SPACE USE AND MULTI-SCALE HABITAT SELECTION OF ADULT RACCOONS IN CENTRAL MISSISSIPPI

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Abstract: Raccoons (*Procyon lotor*) are important furbearers and ecological generalists that exist in a variety of landscapes. Numerous studies have examined raccoon space and macrohabitat use, but information detailing these parameters within pine-dominated landscapes is lacking. Furthermore, no studies using radiotracking have examined raccoon habitat use at multiple spatial scales. We radiomonitored 131 adult raccoons (99 M, 32 F) during 1991–1997 in central Mississippi, USA. We subsequently assessed space use and habitat selection at 3 spatial scales. Males maintained larger home ranges and core areas than females. Size of home ranges differed by season, but raccoons maintained similar-size core areas across seasons. Habitat use differed by gender only at the coarsest spatial scale. Raccoons consistently used mature (>30 years old) pine and hardwood habitats over other available habitats at all spatial scales. Although hardwood-dominated habitats were important to raccoons, our findings suggest that in pine-dominated landscapes, raccoons select multiple seral stages of pine. Raccoons also readily used ≤8-year-old pine habitats, likely because of increased foraging opportunities within these habitats, particularly during spring and summer. Our findings illustrate the importance of juxtaposition of habitat types for raccoons in pine-dominated landscapes, specifically the availability of mature pine and hardwood habitats, as well as early-successional habitats capable of providing beneficial foraging resources. Additionally, our findings offer evidence that prescribed burning may alter landscape use by raccoons, providing the potential that manipulating burning frequencies may allow managers to manage raccoon habitat-use patterns.

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Raccoon home-range sizes may be influenced by many factors, including the distribution of resources (Johnson 1970), winter weather conditions (Glueck et al. 1988), and young-rearing responsibilities for females (Ellis 1964). Raccoons are polygynous (Fritzell 1978*a*) or promiscuous (Gehrt and Fritzell 1997), hence male movements and home-range sizes may increase during breeding periods (Roloff 1990) since male reproductive success should increase with increasing numbers of females encountered. Female home ranges and movements may decline during summer, presumably because of parturition and young-rearing responsibilities (Ellis 1964, Fritzell 1978*b*, Schneider et al. 1971). Although home-range characteristics of raccoons in various landscapes have been examined extensively, information on sizes of seasonal home ranges is lacking. Furthermore, although core-use areas likely contain features important to meso-carnivores (Ewer 1968), such as den sites and preferred foraging areas, no studies have examined characteristics of core areas used by raccoons. Additionally, most inferences regarding raccoon space use in southeastern landscapes are limited to small sample sizes (<40 raccoons) and short duration (<3 years).

Raccoons likely select habitats to fulfill energetic requirements necessary for reproduction and survival. General macrohabitat selection of raccoons has been described in numerous landscapes (Minser and Pelton 1982, Sanderson 1987, Leberg and Kennedy 1988); however, few studies have examined habitat use of raccoons existing in southeastern pine forests. Furthermore, although the need to examine individual habitat use at multiple scales has been recognized (Johnson 1980, Orians and Wittenberger 1991), published studies using radiotelemetry to examine habitat use of raccoons at multiple spatial scales are lacking.

Raccoons are important nest predators for a variety of ground-nesting birds, including notable game species such as eastern wild turkey (*Meleagris gallopavo*; Miller and Leopold 1992) and northern bobwhite (*Colinus virginianus*; Burger 2001). Recently, considerable focus has centered on effects of predation on avian communities (Hurst et al. 1996, Rollins and Carroll 2001) and potential ways to minimize and/or manage predation. Along that line, a first step in managing

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predation without using lethal means could involve habitat manipulation to discourage predator use. Specific to raccoons, a thorough understanding of habitat selection patterns is needed prior to developing landscape-specific management plans to influence predation and to stimulate future research examining effects of landscape management on predation by raccoons.

Our objectives were to estimate gender-specific seasonal space use (home-range and core-use areas) and examine gender-specific seasonal habitat selection at 3 spatial scales for a sample population of adult raccoons in central Mississippi, 1991–1997. We describe seasonal space use for male and female raccoons and present seasonal habitat selection at multiple spatial scales. We discuss our findings in the context of previous studies and raccoon ecology and provide insight into how raccoon behavior differs across landscapes according to spatial scale. We also provide recommendations regarding the potential to alter raccoon habitat selection using landscape management, which may subsequently affect predation of ground-nesting birds and other species by raccoons.

STUDY AREA

We conducted our research on the 14,410-ha Tallahala Wildlife Management Area (TWMA), located within the Bienville National Forest in sections of Jasper, Newton, Scott, and Smith counties, Mississippi (89°24'N, 32°15'W to 89°04'N, 32°05'W). The TWMA comprised approximately 30% mature bottomland hardwood forests, 37% mature pine (*Pinus* spp.) forests, 17% mixed pine–hardwood forests, and 11% 1–15-year-old loblolly pine (*P. taeda*) plantations. In 1992, a tornado bisected TWMA and destroyed approximately 1,000 ha of mature forests. Most (90%) of the damaged area was replanted to loblolly pine following downed timber salvage. During 1994–1997, selected mature pine stands (>30 years old) were placed under management for red-cockaded woodpeckers (RCW, *Picoides borealis*). These stands received extensive hardwood midstory removal and a prescribed burning rotation of approximately 2–3 years, as opposed to a 6–7-year rotation in other pine-dominated stands. Bottomland hardwood stands were placed under custodial management; therefore timber harvest was prohibited from these stands. Pine and mixed stands were harvested by clearcutting and regenerated by direct seeding. Topography on TWMA was gently to moderately rolling, with 0–20% slope. Climate was mild, with a mean annual temperature of 20 °C and mean annual precipitation of 152 cm (Chamberlain et al. 1999).

METHODS

We captured raccoons using wire cage traps from 5 January to 5 March 1991–1997. Additional trapping occurred from April to August 1995–1997 to increase sample sizes. We baited traps with a variety of baits and placed them in areas with abundant raccoon sign. Traps were covered with surrounding vegetation and checked daily between 0600 and 0900 hr.

We anesthetized captured raccoons with ketamine hydrochloride (Ketaset Veterinary Products, Fort Dodge Laboratories, Fort Dodge, Iowa, USA) at approximately 10 mg/kg of estimated body mass (Bigler and Hoff 1974). We recorded gender, age (adult or juvenile estimated by tooth wear; Grau et al. 1970), and reproductive characteristics (Sanderson 1961) of each raccoon. Adults were fitted with a 100–135-g mortality-sensitive radiotransmitter (Advanced Telemetry Systems, Isanti, Minnesota, USA), held for 24 hr to facilitate recovery, and released at the capture site the following morning. We conducted research under Mississippi State University Institutional Animal Care and Use Protocol No. 93-032 and associated amendments.

We located raccoons using triangulation (White and Garrott 1990) from permanent telemetry stations throughout our study. In most (>80%) instances, distance from observer to raccoon was ≤1.0 km. We used systematic point and sequential locations to monitor raccoons intensively throughout the diel period. We obtained systematic point locations by recording 2 locations weekly for each raccoon. We conducted sequential telemetry (focal runs) on a 4–6-hr basis with a location recorded on each raccoon every hour for the entire period. Azimuths for a single radio location were recorded within a 15-min interval to reduce error due to raccoon movement; however, most (94%) consecutive azimuths were recorded within 7 min ($\bar{x}$ = 4.8 minutes, SE = 0.03).

Triangulation angles were maintained between 45 and 135° to reduce error (Kitchings and Story 1979). Telemetry accuracy tests indicated that standard deviation from true bearing averaged ±5.9° across our study. Therefore, a circle circumscribing each raccoon location 1 km from each telemetry station would have an approximate area of 3.4 ha. To derive this circle, we calculated the average distance from a telemetry station to an estimated raccoon location. We calculated the radius of a circle that would be obtained if we were the mean distance from the raccoon, assuming 1.96 multiplied by our telemetry precision. Because the smallest habitat patch on our study area was ≥5 ha and most locations were recorded within 1 km of each raccoon, we assumed that telemetry accuracy was sufficient for our analyses.

We used all locations (sequential and point) taken on each raccoon to estimate home-range and core area sizes. Raccoons on TWMA were observed traversing their home range in <2 hr. Therefore, we suggest that raccoons could access virtually any habitats within their home ranges within 2 hr. Furthermore, raccoons in our study were monitored intensively throughout the diel period, reducing potential negative effects of autocorrelation.

Determination of Home-Range and Core-Use Areas

Raccoon locations were entered into a dBASE III+ database and converted to Universal Transverse Mercator coordinates using program TELEBASE (Wynn et al. 1990). We divided each year into biological seasons: breeding (1 Feb–31 May), young-rearing (1 Jun–30 Sep), and winter (1 Oct–31 Jan). Seasonal home-range (95%) and core-area (50%) contour intervals were estimated using an adaptive kernel estimator in program CALHOME (Kie et al. 1994). We used a 2-way analysis of variance (ANOVA) blocked by year to examine differences in home-range and core-area size between genders across seasons. We blocked by year for all analyses because many raccoons were monitored >1 year and sample sizes were smaller during the early years of our study (Chamberlain et al. 1999). Home-range and core-area sizes were estimated for raccoons that had at least 30 locations/season and were sampled for at least 75% of a given season. We tested homogeneity of variance using a Levene's test (Milliken and Johnson 1992) and normality using the Shapiro-Wilk test (Steel and Torrie 1980).

Habitat Use Analyses

We developed a Geographic Information System (GIS) by digitizing a base layer from color infrared aerial photographs and 1:24,000 U.S. Geological Survey 7.5-min quadrangles in ARC/INFO (Environmental Systems Research Institute 1997). The U.S. Forest Service records from Bienville National Forest were used to classify stands into habitat types based on forest type (i.e., hardwood, pine) and stand age. We used year-specific stand maps and data to create annual habitat coverages ($n = 7$). We used aerial photographs, ground surveys, and landowner consultations to quantify habitat type on private lands within and surrounding TWMA. Habitats were delineated as mature (≥30 years) hardwood, mixed pine–hardwood, pine (≤8 years, 9–15 years, 16–29 years, and ≥30 years), and other habitats (agricultural areas and Conservation Reserve Program lands ≤2 years). Mature pine hereafter refers to ≥30-year-old pine stands.

Home-range and core-area contour intervals and individual point locations by season were converted to ARC/INFO coverages and intersected with year-specific habitat maps of TWMA. Habitat attributes for each seasonal contour interval (home range and core area) and group of point locations were exported to dBASE III+ files and then extracted for further analysis. Study-area habitat availability was determined using a buffer system around roads used to trap raccoons throughout the study. For each year, we identified the largest seasonal home range and measured the major axis. We then used the major axis to buffer the road system; hence, buffer width and study-area availability varied annually. Buffer width was 1 axis length on each side of roads used for trapping (Chamberlain and Leopold 2000). We then estimated annual study-area habitat availability by summing the area for each habitat and dividing it by the total study area. Seasonal home-range and core-area availability for each raccoon were estimated using similar methodology. Used habitat (individual locations) was determined by summing the total number of locations within each habitat type and dividing by the total number of points within the home range.

We assessed habitat selection at 3 spatial scales, based somewhat on spatial scales suggested by Johnson (1980). First, we compared home-range habitat to study-area habitat composition. We then compared core-use area habitat composition to home-range habitat composition. Finally, we compared habitat associated with animal locations to home-range habitat.

We used compositional analysis (Aebischer et al. 1993) to determine whether habitat selection differed between gender or among seasons. We considered raccoon seasons as our experimental unit for analysis. Because number of raccoons sampled varied among years, and because we wished to explicitly explore habitat use between genders and seasons, we treated year as a block within our analysis.

We created ranking matrices (Aebischer et al. 1993) to assess relative habitat preferences. If gender- or season-specific differences were detected in our MANOVA, we created a separate ranking matrix for each group (e.g., if males and females selected habitat differently, we created a ranking matrix for each gender). If we detected a gender-specific difference in habitat use, then we averaged seasonal habitat proportions for each animal and used the resulting data in our ranking matrix. Similarly, if neither gender nor season differed in our MANOVA, we averaged all proportions such that raccoon years were our experimental unit.

RESULTS

Space Use

We estimated 335 seasonal home ranges for 131 adult raccoons (99 M, 32 F). Gender and season did not interact to affect home-range size ($F_{2,323} = 0.88$, $P = 0.416$). Home-range size differed between genders ($F_{1,323} = 29.37$, $P < 0.001$); males maintained larger home ranges (244 ± 11 ha; $\bar{x} \pm$ SE) than females (153 ± 13 ha; Table 1). Home-range sizes differed seasonally ($F_{2,323} = 2.82$, $P = 0.061$) with largest home ranges during breeding (249 ± 17 ha). Gender and season did not interact ($F_{2,323} = 0.45$, $P = 0.641$) to affect core-area size, and size of core areas did not differ across seasons ($F_{2,323} = 1.9$, $P = 0.151$). However, we detected a difference in core-area size between genders ($F_{1,323} = 30.95$, $P < 0.001$) with males maintaining larger core areas (39.7 ± 1.9 ha) than females (23.5 ± 2 ha).

Habitat Use

We used 335 raccoon–seasons in our analyses. We detected a gender-specific difference ($F_{6,318} = 2.91$, $P = 0.009$) in home-range habitat composition relative to study-area habitat composition. In order of relative preference, female raccoons preferred mature pine, mature hardwood, 9 to 15-year-old pine, ≤8-year-old pine, pine–hardwood, 16 to 29-year-old pine, and other habitats. In contrast, males preferred mature pine, ≤8-year-old pine, 9 to 15-year-old pine, mature hardwood, pine–hardwood, and other habitats.

We found no gender- or season-specific differences ($P > 0.10$) in core-use area habitat composition relative to home-range habitat composition. However, core-area habitat composition differed ($F_{6,318} = 7.88$, $P < 0.001$) from that of home ranges. In order of relative preference, raccoons used mature hardwood, mature pine, pine–hardwood, other habitats, 16 to 29-year-old pine, ≤8-year-old pine, and 9 to 15-year-old pine.

We detected no gender- or season-specific differences ($P > 0.10$) in habitat associated with raccoon locations relative to habitat composition of the home range. However, proportion of habitats associated with raccoon locations differed ($F_{6,318} = 9.05$, $P < 0.001$) from habitat composition within the home range. Raccoons preferred mature pine, mature hardwood, ≤8-year-old pine, pine–hardwood, other habitats, 16 to 29-year-old pine, and 9 to 15-year-old pine.

DISCUSSION

Previous studies examining raccoon home ranges have reported gender-specific differences, with males generally maintaining larger home ranges than females (e.g., Johnson 1970, Hoffman and Gottschang 1977, Sanderson 1987, Gehrt and Fritzell 1997). Raccoons are sexually dimorphic, with adult males larger than females (Kaufmann 1982, Ritke and Kennedy 1993) and are polygynous or promiscuous (Gehrt and Fritzell 1997). Hence, males may be expected to maintain larger home ranges to fulfill energetic requirements created by morphology (McNab 1963) and increase probabilities of encountering receptive females during breeding (Sandell 1989). Similarly, male raccoons on TWMA maintained larger home ranges and core areas than females. Furthermore, females maintained smaller home ranges during young-rearing relative to other seasons, presumably because of restricted movements associated with young-rearing responsibilities (Fritzell 1978*b*, Schneider et al. 1971).

Although home ranges generally were largest during breeding, core-area sizes did not correspondingly increase. Core areas are sites of concentrated use (Kaufmann 1962) and likely contain resources seasonally important to animals, including den

Table 1. Mean seasonal home-range (95%) and core-area (50%) sizes with associated standard errors (SE) for adult male and female raccoons on Tallahala Wildlife Management Area, Mississippi, USA, 1991–1997. Note: *n* represents number of individual gender-specific home ranges and core areas estimated during the respective season.

			Home range (ha)		Core area (ha)	
Sex	Season	*n*	Mean	SE	Mean	SE
Male	Breeding[a]	102	277.5	19.8	45.6	3.6
	Young-rearing[b]	105	212.6	12.4	34.1	2.4
	Winter[c]	46	238.7	23.9	39.3	3.5
Female	Breeding[a]	33	159.5	22.6	24.9	3.9
	Young-rearing[b]	33	129.4	24.7	19.9	2.2
	Winter[c]	16	185.3	33.3	27.9	4.9

[a] 1 Feb–31 May.
[b] 1 Jun–30 Sep.
[c] 1 Oct–31 Jan.

sites, escape cover, resting areas, and quality foraging areas (Ewer 1968). Because these resources are important to raccoons regardless of season and likely are concentrated in core areas, raccoons would maintain similar-sized core areas during all seasons.

Research at northern latitudes (Iowa, Michigan) has reported a reduction in home-range size during winter (Stuewer 1943, Glueck et al. 1988). However, Gehrt and Fritzell (1997) noted that raccoons in Texas did not decrease home ranges during winter, presumably due to a lack of drastic temperature fluctuation and consistent annual growth of plants used by raccoons. Although raccoons on TWMA maintained larger home ranges during breeding, females tended to maintain their largest seasonal home range during winter. Therefore, our findings support those of Gehrt and Fritzell (1997), suggesting that a lack of freezing temperatures and relatively consistent resource availability during fall and winter periods at southern latitudes may enable raccoons to use space consistently during winter, as in other seasons.

Mature pine and hardwood habitats were consistently selected by raccoons at all 3 spatial scales. Bottomland hardwoods have long been recognized as providing quality raccoon habitat (Kaufmann 1982) due to availability of den sites and foraging areas containing free water (Stuewer 1943, Leberg and Kennedy 1988). Free water is limited to streams within bottomland hardwoods on TWMA, especially during summer, and quality den sites likely are confined to areas with hardwoods because of timber harvest in mature pine stands. Additionally, raccoons consume hard mast during winter (Johnson 1970), a resource most prevalent in bottomland hardwood habitats on TWMA. Therefore, selection of mature hardwood habitats likely is a function of quality foraging and denning opportunities, as well as the availability of free water.

Although mature hardwood habitats were important to raccoons on TWMA, the selection of mature pine at all spatial scales suggests that these habitats are equally important. Mature pine was the most available habitat on TWMA and was ranked greater than mature hardwood habitats at 2 spatial scales. Until 1995, mature pine stands on TWMA were on a 6.5-year burning rotation and understory conditions in these habitats were dominated by woody saplings and vines (Palmer et al. 1996), such as American beautyberry (*Callicarpa americana*), blackberry (*Rubus* spp.), and grape (*Vitis* spp.; Chamberlain 1999). Raccoons readily consume fruits of these species during spring, summer, and early fall (Johnson 1970, Sanderson 1987). Endres (1988) noted that raccoons often located dens around berry thickets. Thus, mature pine stands on TWMA likely provided quality foraging habitats, particularly during periods when soft mast species were available.

Prescribed burning was used more frequently during the latter portions of our study within areas designated as being managed for RCWs, and raccoons used these areas less relative to other mature pine stands (Chamberlain 1999). Prescribed burning promotes herbaceous vegetation and may enhance conditions for small mammals (McMurry et al. 1994, Masters et al. 1998) and invertebrates (Madison et al. 1995). However, fire reduces vines and woody saplings (Palmer et al. 1996), and, coupled with extensive hardwood midstory removal, likely reduces habitat quality for raccoons. Management of mature pine habitats for RCWs was not uniform across TWMA, but rather was applied to selected stands. These stands were primarily juxtaposed to mature pine stands with burning rotations typical of the remainder of TWMA, or mature hardwood habitats, thereby providing raccoons with foraging and denning opportunities in nearby habitats.

Although raccoons consistently used mature pine and hardwood habitats at all spatial scales, ≤8-year-old pine stands were selected by males when establishing home ranges and often used by both genders. Muscadine (*Vitis rotundifolia*, blackberry, and dewberry (*Rubus* spp.), all soft mast species selected by raccoons (Johnson 1970), were most abundant in ≤8-year-old pine stands on TWMA (Chamberlain 1999). Therefore, raccoon use of these pine habitats likely was a function of forage availability. Alternatively, some raccoons occupied dens within these habitats, mostly within woody residue and slash that remained following timber harvest (M. J. Chamberlain, unpublished data). The availability of den sites, coupled with quality foraging areas, likely provided high-quality habitat for raccoons, particularly during summer and early fall.

MANAGEMENT IMPLICATIONS

Raccoons in our study used multiple habitat types or varying seral stages to fulfill energetic requirements and acquire resources necessary for survival and reproduction. We suggest that land managers consider the plasticity of raccoon habitat selection patterns when planning habitat management scenarios and making inferences regarding raccoon habitat use. Our findings provide evidence that habitats historically considered poor for raccoons may indeed provide foraging and denning resources.

Management of pine-dominated landscapes with prescribed fire on a short (2–3 year) rotation, and goals of reducing hardwood distribution and abundance through stand-level midstory and overstory removal, likely will reduce habitat quality for raccoons. Hence, managers may alter raccoon movements and foraging behavior by using prescribed fire in pine-dominated landscapes, thereby influencing raccoon use of specific habitats and the ability of raccoons to procure resources. Populations of meso-carnivores are reportedly increasing throughout the southeastern United States (Lovell et al. 1998). Because meso-carnivores like the raccoon are nest predators, the potential role of predation in limiting ground-nesting bird populations has received increased attention in recent years (Hurst et al. 1996). Correspondingly, public sentiment regarding direct management of mesocarnivore populations is dynamic, and frequently oriented toward specific management objectives (Messmer et al. 1999). That said, many have postulated that habitat manipulation and management may serve as viable, nonlethal ways to influence predation rates by subsequently altering meso-carnivore use of landscapes (Chamberlain 1999, Rollins and Carroll 2001). For instance, Rollins and Carroll (2001) suggested an integrated pest management approach to predation management, which involves applying nonlethal means of predation management, of which habitat manipulation is a primary consideration.

Specific to raccoons, our findings suggest that implementing prescribed fire on rotations similar to that practiced by managers manipulating landscapes for RCWs may serve as a suitable approach to predation management. However, because raccoons on TWMA were able to fulfill life-history requirements in a variety of habitat types at multiple seral stages, implementing such an approach would require knowledge of resource selection within microhabitats of multiple macrohabitat types, not just pine-dominated habitats. This information could be gained by altering the scale of study. For instance, incorporating the fourth spatial scale discussed by Johnson (1980; specific habitat elements used for feeding or denning) into a long-term, organism-based telemetry program would provide such information, thereby improving the inferential ability of the study beyond the spatial scales used in our study. We suggest that researchers consider designing field studies with multiple spatial scales incorporated into the planning process, thereby providing opportunities to address relevant questions regarding animal use of landscapes and potential response by species to land management.

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