Male-Female	Agriculture	8	53	12
	Riverine	8	11	11
	AWMA	2	67	13
Male-Male	Agriculture	2	60	33
	Riverine	14	19	7
	AWMA	30	7	3
Female-Female	Agriculture	14	27	10
	Riverine	2	0	0
	AWMA	2	52	10

[1] Number of calculated overlap indices.

Table 2.4. Area (ha) and percent composition (%) of habitat types available to raccoons at agricultural, riverine[1], and AWMA sites, Alabama, 2004-2005.

	Habitat Type						
Study Site	Hardwood	Field/grass	Human Development	Pine	Regenerated Pine	Water	Total
Agricultural	2299.7 (42.5%)	2764.8 (51.1%)	84.2 (1.6%)	147.1 (2.7%)	0	115.4 (2.1%)	5411.2
Lowndes WMA	2782.8 (45.4%)	2217.7 (36.2%)	134.1 (2.2%)	183.5 (3.0%)	326.9 (5.3%)	484.6 (7.9%)	6129.6
General Electric	856.2 (37.9%)	740.4 (32.8%)	80.8 (3.6%)	330.5 (14.6%)	77.8 (3.4%)	173.6 (7.7%)	2259.5
AWMA	3270. 7 (39.3%)	1403.6 (16.8%)	429.6 (5.2%)	1864.0 (22.4%)	1335.4 (16.0%)	28.2 (0.3%)	8331.4

[1] The riverine study area combined raccoon habitat composition of Lowndes WMA and General Electric's property.

Table 2.5. Average ranks[1] for raccoons based on comparing proportional habitat within 95% ADK home ranges with proportions of total available habitat types at agricultural, riverine, and AWMA areas, Alabama, 2004-2005. [2]

	Habitat Type					
Study site	Field/Grass	Hardwood	Human Development	Pine	Regenerating Pine[3]	Water
Agriculture	3	2	1	0	N/A	4
Riverine	2	5	3	1	0	4
AWMA	2	4	0	5	3	1

[1] Increased use is represented by an increase in rank value.

[2] Simplified ranking matrices used to create the ranking orders at the second-order scale of habitat use are provided in Appendices 2a-c.

3 Areas of regenerating pine were not available for selection in the agricultural area; this category was omitted from the analysis of this area.

Table 2.6. Simplified ranking matrix for raccoons based on comparing the proportions of habitat within 50% ADK core-areas with proportions of habitat within 95% ADK home-ranges from agricultural, riverine, and AWMA sites, Alabama, 2004-2005. Habitat selection and avoidance is designated by positive and negative signs, respectively. A significant deviation from random ($P < 0.05$) is represented by triple signs.

	Habitat Type						
Habitat Type	Field/Grass	Hardwood	Human Development	Pine	Regenerating Pine	Water	Rank[1]
Field/Grass		- - -	-	-	+	-	1
Hardwood	+++		+++	+	+++	+++	5
Human Development	+	- - -		-	+	-	2
Pine	+	-	+		+	-	3
Regenerating Pine	-	- - -	-	-		-	0
Water	+	- - -	+	+	+		4

[1] Increased use is represented by an increase in rank value.

Table 2.7. Simplified ranking matrix for raccoons based on comparing the proportions of radio-locations within each habitat type with proportions of habitat within 95% ADK home-ranges from agricultural, riverine, and AWMA sites, Alabama, 2004-2005. Habitat selection and avoidance is designated by positive and negative signs, respectively. A significant deviation from random ($P < 0.05$) is represented by triple signs.

	Habitat Type						
Habitat Type	Field/Grass	Hardwood	Human Development	Pine	Regenerating Pine	Water	Rank[1]
Field/Grass		- - -	+++	-	-	+	2
Hardwood	+++		+++	+	+	+++	5
Human Development	- - -	- - -		- - -	- - -	-	0
Pine	+	-	+++		+	+++	4
Regenerating Pine	+	-	+++	-		+++	3
Water	-	- - -	+	- - -	- - -		1

[1] Increased use is represented by an increase in rank value.

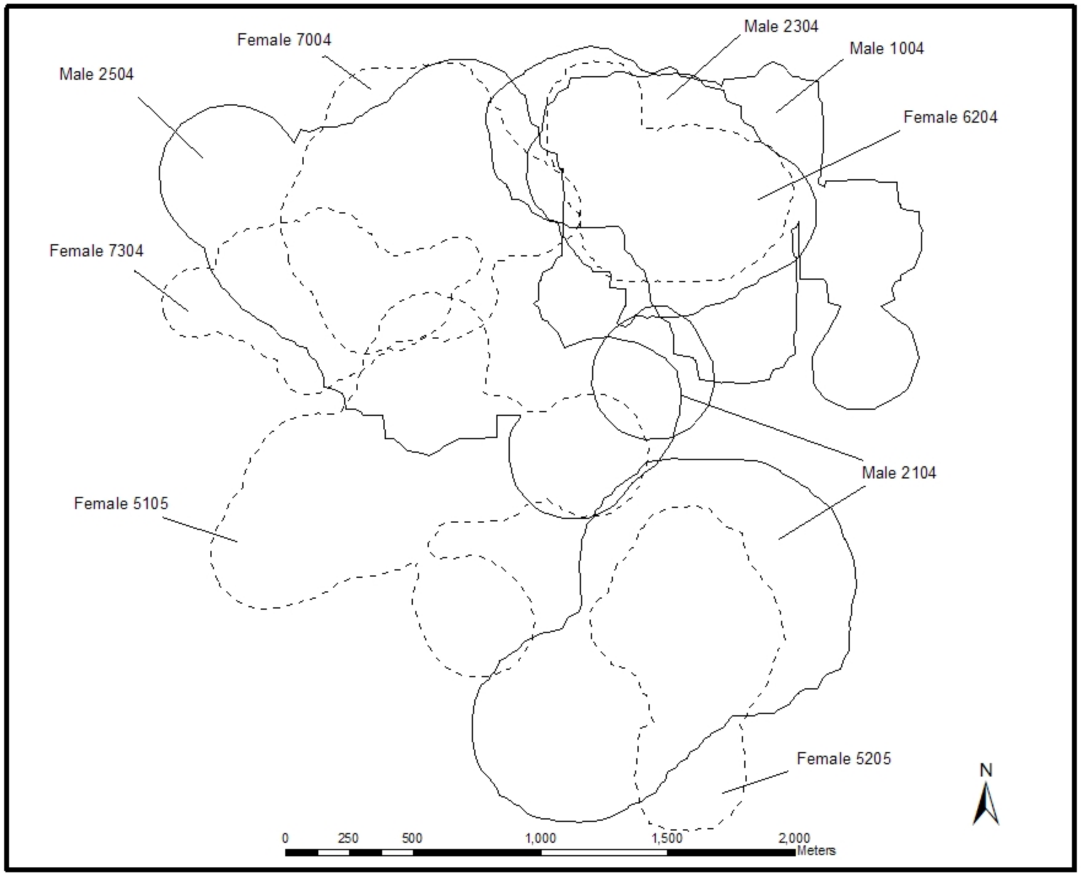

Figure 2.1a. ADK 95% home range isopleths illustrating static overlap between neighboring male and female raccoons during breeding season on agricultural site, Alabama, 2005.

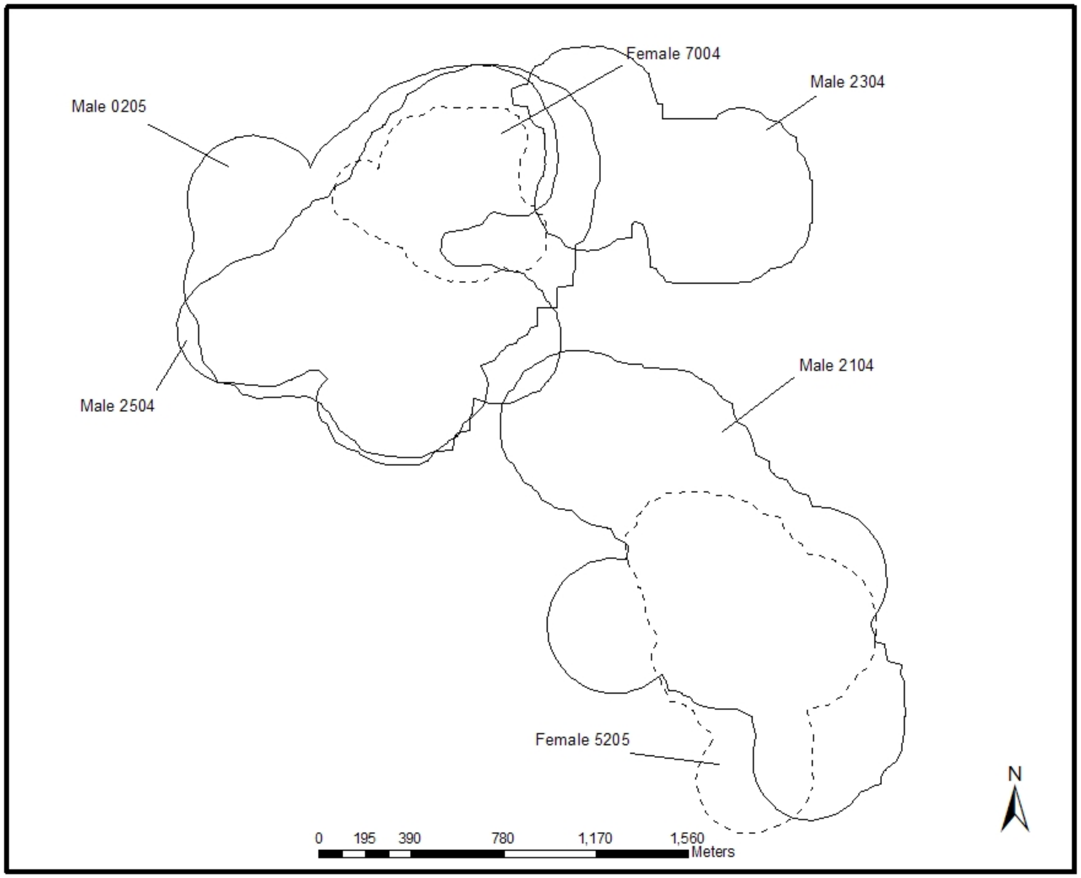

Figure 2.1b. ADK 95% home range isopleths illustrating static overlap between neighboring male and female raccoons during young-rearing season on agricultural site, Alabama, 2005.

Figure 2.1c. ADK 95% home range isopleths illustrating static overlap between neighboring male and female raccoons during dispersal season on agricultural site, Alabama, 2005.

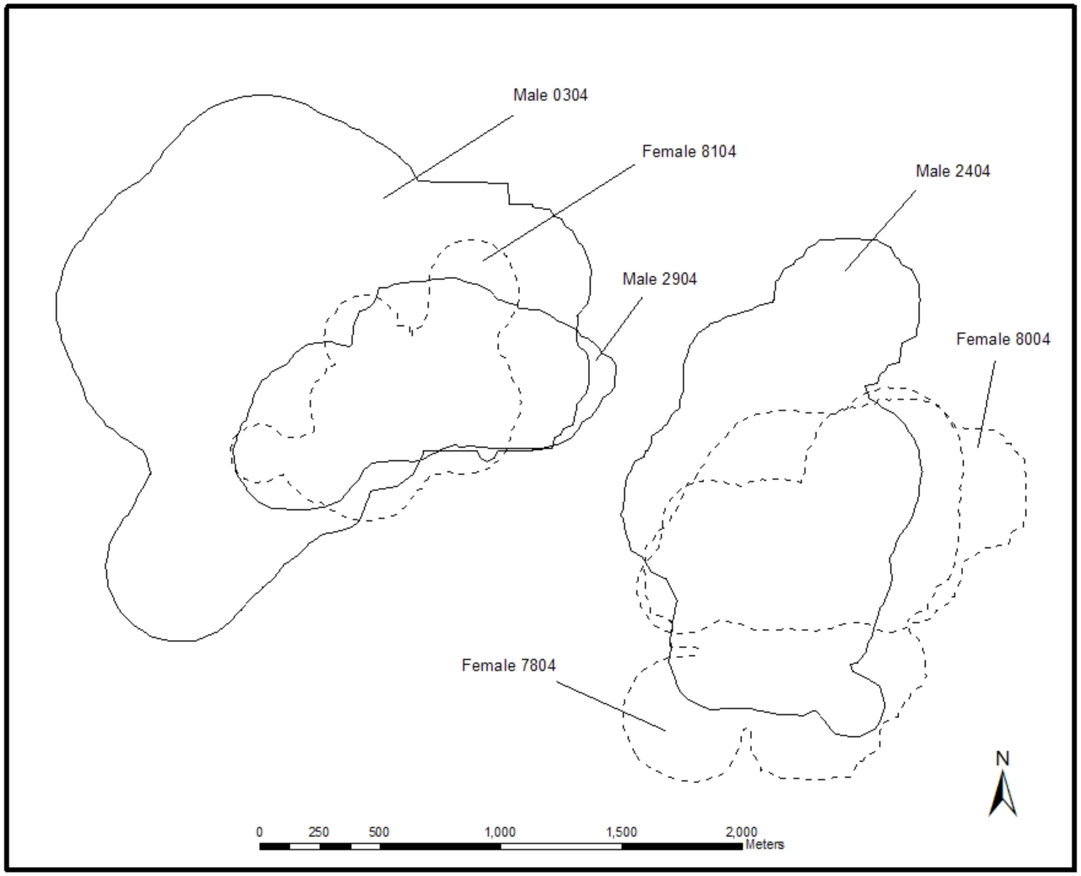

Figure 2.2a. ADK 95% home range isopleths illustrating static overlap between neighboring male and female raccoons during breeding season on riverine site, Alabama, 2005.

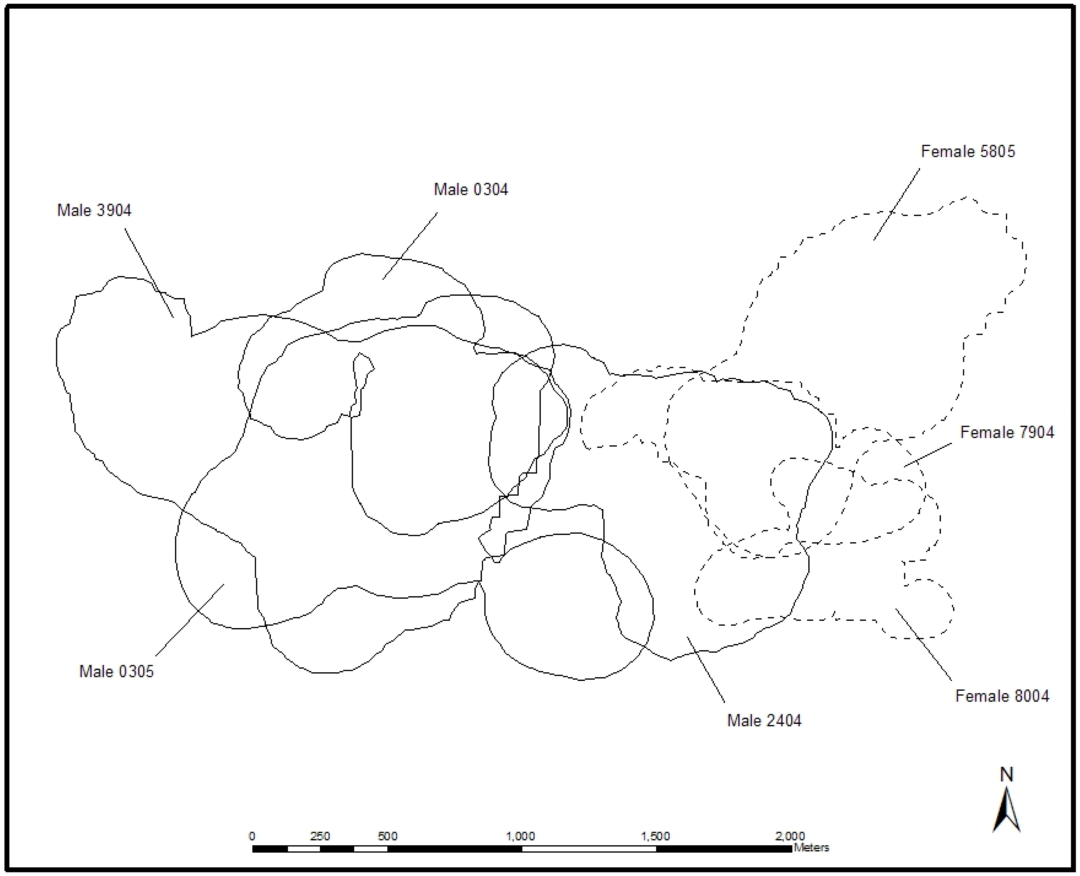

Figure 2.2b. ADK 95% home range isopleths illustrating static overlap between neighboring male and female raccoons during young-rearing season on riverine site, Alabama, 2005.

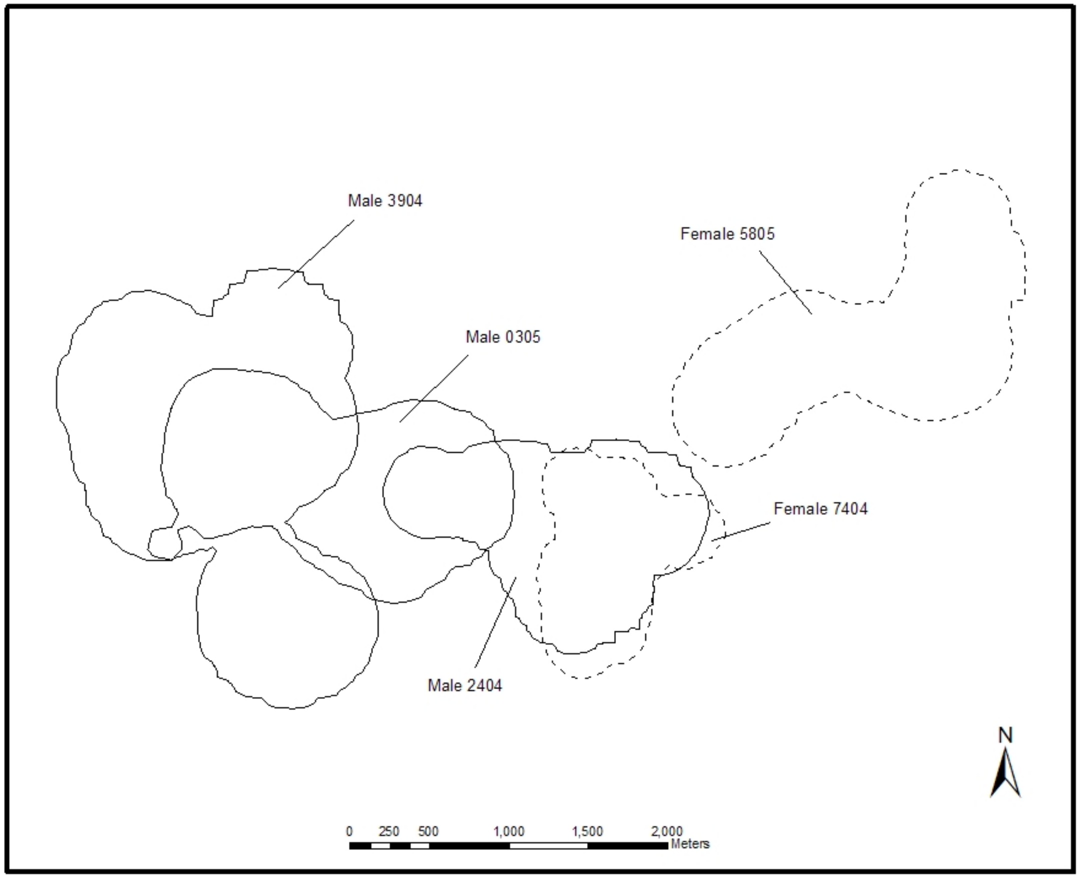

Figure 2.2c. ADK 95% home range isopleths illustrating static overlap between neighboring male and female raccoons during dispersal season on riverine site, Alabama, 2005.

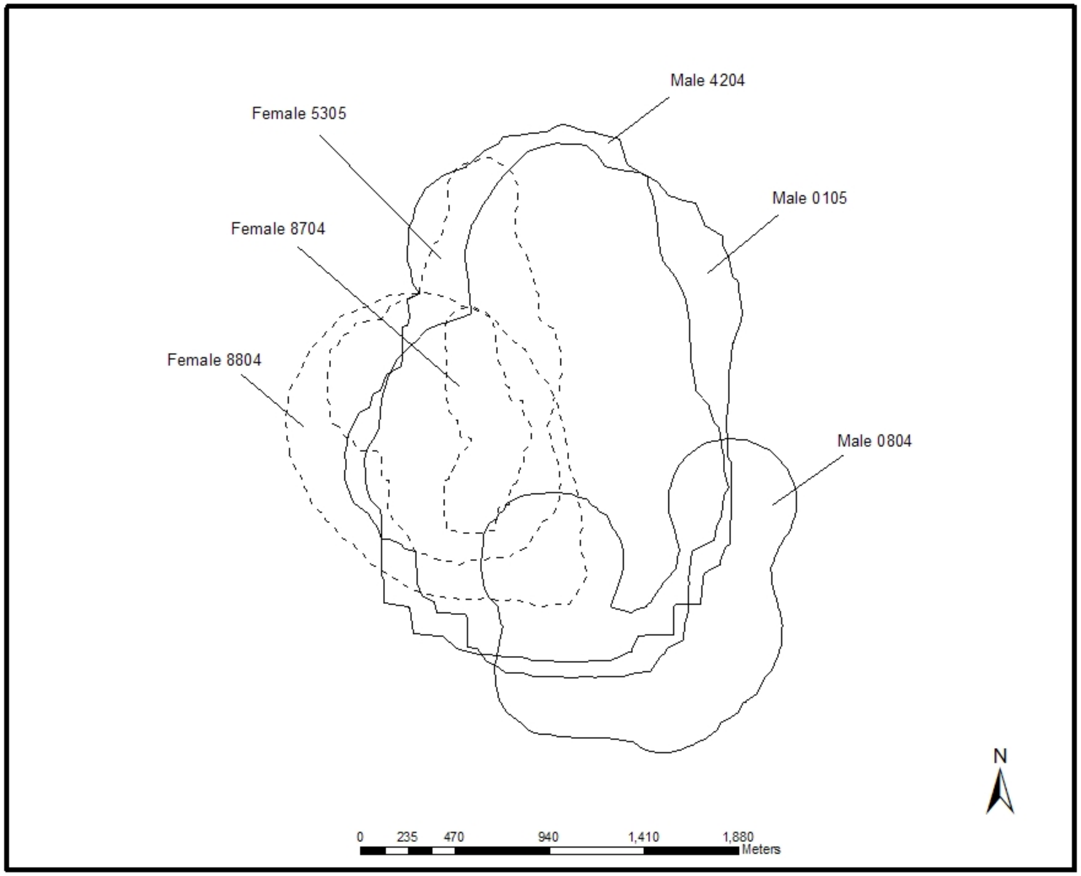

Figure 2.3a. ADK 95% home range isopleths illustrating static overlap between neighboring male and female raccoons during breeding season on AWMA site, Alabama, 2005.

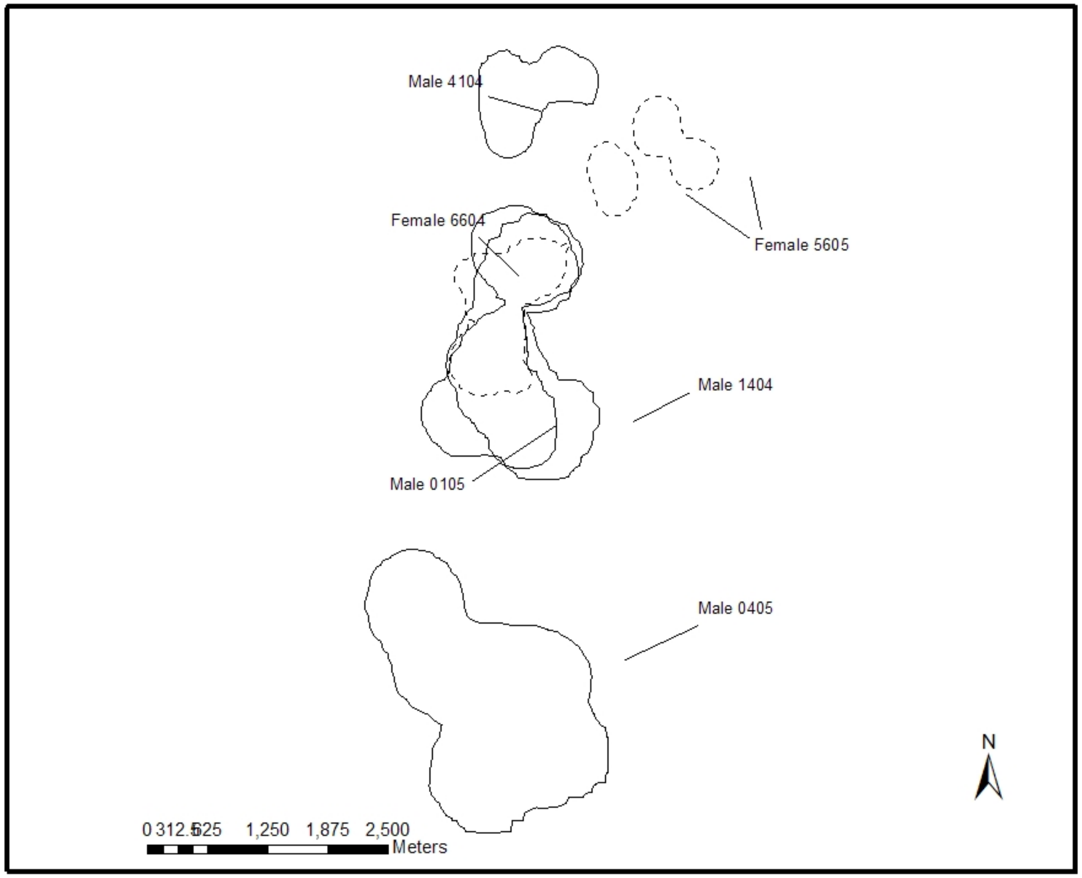

Figure 2.3b. ADK 95% home range isopleths illustrating static overlap between neighboring male and female raccoons during young-rearing season on AWMA site, Alabama, 2005.

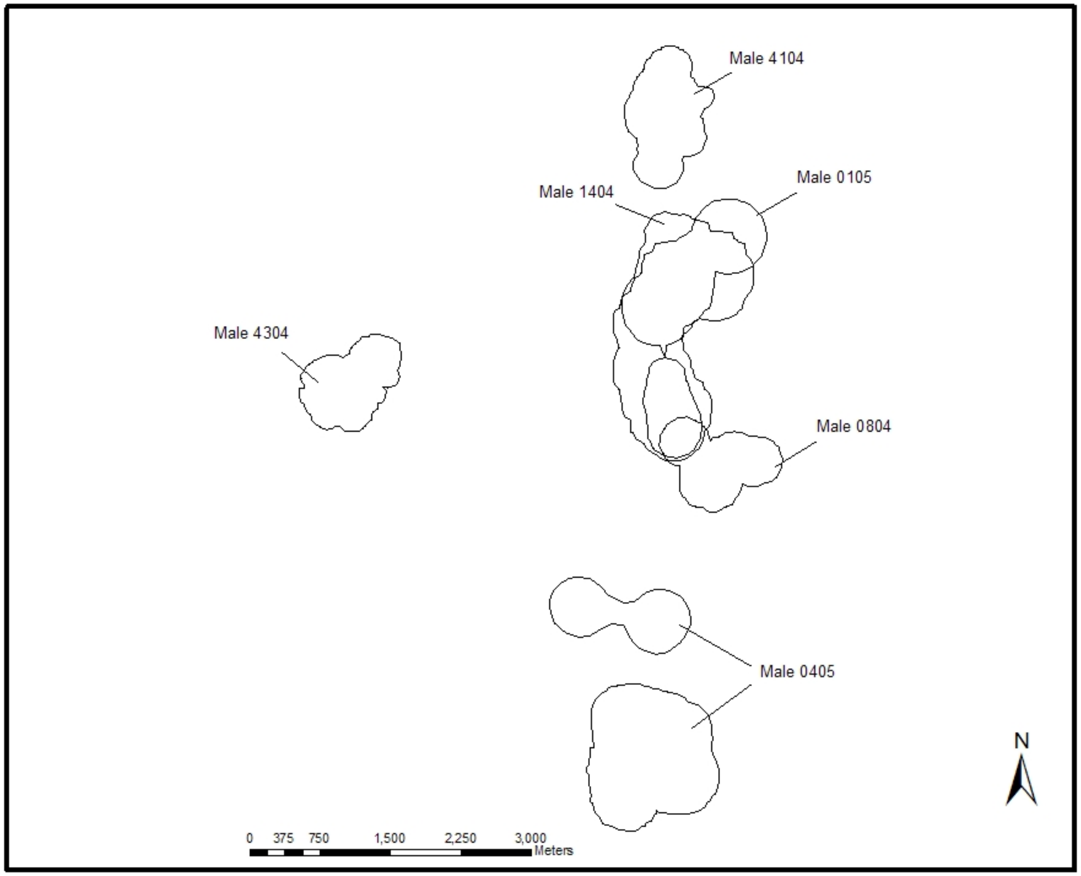

Figure 2.3c. ADK 95% home range isopleths illustrating static overlap between neighboring male raccoons during the dispersal season on AWMA site, Alabama, 2005. The dispersal home range for the remaining radio-collared female at AWMA in 2005 was not estimated due to small sample size of independent locations.

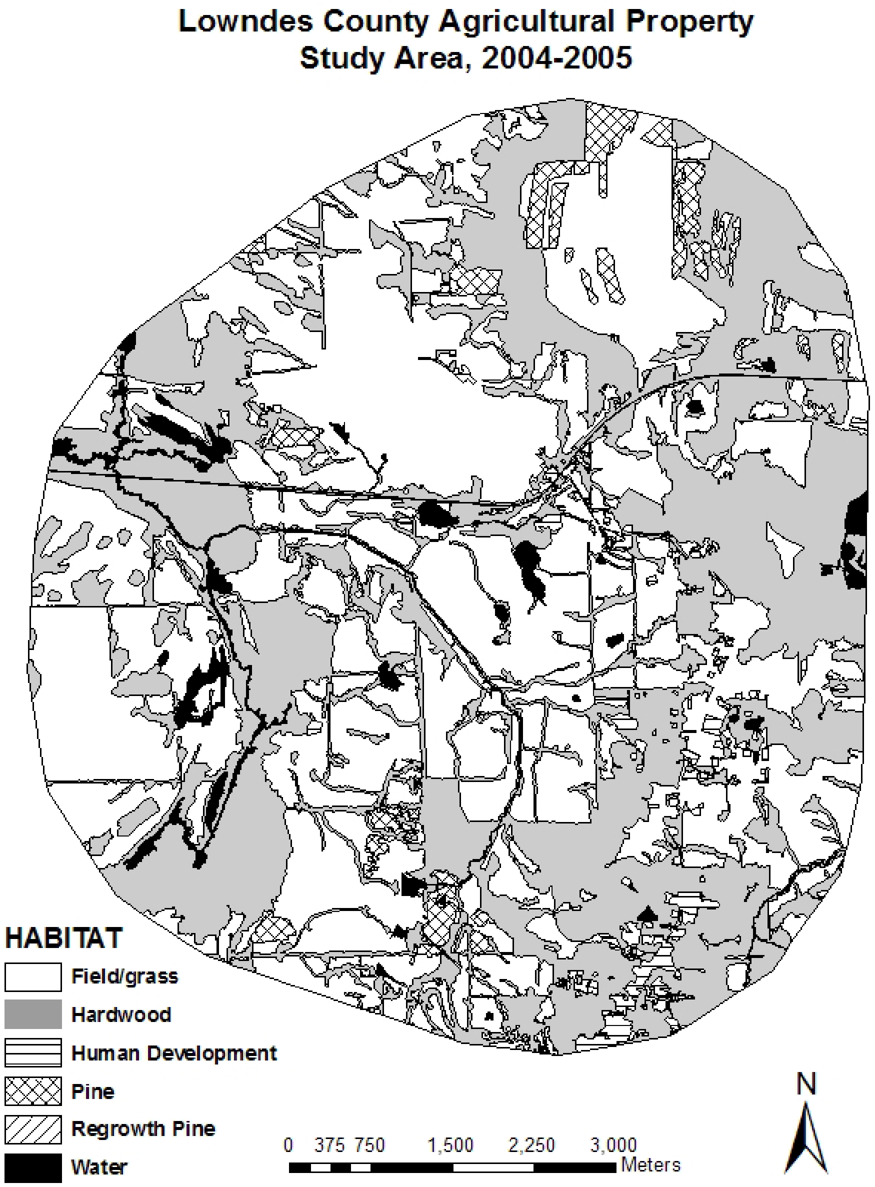

Figure 2.4. Study area for agricultural property and surrounding area, Lowndes County, Alabama, 2004-2005.

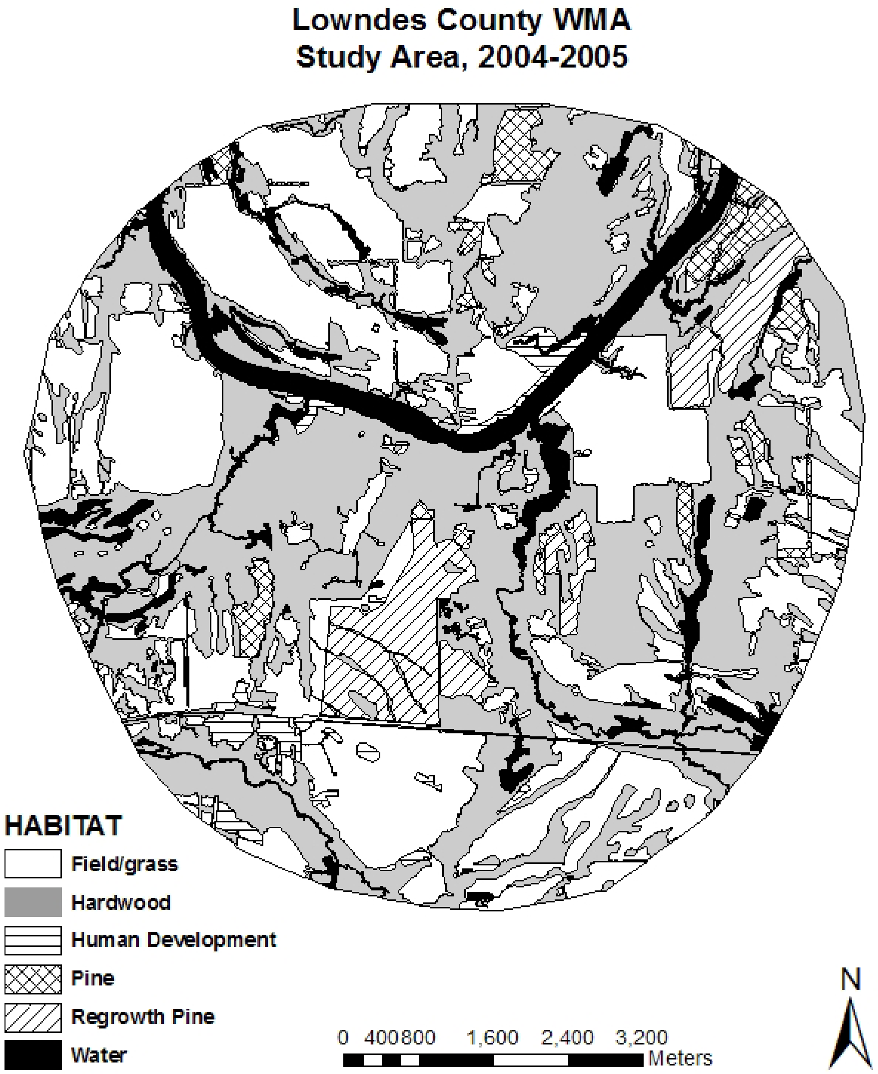

Figure 2.5. Study area for Lowndes County WMA and surrounding area, Lowndes County, Alabama, 2004-2005.

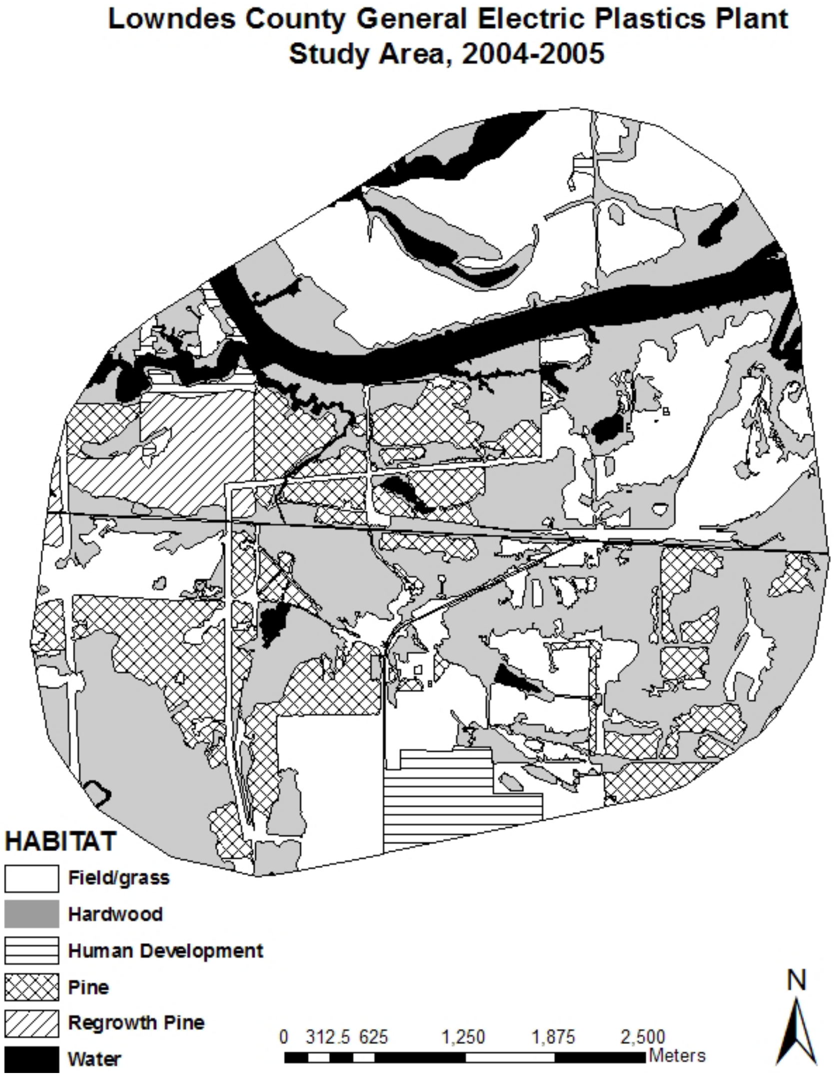

Figure 2.6. Study area for General Electric Plastics Plant and surrounding area, Lowndes County, Alabama, 2004-2005.

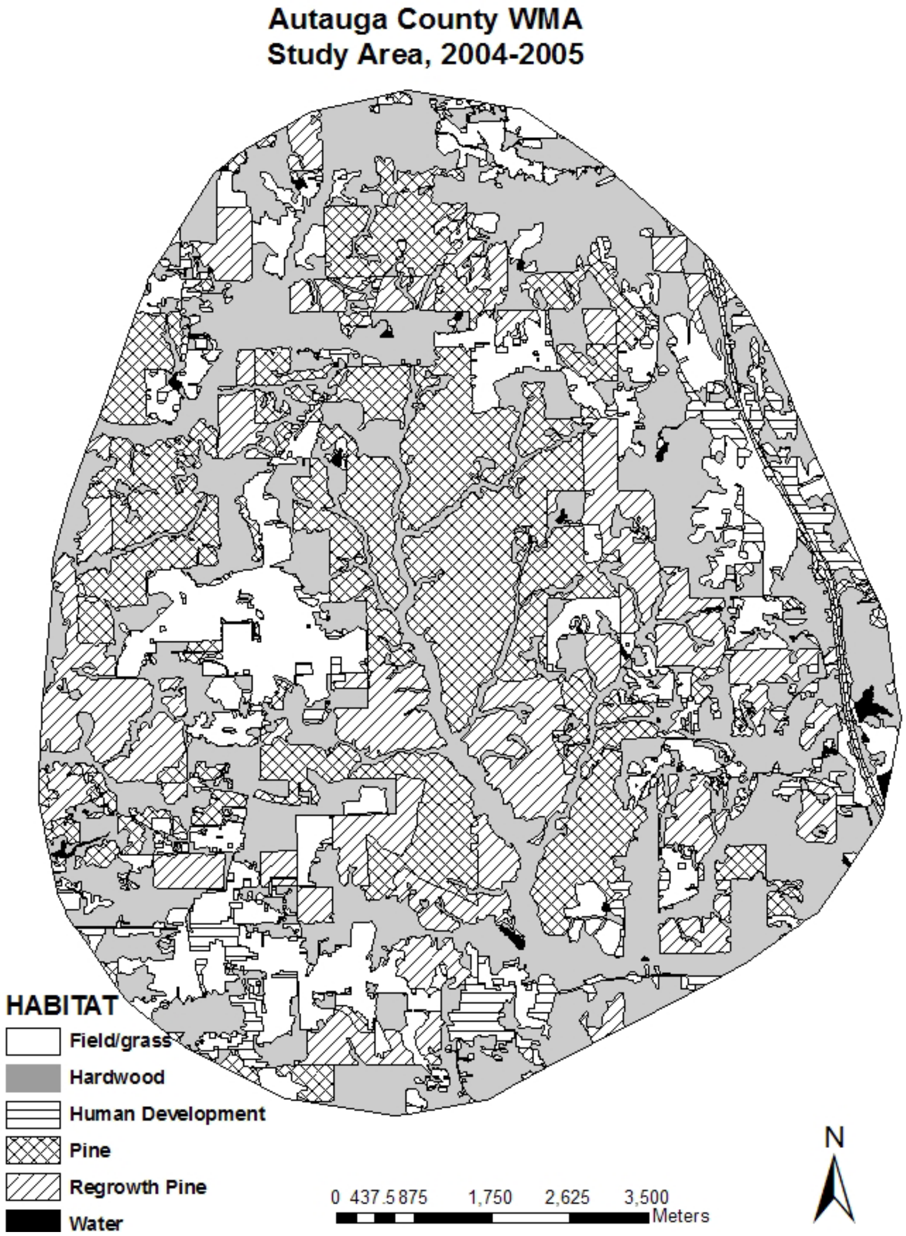

Figure 2.7. Study area for Autauga WMA and surrounding area, Autauga County, Alabama, 2004-2005.

MANAGEMENT IMPLICATIONS

Raccoons are one of the most familiar mammals in North America, largely due to their ubiquitous distribution on the continent (Gehrt 2003). As a wildlife resource, raccoons provide a number of positive values to humans. The species is economically important, dominating the fur harvest and producing large amounts of revenue with the sale of pelts in the 19th and 20th centuries (Sanderson 1987). Additionally, the species is recreationally valuable; many people consider the animal to be aesthetically pleasing and enjoy viewing its activities, while others take pleasure in hunting raccoons (Conover 2002). However, with the growing populations of *Procyon lotor* throughout its range in the last half of the 20th century, raccoons are increasingly associated with negative values as disease vectors and nuisance animals (Gehrt 2003).

Regardless of urbanization and forestry practices that are altering landscapes and wildlife resources in the Southeast, raccoon populations thrive. This study has shown that these animals focus areas of intense activity in riparian and hardwood habitats but prefer to construct home ranges that also include managed pine stands, grassy areas, and human development. Static overlap indices indicate a high level of social tolerance between raccoons, male and female alike. Male raccoons maintain larger territories than females; however, habitat use within these territories does not differ between genders. Survivorship of raccoons is generally high in all habitats, with little observable difference between genders.

Increased populations of raccoons in the southeast impact other wildlife species, through efficient predation of ground-nesting game birds (Balser et al. 1968, Pharris and Goetz 1980, Sargeant et al. 1995), seabirds (Hartman and Eastman 1999), turtles (Johnson and Rauber 1970, Ratnaswamy et al. 1997), and muskrats (Wilson 1953). Raccoons are also common predators of waterfowl and many studies have been undertaken to investigate the impact of raccoon depredation on waterfowl populations (Llewellyn and Webster 1960, Bellrose et al. 1964, Eaton 1966, Urban 1970). Due to their omnivorous diet of both terrestrial and aquatic components, high population levels, a tendency to use human-altered habitats, and a propensity to travel extended distances, raccoons are useful bioindicators of environmental pollutants in riparian areas (Gaines et al. 2000). They are one of several species that are thriving in urbanized environments; other such species include coyotes, white-tailed deer, and opossums. The presence of abundant food and den resources in urban areas ensure close contact of raccoons with humans (Prange and Gehrt 2004, Prange et al. 2004) and the potential for disease transmission exists, as the species is known to harbor parasites and other disease organisms (Riley et al. 1998).

Risk of disease transmission may be regarded as a nuisance, and should be handled in the same manner. Management of raccoons in urban areas often involves trapping and relocating the offending animals to rural areas or parks but this practice increases the potential for disease spread among raccoons and humans. Additionally, many nuisance animals will cause the same damage somewhere else, if possible (Conover 2002).

Translocation is not a healthy alternative for offending raccoons, although the general public believes it is more humane than lethal control (Garrott et al. 1993). Often, capture is a stressful, and sometimes fatal, event. The animal is relocated to an environment into which it is not familiar; it must find food, shelter and protection from other species that are all ready established in the habitat. The resident population may suffer from additional animals entering the population, due to competitive interactions, disease transmission, or decrease in fitness. It is also possible for some animals to return to their original locations (Conover 2002).

Public education programs should be encouraged in order to reduce nuisance problems and exposure to diseased raccoons. Conflicts can be reduced through exclusion and habitat modification, such as removing food sources (*e.g.*, trash, outside pet food) and preventing access to homes and outbuildings. Trapping to remove the offending animals should be target-specific and should emphasize lethal removal, through humane euthanasia. Raccoons are protected animals, with state established seasons for hunting and trapping, but state wildlife officials often work with landowners to reduce problems on personal properties.

Raccoons are the predominant reservoir for rabies in the eastern United States and pose a significant threat to the health and safety of humans and other animals (Gehrt 2003). Vaccinating raccoon populations and large scale lethal control of diseased animals is an expensive undertaking; while the effectiveness of this prevention is not known, the cost of widespread post-exposure rabies treatment may be even more detrimental to the economy. Public notices and education are also important for wildlife disease management.

Effective management of raccoons in an effort to conserve other wildlife populations and protect human health and safety will benefit from further demographic research on a multi-scale level. In Alabama, studies of dispersal patterns, dynamic interactions, population densities, and population recruitment in a variety of urban and rural habitats would provide many avenues to do just that.

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APPENDICES

Appendix 1. Capture and monitoring data for radio-collared raccoons at agricultural, riverine, and AWMA study sites, Alabama, 2004-2005.

Animal ID #	Sex	Capture Date	Capture Site	Last Monitored	Status
C0104	M	1/27/2004	GE	12/26/2004	Radio dead
C0105	M	2/4/2005	AWMA	12/16/2005	Alive
C0204	M	1/27/2004	GE	7/6/2004	Dead
C0205	M	2/15, 9/24/2005	Ag	9/24/2005	Alive
C0304	M	1/28, 10/7/2004	HG	12/16/2005	Alive
C0305	M	6/19/2005	HG	12/16/2005	Alive
C0404	M	1/29, 10/3/2004	HG	2/17/2005	Radio dead
C0405	M	7/20/2005	AWMA	11/21/2005	Alive*
C0504	M	1/29/2004	GE	3/4/2004	Lost radio contact
C0704	M	1/29/2004	GE	3/25/2004	Lost radio contact
C0804	M	3/30/2004, 2/4/2005	AWMA	12/16/2005	Alive
C0805	M	7/27/2005	HG	11/26/2005	Alive*
C0904	M	3/30/2004	AWMA		Slipped collar
C1004	M	4/1, 10/3/2004	Ag	6/1/2005	Dead
C1005	M	9/19/2005	Ag	12/16/2005	Alive
C1104	M	4/1/2004	GE		Slipped collar
C1204	M	4/1/2004	AWMA	7/29/2004	Lost radio contact
C1205	M	9/21/2005	HG	9/22/2005	Radio failure
C1304	M	4/1/2004	AWMA	8/5/2004	Lost radio contact
C1404	M	4/1/2004, 7/18/2005	AWMA	11/25/2005	Alive*
C2004	M	1/28, 10/6/2004	HG	2/17/2005	Radio dead
C2104	M	10/2/2004	Ag	8/11/2005	Dead
C2204	M	10/2/2004	HG	9/13/2005	Lost radio contact
C2304	M	10/2/2004	Ag	10/5/2005	Dead
C2404	M	10/2/2004	HG	12/16/2005	Alive
C2504	M	10/3/2004	Ag	8/22/2005	Lost radio contact
C2804	M	10/4/2004	HG	2/17/2005	Lost radio contact
C2904	M	10/4/2004	HG	5/17/2005	Lost radio contact
C3904	M	10/12/2004, 6/18/2005	HG	10/26/2005	Alive*
C4104	M	12/6/2004	AWMA	12/16/2005	Alive
C4204	M	12/6/2004	AWMA	4/21/2005	Alive*
C4304	M	12/7/2004	AWMA	12/16/2005	Alive
C5104	F	1/27/2004	HG	11/4/2004	Dead
C5105	F	1/6/2005	Ag	6/14/2005	Lost radio contact
C5204	F	1/27/2004	GE	1/11/2005	Radio dead
C5205	F	1/6/2005	Ag	12/16/2005	Alive
C5304	F	1/27/2004	GE	12/26/2004	Radio dead
C5305	F	1/7/2005	AWMA	6/17/2005	Lost radio contact
C5405	F	7/18/2005	AWMA	8/3/2005	Dead
C5504	F	1/29/2004/9/25/2005	HG	9/25/2005	Alive
C5505	F	7/19/2005	AWMA	7/19/2005	Slipped collar
C5604	F	3/30, 12/7/2004	AWMA	1/25/2005	Dead
C5605	F	7/20/2005	AWMA	12/16/2005	Alive
C5804	F	3/30, 12/06/2004	AWMA	5/9/2005	Dead

C5805	F	7/28/2005	HG	11/17/2005	Alive*
C5905	F	9/18/2005	Ag	12/1/2005	Dead
C6104	F	5/6/2004, 9/19/2005	Ag	11/15/2005	Dead
C6204	F	3/30/2004, 9/20/2005	Ag	12/16/2005	Alive
C6304	F	3/30/2004	Ag	7/29/2004	Slipped collar
C6404	F	5/6/2004	GE	9/14/2004	Alive*
C6504	F	3/30/2004	Ag	4/6/2004	Slipped collar
C6604	F	5/6/2004, 1/7/2005	AWMA	10/11/2005	Slipped collar
C7004	F	10/2/2004, 9/23/2005	Ag	11/16/2005	Lost radio contact
C7304	F	10/4/2004	Ag	3/19/2005	Dead
C7404	F	10/4/2004, 9/20/2005	HG	12/16/2005	Alive
C7804	F	10/6/2004	HG	6/14/2005	Slipped collar
C7904	F	10/6/2004, 7/28/2005	HG	10/12/2005	Lost radio contact
C8004	F	10/7/2004, 9/18/2005	HG	10/5/2005	Slipped collar
C8104	F	10/8/2004	HG	5/24/2005	Dead
C8704	F	5/6, 12/6/2004	AWMA	4/15/2005	Alive*
C8804	F	12/7/2004	AWMA	3/29/2005	Lost radio contact

* Indicates this animal was radio-collared with a GPS- Posrec™ transmitter and was known to be alive at the time of collar release. Please refer to the Capture and Handling Methods of Chapter One for a detailed description of the GPS-Posrec™ transmitters.

Appendix 2a. Simplified ranking matrix for raccoons based on comparing the proportions of habitat within 95% ADK home-ranges with proportions of habitat within agricultural study site, Alabama, 2004-2005. Habitat selection and avoidance is designated by positive and negative signs, respectively. A significant deviation from random ($P < 0.05$) is represented by triple signs.

	Habitat Type						
Habitat Type	Field/Grass	Hardwood	Human Development	Pine	Regenerating Pine	Water	Rank[1]
Field/Grass		+++	+++	+++		-	3
Hardwood	- - -		+	+++		- - -	2
Human Development	- - -	-		+++		- - -	1
Pine	- - -	- - -	- - -			- - -	0
Regenerating Pine							N/A
Water	+	+++	+++	+++			4

[1] Increased use is represented by an increase in rank value.

Appendix 2b. Simplified ranking matrix for raccoons based on comparing the proportions of habitat within 95% ADK home-ranges with proportions of habitat within riverine study sites, Alabama, 2004-2005. Habitat selection and avoidance is designated by positive and negative signs, respectively. A significant deviation from random ($P < 0.05$) is represented by triple signs.

	Habitat Type						
Habitat Type	Field/Grass	Hardwood	Human Development	Pine	Regenerating Pine	Water	Rank[1]
Field/Grass		- - -	-	+	+++	-	2
Hardwood	+++		+	+++	+++	+	5
Human Development	+	-		+++	+++	-	3
Pine	-	- - -	- - -		+	- - -	1
Regenerating Pine	- - -	- - -	- - -	-		- - -	0
Water	+	-	+	+++	+++		4

[1] Increased use is represented by an increase in rank value.

Appendix 2c. Simplified ranking matrix for raccoons based on comparing the proportions of habitat within 95% ADK home-ranges with proportions of habitat within AWMA study site, Alabama, 2004-2005. Habitat selection and avoidance is designated by positive and negative signs, respectively. A significant deviation from random ($P < 0.05$) is represented by triple signs.

	Habitat Type						
Habitat Type	Field/Grass	Hardwood	Human Development	Pine	Regenerating Pine	Water	Rank[1]
Field/Grass		- - -	+	- - -	-	+	2
Hardwood	+++		+++	- - -	+++	+++	4
Human Development	-	- - -		- - -	- - -	-	0
Pine	+++	+++	+++		+++	+++	5
Regenerating Pine	+	- - -	+++	- - -		+	3
Water	-	- - -	+	- - -	-		1

[1] Increased use is represented by an increase in rank value.