Space Use and Movements of Raccoons in Two Forested Ecosystems

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Abstract: Raccoons *(Procyon lotor)* are important furbearers that generate considerable income and recreation across the southeastern United States. Growing concerns about impacts of raccoons on wildlife populations necessitates sound information on raccoon behavior and population dynamics. Forest management has changed throughout the southeastern United States due to increased demands for wood fiber and changing land-use objectives on public lands. However, little research has examined potential influences of forest management strategies on raccoon ranging behavior, particularly within intensively managed forests. We examined spatial use patterns and movements of 118 radio-marked raccoons on 2 areas in central Mississippi during 1996–97. The Tallahala Wildlife Management Area (TWMA) was managed by the U.S. Forest Service for multiple use, whereas the Timber Company lands (TC) were managed intensively for wood fiber production. Raccoons on TWMA maintained larger home ranges and core areas (P <0.05), and moved at greater rates, than raccoons on TC. Forest management strategies likely influence ranging behavior of raccoons, particulary across intensively managed landscapes. We suggest land managers consider influences of differing forest management strategies on how raccoons establish ranges and subsequently travel within southeastern landscapes.

Raccoons provide numerous aesthetic, recreational, and economic benefits for the southeastern United States (Chamberlain et al. 1999a). Home range characteristics of raccoons have been examined (Johnson 1970, Hoffman and Gottschang 1977)

because reliable estimates of home range and core use area sizes are essential to understand a species' behavioral ecology (Bekoff and Mech 1984). Likewise, understanding movement patterns may provide insight into a species' behavior, energy expenditures, and/or foraging patterns (Johnson 1970). Consequently, patterns of raccoon movement are well documented (Schneider et al. 1971, Allsbrooks and Kennedy 1980, Greenwood, 1982). Male raccoons maintain larger home ranges than females, and move at greater rates than females (Chamberlain et al. 1999a).

Forest products industry is a leading economic factor in the southeastern United States and the demand for wood fiber is increasing. Many forests have been converted to intensively managed pine (*Pinus* spp.) forests and such conversions are expected to increase to 18.6 million ha by 2030 (Allen et al. 1996). Throughout their range, raccoons are typically found everywhere that water is available, but traditionally, they have not been associated with southern pine forests (Kaufmann et al. 1982). However, recent studies have suggested that raccoons are found readily in these habitats (Burton 1998, Chamberlain 1999). Coincidentally, increasing acreages of public lands are being managed to benefit the federally endangered red-cockaded woodpecker *(Picoides borealis)*, by increasing prescribed burning frequency and hardwood midstory removal (Burger et al. 1998). Many studies have reported associations between raccoon abundance and bottomland hardwood systems, likely a function of selected foraging areas and den availability (e.g., Stuewer 1943; Leberg and Kennedy 1988). Intensive management of forested landscapes for wood fiber production and landscape-level reductions of availability of hardwoods could influence raccoon spatial use and foraging patterns. However, whether raccoons inhabiting these forests exhibit space use patterns similar to raccoons on areas being managed with more traditional forest management techniques is unclear. Therefore, our objectives were to compare sizes of raccoon home ranges and core use areas between 2 areas with differing, but prevalent, forest management strategies. Secondly, we compared seasonal movement rates of raccoons between these areas.

Methods

Study Area

This research was conducted on an approximately 5,000-ha portion of the 14,410-ha Tallahala Wildlife Management Area (TWMA) and a 2,000-ha area owned by TC in

sections of Jasper, Newton, Scott, and Smith counties, Mississippi. The TWMA contained 30% mature (>30-year-old) bottomland hardwood forests, 37% mature pine (loblolly, *P. taeda;* shortleaf, *P. echinata*) forests, 17% mixed pine-hardwood forests, and 11% in 1- to 15-year old loblolly pine plantations. Additionally, many mature pine stands were managed for red-cockaded woodpecker with hardwood midstory removal and prescribed burning common on a 1- to 3-year rotation. The TC area, located adjacent to TWMA, was managed primarily for wood fiber production with 90% of the area composed of 1- to 35-year-old loblolly pine plantations, and the remaining 10% in Streamside Management Zones along creek drainages. Prescribed burning did not occur during the 2 years prior to or during our study on TC. Topography was gently to moderately rolling, with 0%–20% slope. Climate was mild, with a mean annual temperature of 20 C and a mean annual precipitation of 152 cm (Chamberlain 1999).

Raccoon Capture and Telemetry

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 system during March and June–August, with each grid block measuring approximately 40.5 ha. One cage trap was set/block in areas selected for maximum trap success. We sampled each grid 16–17 consecutive nights during each of the 2 trapping periods. Additionally, we captured raccoons systematically during January–March, particularly in areas devoid of radiomarked raccoons. Using these trapping systems, we attempted to capture all raccoons across the landscape and radiomonitor individuals equivocally across all habitat types. We anesthetized captured raccoons using ketamine hydrochloride (Ketaset, Veterinary Prduct, Fort Dodge Lab., Fort Dodge, Iowa) at a rate of 10 mg/kg of estimated body mass (Bigler and Hoff 1974). Adult ($\geq$1 year) raccoons were fitted with a 130-g mortality-sensitive radiotransmitter and released at the capture site the following morning. We conducted research under Mississippi State University IACUC Protocol No. 93–032 and its associated amendments.

Raccoon locations were determined via triangulation (White and Garrott 1990) using a hand-held 3-element Yagi antenna (Wildl. Mat., Carbondale, Ill.) from fixed telemetry stations ($N=480$) $\geq$2 times/week. We used 2 telemetry techniques to monitor raccoons: systematic point and sequential locations. We obtained systematic point locations by recording 2 locations weekly for each raccoon. We conducted sequential telemetry (focal runs) on a 4-hour basis with a location recorded on each raccoon every hour during the focal run. At least 12-hours separated focal runs for the same raccoons to ensure independence (Hodges 1998). 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-minute interval to reduce error due to raccoon movement; however, most (94%) consecutive azimuths were recorded within 7 minutes (4.8 ± 0.03, mean + SE). 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°. The same observers monitored raccoons on both areas.

Estimating Home Range and Core Area Sizes

Raccoon locations were converted to a coordinate system using program TELE-BASE (Wynn et al. 1990). We divided each year into breeding (1 Feb–31 May), young-rearing (1 Jun–30 Sep), and winter (1 Oct–31 Jan) seasons. 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 3-way analysis of variance (ANOVA) blocked by year to examine differences in size of home range and core areas between areas and sexes, and across seasons. 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 (93%) estimates contained ≥50 radiolocations.

Seasonal Movements

We estimated movement rates (m/hour) by dividing the straight-line distance between consecutive locations by the time interval. Only locations separated by <1.25 hours were used to ensure that distances between locations were associated with actual distances moved (Reynolds and Laundré 1990). We examined movement patterns seasonally during crepuscular and nocturnal periods because raccoons were rarely active during diurnal periods (Chamberlain 1999). We considered the seasonal movement rate for each raccoon as the experimental unit. We used a 3-way ANOVA blocked by year to examine possible interactions between combinations of independent variables (season, area, sex). If no 2-way interactions were detected, we examined 1-way ANOVA for main effects. We used least significant difference multiple comparisons to test differences in main effects. For movement rates and home ranges, we tested homogeneity of variance and normality using Levene's test (Milliken and Johnson 1992) and the Shapiro-Wilk test (Conover 1980), respectively. Home range sizes violated assumptions and were subsequently natural-log transformed (Steel and Torrie 1980).

Results

We estimated 320 seasonal home ranges with associated core areas (222 on TWMA, 98 on TC) for 114 raccoons [83 (61 m, 22 f) on TWMA, 31 (23 m, 8 f) on TC] from 1 January 1996 to 31 December 1997 (Table 1). Overall catch/unit effort was 1.8 and 2.5 raccoons/100 trapnights on TWMA and TC, respectively. Area, sex, and season did not interact to affect home range ($F_{2,308}=0.10$, $P=0.907$) or core area size ($F_{2,308}=0.54$, $P=0.586$). Likewise, we detected no 2-way interactions affecting home range or core area sizes. Home range ($F_{2,308}=0.94$, $P=0.393$) and core area sizes ($F_{2,308}=1.50$, $P=0.224$) did not differ across seasons. We detected differences in home range ($F_{1,308}=15.31$, $P<0.001$) and core area sizes ($F_{1,308}=14.62$, $P<0.001$) between areas. Home range sizes were larger on TWMA (228 ± 10 ha; $\bar{x}$ ± SE) than TC (139 ± 13 ha). Likewise, core area sizes were larger on TWMA (37.4 ±

Table 1.   Mean home range (HR) and core area (CA) sizes (ha) with associated standard errors (SE) for adult raccoons in the Tallahala Wildlife Management Area (TWMA) and the Timber Company lands (TC), Mississippi, 1996–1997.

Area	Sex	Season	N	HR	SE	CA	SE
TWMA	Male	Breeding	61	259	22	44	5
		Young-rearing	67	237	17	37	3
		Winter	41	254	25	43	4
	Female	Breeding	19	157	33	26	5
		Young-rearing	20	142	22	22	2
		Fall-winter	14	195	37	30	5
TC	Male	Breeding	31	153	25	17	3
		Young-rearing	24	132	26	21	4
		Winter	20	173	36	30	8
	Female	Breeding	9	78	18	18	6
		Young-rearing	7	94	18	9	1
		Winter	7	125	22	20	5

2 ha) than TC (21 $\pm$ 2 ha). We also detected differences in home range ($F_{1,308}=11.11$, $P=0.001$) and core area sizes ($F_{1,308}=8.96$, $P=0.003$) between sexes, with males maintaining larger home ranges (219 $\pm$ 10 ha) and core areas (35 $\pm$ 2 ha) than females (142 $\pm$ 13 ha and 23 $\pm$ 2 ha, respectively).

We used 118 raccoons [87 (65 m, 22 f) on TWMA, 31 (23 m, 8 f) on TC] and 16,750 sequential radiolocations to estimate seasonal movement rates between areas. Area, sex, and season did not interact ($F_{2,255}=0.85$, $P=0.427$) to affect movement rates and we detected no 2-way interactions to affect movement rates. Likewise, we detected no differences in movement rates across seasons ($F_{2,255}=1.52$, $P=0.219$). However, movement rates differed between areas ($F_{1,255}=26.70$, $P<0.001$) with raccoons on TWMA (362 $\pm$ 10 m/hour) moving at greater rates than those on TC (248 $\pm$ 12 m/hour). Similarly, movement rates differed between sexes ($F_{1,261}=9.09$, $P=0.003$) with males (346 $\pm$ 11 m/hour) moving at greater rates than females (279 $\pm$ 14 m/hour).

Discussion

Previous studies examining space use and movements of raccoons have reported sex-specific differences, with males generally maintaining larger home ranges than females (e.g., Johnson 1970, Hoffman and Gottschang 1977, Gehrt and Fritzell 1997) and moving at greater rates (Greenwood 1982). Similarly, home range size and core area sizes differed between sexes on TWMA and TC with males consistently maintaining larger home ranges. Likewise, males consistently moved at greater rates than females. Raccoons are sexually dimorphic with adult males being larger than females (Kaufmann 1962, Ritke and Kennedy 1993), hence one would expect males to maintain larger home ranges and core areas and move at greater rates within these spaces to fulfill energetic requirements created by morphology (McNab 1963).

Our findings provide evidence that forest management may influence spatial use patterns and movements of raccoons. However, we recognize that factors not directly assessed in our study could influence the spatial distribution of raccoons across landscapes. Home range sizes in raccoons are likely influenced by density (Ellis 1964), and although catch/unit effort was not markedly different between areas, raccoon density could be greater on TC than TWMA. If density was greater on TC, one would expect home range size to correspondingly decrease, as competition for space forced individuals to occupy smaller areas of the landscape (Sandell 1989). However, whether differences in catch/unit effort reflect density in the populations we measured is uncertain. Additionally, harvest could influence the spatial use patterns in raccoons, particularly if 1 population was exploited intensively. Harvest did not occur on TC and was considered light on TWMA (Chamberlain et al. 1999a); trapping did not occur on either area. Hodges et al. (2000) reported that increasing harvest intensity on TWMA did not strongly influence home range sizes relative to raccoons not subjected to increased exploitation, therefore, we had no reason to suspect that the minimal differences in harvest regimes introduced observable biases into our results.

Availability of critical resources influences raccoon spatial use patterns (Gehrt and Fritzell 1998). When habitat patch quality is variable, raccoons should abandon patches of decreasing quality to locate patches of greater quality. Under conditions of declining habitat quality or decreasing foraging efficiency, raccoons would be forced to increase home range and core area sizes to include patches capable of providing the net energy gain to fulfill energetic and life requisites. Raccoons on TWMA maintained larger home ranges and core areas, and moved substantially more within these ranges, than raccoons on TC. This suggests that forest management on TWMA potentially decreased habitat quality for raccoons relative to TC.

We suggest the differences in space use and movements between areas resulted from differences in prescribed burning frequencies. No burning occurred on TC during, or 2 years prior to, our study. Furthermore, all stands >15 years were fertilized during this study, potentially improving forage production within these stands. Understory vegetative conditions were dominated by hardwood saplings and vine, particularly blackberry and dewberry (*Rubus* spp.), grape (*Vitis* spp.), and beautyberry (*Callicarpa americana;* Chamberlain 1999). These soft mast species are used frequently by raccoons (Johnson 1970) and offer readily available forage during a substantial portion of the annual cycle. Increasing availability of potential food items likely increased foraging efficiency on TC, thereby allowing raccoons to maintain smaller home ranges and core areas, and move less within these ranges, to acquire necessary resources. Conversely, an increased burning frequency on TWMA, particularly within stands managed for red-cockaded woodpecker, resulted in increased herbaceous understory vegetation and decreased availability of vines and woody saplings (Palmer et al. 1996). Hence, prescribed burning likely created large areas of relatively poor quality habitat, particularly during spring and summer when soft mast species are most used (Johnson 1970), resulting in raccoons maintaining larger home ranges and moving substantially more within these ranges. Likewise, removal of most mast producing hardwoods from pine stands managed for red-cockaded woodpeckers

reduced hard mast availability during fall-winter, thereby reducing habitat quality during these periods.

Management Implications

Considerable discussion has centered on potential influences of intensive forest management on a suite of wildlife species (e.g., Bowman et al. 1999, Burger et al. 1998, Chamberlain et al. 1999*b*). We recognize that landscape composition and configuration differ across areas with similar forest management strategies and many factors influence macro- and microhabitat conditions across landscapes. However, our findings suggest that intensive forest management for wood fiber production may allow raccoons to maintain smaller home ranges and exhibit lesser movements than management aimed at reducing total basal area and hardwood midstory vegetation. Furthermore, if mesocarnivore home range sizes are indicative of habitat quality (Sandell 1989), our findings indicate that intensive forest management (i.e., stand rotation <35 years) without prescribed burning may produce greater quality habitat for raccoons than more traditional forest management with regular (<3 year rotation) prescribed burning and longer stand rotations.

As an ecological generalist, the raccoon is able to exploit a wide variety of resources and exists in a variety of landscapes. Although this study demonstrates that raccoons readily exist within intensively managed forests, future research should examine density, space use, and movements of raccoons in other intensively managed landscapes. Furthermore, research should examine influences of intensifying forest management on other aspects of raccoon ecology and behavior, including habitat selection and denning ecology.

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