Am. Midl. Nat. 147:102–108

Seasonal Habitat Selection by Raccoons (Procyon lotor) in Intensively Managed Pine Forests of Central Mississippi

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Abstract.—Raccoons (*Procyon lotor*) are ecological generalists, existing in diverse landscapes. Although general habitat use patterns of raccoons have been extensively described, little research has examined raccoon habitat selection within landscapes managed intensively for wood fiber production. Furthermore, no published studies using radio-telemetry have detailed raccoon habitat selection at multiple spatial scales. We monitored 31 raccoons on a 2000 ha area characterized by short-rotation (<35 y) pine forests in central Mississippi during 1996–1997 and examined seasonal habitat selection at three spatial scales. Habitat selection at the home range scale differed ($P = 0.004$) between genders. Gender and season interacted to affect habitat selection at the core area scale of selection. Both male and female core areas contained greater proportions of mature hardwood habitats during breeding and young-rearing. Habitat use within home ranges, as determined by point locations, did not differ ($P > 0.440$) with gender or season. However, raccoons used habitats disproportionately ($P = 0.016$) relative to habitat composition of the home range. Our findings illustrate the importance of examining individual habitat selection at multiple scales, as raccoon habitat selection in our study varied by scale. Furthermore, our results indicate the importance of hardwood dominated habitats for raccoons existing in pine-dominated landscapes.

Introduction

Knowledge of the habitats an animal uses is necessary to understand a species' ecology. Presumably, animals select habitats to fulfill energetic requirements, acquire resources necessary for reproduction and survival and/or to meet thermoregulatory requirements. Historically, studies examining habitat use by raccoons have attempted to determine if habitats were used randomly or in proportion to a perceived availability (Fritzell, 1978; Glueck *et al.*, 1988). Furthermore, the relative importance of various habitats to a particular animal is often inferred based on use of habitats available across the landscape. However, studies examining habitat use of individuals at one spatial scale potentially provide spurious conclusions, primarily because the scale at which habitats are selected is unknown. Recently, techniques have become available to examine habitat use at multiple spatial scales (Aebischer *et al.*, 1993) and, although the need to examine habitat use patterns at multiple scales was recognized earlier (Johnson, 1980), these techniques have generally not been applied to meso-carnivores.

The raccoon (*Procyon lotor*) is an ecological generalist that occupies diverse habitats and patterns of habitat use have been attributed to gender, age and reproductive status (Urban, 1970; Fritzell, 1978; Glueck *et al.*, 1988). Raccoons inhabiting landscapes within the southeastern United States are frequently associated with bottomland hardwood and pine-hardwood habitats (Sanderson, 1987; Leberg and Kennedy, 1988). Although raccoons have not traditionally been associated with managed pine forests, recent studies have suggested that raccoons readily occupy these forests (Burton, 1998; Chamberlain, 1999; Chamberlain *et al.*, 2000). Coincidentally, increasing acreages of forested lands throughout the southeastern United States are being converted to managed pine forests as the demand for wood fiber continues to increase (Allen *et al.*, 1996). This landscape-level change in conditions of forested habitats could influence raccoon habitat use, thereby affecting parameters influenced by habitat use, such as survival and reproduction. Therefore, information detailing raccoon habitat selection within managed pine forests is necessary to thoroughly understand the ecology of this meso-carnivore. Our first objective was to detail patterns of habitat selection at multiple spatial scales for raccoons existing in a landscape managed intensively for wood fiber production. Second, we desired to examine if there are gender and season-specific differences in habitat use at each scale.

STUDY AREA

This research was conducted on a 2000-ha area owned by the Timber Company (TC) in Jasper County, Mississippi. The area was managed primarily for wood fiber production with 90% of the area composed of 1 to 35-y-old loblolly pine (*Pinus taeda*) plantations and mixed pine-hardwood (hereafter pine-hardwood) forests, with the remaining 10% in Streamside Management Zones along creek drainages. Plantations were thinned at approximately 15 y. The streamside management zones rarely exceeded 50 m in width and were primarily dominated by hardwood species [*e.g.*, hickories (*Carya* spp.), oaks (*Quercus* spp.) and sweetgum (*Liquidambar styraciflua*)]. Areas immediately surrounding streamside management zones were frequently pine-hardwood habitats, characterized by >70% pine canopy with scattered hardwoods not removed during timber harvest. Extensive (>100 ha) timber harvests using clearcutting were common. Prescribed burning did not occur during the 2 y before or during our study. Topography 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, 1999).

METHODS

Raccoon captures.—Raccoons were captured using wire cage traps from January 1996 to June 1997. Traps were checked and baited daily with various mixtures of fish, jelly and molasses. We trapped raccoons on a 50-trap grid during March and June, with each grid block measuring approximately 40.5 ha. One cage trap was set/block in areas selected for maximum trap success, such as sites that contained habitat features thought to attract raccoons (creeks, roads, habitat edges). We trapped the grid 16–17 consecutive nights during each of the 2 trapping periods each year. Additionally, we captured raccoons by trapping opportunistically at sites containing abundant raccoon sign (tracks, scat) during January–March, particularly in areas devoid of radiomarked raccoons. Using these trapping systems, we attempted to capture all raccoons across the landscape and to radiomonitor individuals distributed throughout the study area in all available habitat types. We anesthetized captured raccoons using ketamine hydrochloride (Ketaset, Veterinary Products, Fort Dodge Laboratories, Fort Dodge, Iowa) at a rate of 10 mg/kg of estimated body mass (Bigler and Hoff, 1974). We recorded gender and estimated age by tooth wear (Grau *et al.*, 1970) and reproductive characteristics (Sanderson, 1961). Adult (≥1 yr) raccoons were fitted with a 130-g mortality-sensitive radiotransmitter (Advanced Telemetry Systems, Isanti, Minnesota) and released at the capture site the following morning. We conducted research under

Mississippi State University Institutional Animal Care and Use Committee Protocol No. 93-032 and its associated amendments.

Radiotelemetry.—We determined raccoon locations using triangulation (White and Garrott, 1990) with a hand-held 3-element Yagi antenna (Wildlife Materials, Carbondale, Illinois) from permanent points ≥3 times/wk. Raccoons were monitored from January 1996 to December 1997. We used two telemetry techniques to monitor raccoons: systematic point and sequential locations. We obtained systematic point locations by recording two locations weekly for each raccoon. We conducted sequential telemetry (focal runs) on a 4-h basis with a location recorded on each raccoon hourly during the focal run. We conducted all radiotelemetry throughout the diel period to ensure equitable and representative samples of raccoon movements. Azimuths for a single radio location were recorded within a 15 min interval to reduce error due to raccoon movement; however, most (>90%) consecutive azimuths were recorded within 6 min. 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 was 5.9°. Therefore, a circle circumscribing each raccoon location 1 km from each telemetry station would have an approximate area of 3.4 ha. Because the smallest habitat patch on the study area was >5 ha and most (99%) locations were recorded within 1 km of each raccoon, we assumed telemetry accuracy was sufficient for our analyses.

Analysis.—Raccoon locations were converted to a coordinate system using program TELEBASE (Wynn *et al.*, 1990). We divided each year into breeding (1 Feb.–31 May), young-rearing (1 June–30 Sept.) and winter (1 Oct.–31 Jan.) seasons. To examine habitat selection at multiple spatial scales, we estimated seasonal home range (95%) and core area (50%) contour intervals using an adaptive kernel estimator in program CALHOME (Kie *et al.*, 1994). We pooled all focal run and systematic telemetry locations to ensure adequate sampling to estimate home ranges and core areas. We only calculated seasonal home range and core area estimates for raccoons with at least 30 radiolocations, but most (90%) estimates contained >50 radiolocations. We realize that habitat use at the location level may be influenced by autocorrelation, even if size of home ranges and core areas were not. Hence, we selected point locations separated by ≥2 h to examine habitat use at the location level. We documented many instances of raccoons traversing their estimated seasonal home range within 2 h, hence our assumption that locations separated by ≥2 h were independent for assessing habitat use.

We developed a Geographic Information System (GIS) (ARC/INFO; Environmental Systems Research Institute, Redlands, California) with color infrared aerial photographs and 1:24,000 U.S. Geological Survey 7.5-min quadrangles. Stand data from the Timber Company were used to classify individual forest 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 = 2).

Home range and core area contour intervals, and individual point locations by season, were intersected with year-specific habitat maps of the study area. We exported habitat attributes for each polygon (home range and core area) and group of point locations to dBASE III+ files (Ashton-Tate, Inc., Torrence, California). Habitats were delineated as: hardwood (≥30 y), mixed pine-hardwood (≥30 y) and pine (0–8 y, 9–15 y, 16+ y).

We determined the outer boundary of our study area by creating a buffer in ARCVIEW (Environmental Systems Research Institute, Redlands, California) around the outermost traps used to trap raccoons during the study. Initially, we created a polygon by joining the outermost points used for trapping raccoons. Secondly, for each year we identified the largest seasonal home range and subsequently measured its major axis. We then used the major axis to create a buffer distance that was placed around the outermost trapping sites. Lastly, we estimated habitat availability within the study area each year by summing the area for each habitat and dividing it by the total buffer area. Habitat availability within the home range and core area of each radiotracked raccoon was estimated using similar methodology. We determined habitat use (point locations) 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 three spatial scales, based somewhat on spatial scales suggested by Johnson (1980). First, we compared habitat composition of the home range to habitat composition of the study area. We then compared habitat composition of core use areas to habitat composition of the home range. Finally, we compared habitat associated with raccoon locations to habitat composition of the home range.

We used compositional analysis (Aebischer *et al.*, 1993) to determine if habitat selection differed between genders or among seasons. In this analysis raccoon-seasons were considered as our experimental unit. We used log-ratio differences as our dependent variables and gender, season and the gender by season interaction as main effects in a MANOVA to determine if habitat selection differed from availability and if habitat use, after correcting for availability, differed between genders or among seasons. Because number of raccoons sampled varied between years, 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). We averaged habitat selection and habitat availability to ensure the correct experimental unit was used in the analysis. For example, if we detected a gender-specific difference in habitat selection, we then averaged seasonal habitat proportions for each animal-year 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

We estimated 98 seasonal home ranges and core areas for 31 adult raccoons (23 M, 8 F) resulting in 98 raccoon-seasons used in habitat use analyses. When we assessed habitat composition within the home range relative to habitat composition of the study area, we detected a gender-specific difference ($F_{4,88}$ = 4.19, P = 0.004) in habitat selection. Therefore, we created a ranking matrix for each gender using each raccoon-year as a sample. In order of relative preference, female raccoons selected 16+ y-old pine, pine-hardwood, 9–15 y-old pine, 0–8 y-old pine and hardwood habitats. In contrast, males selected 16+ y-old pine, pine-hardwood, 0–8 y-old pine, 9–15 y-old pine and hardwood.

When we assessed habitat composition within core areas relative to habitat composition of the home range, we detected a gender by season interaction ($F_{4, 89}$ = 3.12, P = 0.019). Therefore we created a separate ranking matrix for each gender and season combination using raccoon-seasons as independent samples (Table 1). When we assessed habitat associated with raccoon locations relative to habitat composition of the home range, we detected no gender or season specific differences in habitat use ($F_{4, 88}$ = 0.95, P = 0.441 and $F_{4, 89}$ = 0.82, P = 0.513, respectively). However, raccoons did use habitats disproportionately ($F_{4, 88}$ = 3.22, P = 0.016) relative to habitat composition of the home range. In order of relative preference, raccoons used pine-hardwood, 16+ y-old pine, hardwood, 9–15 y-old pine and 0–8 y-old pine.

TABLE 1.—Mean ranks (1 = least, 5 = greatest) of habitat selection in core areas vs. availability of habitats within home ranges based on compositional analysis for adult male (M) and female (F) raccoons on the Timber Company lands, Mississippi, 1996–97

	Season					
	Breeding		Young-rearing		Winter	
Habitat type	*M*	*F*	*M*	*F*	*M*	*F*
Hardwood (≥ 30-y old)	5	5	5	5	3	5
Pine-hardwood (≥ 30-y old)	2	2	1	3	5	3
Pine (0-8-y old)	3	3	4	2	1	4
Pine (9-15-y old)	1	1	3	1	2	1
Pine (≥ 16-y old)	4	4	2	4	4	2

DISCUSSION

Macrohabitat selection has been described for raccoons in a variety of landscapes (Fritzell, 1978; Greenwood, 1982; Leberg and Kennedy, 1988) and specific to the southeastern United States, Atkenson and Hulse (1953) determined that hardwood forests were important to raccoons. However, raccoons are ecological generalists and thus, are able to exploit a wide variety of habitat types given necessary resources are available (Sanderson, 1987). Although our findings indicate that raccoons are capable of successfully exploiting resources in pine-dominated habitats, availability of hardwood habitats influences selection at the core area scale of use.

Because core areas represent concentrated use within home ranges, it is inferred that these areas are important to the animal (Leuthold, 1977). Indeed, core areas frequently contain sites critical to a particular animal, including den sites or selected foraging areas (Ewer, 1973). Although we did not directly quantify den site availability across habitat types, we assume that tree den availability was restricted to hardwood and pine-hardwood habitats given the intensity of timber harvest on the area and the propensity for raccoons to den in mature hardwood trees (Kaufmann, 1982). Therefore, females would be expected to concentrate use within these areas, particularly during breeding and young-rearing. Furthermore, raccoon habitat use and individual distribution can be influenced by availability of free water (Gehrt and Fritzell, 1998). Free water on our study area was limited to streams and hardwood habitats were primarily located within streamside management zones, thus both genders would be expected to use these areas and maintain core areas containing this resource.

Our coarsest scale of habitat selection (composition of home range relative to study area) suggested that 16+ y-old pine and pine-hardwood habitats were important to raccoons when establishing a home range. We suggest that this finding is a synergistic function of landscape configuration and the quality of these habitats for foraging. As indicated earlier, hardwood habitats were restricted to areas along streams, and pine-hardwood habitats were frequently juxtaposed to these hardwood habitats. Raccoons selecting core areas with great availability of hardwood habitats would likewise maintain home ranges with a high composition of pine-hardwood habitats.

Prescribed burning of pine forests reduces woody vegetation and generally promotes herbaceous understory vegetation (Palmer *et al.*, 1996). Because prescribed burning did not occur immediately before or during this study, 16+ y-old pine habitats contained dense understory vegetation dominated by woody saplings and vines, primarily American beautyberry (*Callicarpa americana*) and blackberry and dewberry (*Rubus* spp.). Raccoons readily consume these fruits during spring, summer and early fall (Johnson, 1970; Sanderson, 1987) and Endres (1988) noted that raccoons often located dens around berry thickets. Thus, 16+ y-old pine habitats provided quality foraging habitats, particularly during periods when soft mast species were available. Additionally, 16+ y-old pine and pine-hardwood habitats were consistently used in greater proportion than available within home ranges based on our finest scale of selection.

Foraging needs of raccoons change seasonally (Johnson, 1970; Kaufmann, 1982). Specifically, raccoon diets contain a great proportion of soft mast during spring and summer, and hard mast during winter (Johnson, 1970). Because pine-hardwood habitats contained scattered mast producing hardwoods, these habitats offered hard mast during winter and potential den sites across seasons. Also, the lack of prescribed burning resulted in pine-hardwood habitats having understory conditions similar to 16+ y-old pine habitats. Therefore, raccoons could fulfill foraging requirements within pine-hardwood habitats during multiple seasons, as soft mast species produced fruits during spring and summer, and hardwood mast became available during winter.

The scale at which animals select habitats is unknown. Our findings illustrate the importance of examining individual habitat selection at multiple spatial scales. Notably, our inferences regarding the relative importance of specific habitat types would have differed markedly had only one scale been examined. This point illustrates the importance of human decisions in selecting the appropriate scale for habitat analyses. Therefore, we suggest future studies assessing habitat selection of meso-carnivores incorporate multiple scales.

Acknowledgments.—We appreciate field assistance provided by R. Andrus, J. G. Burton, T. Gehr and K. M. Hodges. Funding and support were provided by the Mississippi Department of Wildlife, Fisheries and Parks through Federal Aid in Wildlife Restoration Funds Project W-48, Study 30, the National Wild Turkey Federation (NWTF), Mississippi Chapter of NWTF, the Timber Company, the School of Forestry, Wildlife and Fisheries at Louisiana State University (LSU), the LSU Agricultural Center and the Joseph W. Jones Ecological Research Center. This manuscript was approved for publication by the School of Forestry, Wildlife and Fisheries at LSU and the LSU Agricultural Center.

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SUBMITTED 16 JULY 2001 ACCEPTED 12 SEPTEMBER 2001