Bobcat Home Range, Density, and Habitat Use in East-central Mississippi

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Abstract: Fifteen bobcats (10 females, 5 males) were monitored using radio telemetry from 1 January 1989–31 December 1991 in east-central Mississippi. Male composite home ranges (HR) averaged 36.5 km^2 (S.E. = 12.7) while female HR's averaged 20.6 km^2 (S.C. = 7.7). Composite and seasonal HR sizes differed between sexes ($P = 0.03$ and $P < 0.001$, respectively). HR's were larger during the 1989 post-parturition (1 May–31 Aug) and fall (1 Sept–31 Dec) seasons than during most other seasons ($P < 0.05$). Intersexual HR overlap occurred during 5 of 9 seasons. Female-female HR overlap occurred during 3 seasons while male-male overlap occurred during 2 seasons. Much female-female HR overlap was explained by dispersing sub-adults. Minimum winter bobcat density averaged 1 bobcat/10.4 km^2. Pine plantations and agricultural areas were preferred (use > available) habitats, while mature pines were used less than available ($P < 0.10$). Use of hardwood bottoms by bobcats varied. Females had more pronounced habitat preferences than males.

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Passage of the Endangered Species Conservation Act of 1969 increased demand for non-endangered spotted cats of North America, specifically the bobcat (*Felis rufus*) and lynx (*F. lynx*). Concern of over-exploitation of bobcats caused their listing in Appendix II of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). These events have fostered an abundance

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of recent research concening bobcat ecology as each state is responsible under CITES for insuring non-detrimental bobcat harvest (Anderson 1987). Bobcats have shown pronounced differences in home range (HR) size, density, and habitat use throughout their range (Hamilton 1982, Shiflet 1984, Litvaitis 1985, Rucker et al. 1989). Data concerning basic bobcat ecology is needed on a regional basis to assist biologists in making management decisions concerning this important predator.

Home range sizes for southeastern bobcats were highly variable, ranging from 1.1 km^2 for females and 2.6 km^2 for males in Alabama (Miller and Speake 1979) to 24.5 km^2 for females and 64.2 km^2 for males in Arkansas (Rucker et al. 1989). In general, male HR sizes were 2 to 3 times larger than female HR's (Hall and Newsom 1976, Buie et al. 1979, Miller and Speake 1979, Shiflet 1984, Wassmer et al. 1988, Rucker et al. 1989). Anderson (1987) and Sandell (1989) stated that female HR size might be regulated by diversity, abundance, and stability of prey populations, while male HR size was influenced by number of mating opportunities. Bobcat intrasexual HR overlap was rare (Hall and Newsom 1976, Buie et al. 1979, Miller and Speake 1979, Shiflet 1984).

There are few bobcat density estimates for the Southeast. Hamilton (1982; Missouri) estimated bobcat densities to range from 1 bobcat/0.3 km^2–1 bobcat/15.6 km^2, Wassmer et al. (1988; Florida) estimated density to be 1 adult bobcat/7.7 km^2, and Rucker et al. (1989; Arkansas) estimated density as 1 bobcat/9.6 km^2. Bobcat density has been linked to habitat quality and prey abundance (Knick 1990).

Bobcats use a variety of habitats. In the Southeast, the most prevalent habitats utilized included early successional vegetation (Kitchings and Story 1978), bottomland hardwoods in mid-successional stages (Hall and Newsom 1976), mature bottomland hardwoods, old fields, 1- to 4-year-old pine plantations (Heller and Fendley 1982), and agricultural areas (Lancia 1982). Wassmer et al. (1988) found bobcats use habitats within their home range disproportionately to their availability; however, there were no consistent trends in use of specific habitats. Rucker et al. (1989) found bobcats preferred 0- to 20-year-old forest regeneration areas and mature hardwood timber more than other habitats.

The primary explanation for differential habitat use by bobcats was prey abundance. Litvaitis (1985) related bobcat habitat selection to abundance of snowshoe hares (*Lepus americanus*). Bailey (1979) suggested that location of den sites and breeding habitat is a function of prey abundance. Fuller et al. (1985) hypothesized that deer abundance influenced habitat selection by bobcats in Minnesota. Knowles (1985) and Boyle and Fendley (1987) correlated bobcat habitat to preferred habitat of bobcat prey items. Anderson (1987) concluded that habitats which positively influence diversity, abundance, and stability of prey items may play a major role in dictating bobcat habitat use.

Our objectives were to determine HR size, percent HR overlap, winter densities, and seasonal habitat use patterns withing a managed forest. Our results should be applicable to all lower coastal plain forests managed for multiple use and sustained yields.

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Methods

The study was conducted on the 142km^2-Tallahala Wildlife Management Area (TWMA) in the Strong River District of the Bienville National Forest in east-central Mississippi. Mean annual temperature was 18° C and annual precipitation averaged 152 cm (Carraway 1990). Mature (>20 years of age) pine (*Pinus* spp.) stands comprised approximately 54% of the study area. Mature bottomland hardwood stands accounted for 30% of the area. Approximately 15% of the area was pine plantations (<20 years of age). The remaining 1% of the area was in agriculture (row crops or pasture).

Bobcats were captured using Victor Soft-catch traps. Following animal capture, bobcats were netted and drugged with Ketamine hydrochloride (15 mg/kg body weight). Bobcats were weighed, standard measurements were taken, and ear tags installed. Bobcats were separated into 3 age classes (kitten <1.0 years, sub-adult 1–2 years, adult >2 years) based on tooth eruption, staining, and wear; general body size (Crowe 1975); pelage characteristics; teat condition on females; and scrotum of males. All adult and sub-adult females were fitted with a radio collar (151–152 Mhz, Wildl. Materials, Carbondale, Ill.). Selected adult males (animals captured in the interior of the study area) also were monitored. Cats were kept in a carrying cage at approximately 20° C for 24 hours to monitor recovery. Upon recovery, bobcats were released at the capture site. Transmittered animals were allowed 1 week to recover from capture before radio-tracking was initiated. Animals were trapped during winters (7 Jan–15 Mar) 1989, 1990, and 1991. Each year, we attempted to capture all bobcats on the study area.

Bobcats were monitored using a TRX-100S radio receiver and a hand-held 3-element Yagi antenna (Wildl. Materials, Carbondale, Ill.). Locations were determined by triangulation from known points (telemetry stations) within the study area (Cochran 1980, Kenward 1987, White and Garrott 1990). Three or more azimuths were frequently recorded to minimize erroneous locations. Azimuth differences were kept between 60° and 120° (Cochran 1980, Kenward 1987, White and Garrott 1990). A maximum of 15 minutes was allowed between azimuths to decrease error associated with animal movement. Azimuths were converted to x,y coordinates using the program TELEBASE (Wynn et al. 1990). Telemetry locations were non-biased and estimated accurate within 117 m based on accuracy tests as described by White and Garrott (1990).

Jackson and Jacobson (1987) observed that captive bobcats in Mississippi breed during February and early March with parturition following a gestation of 63 days.

These observations were used to determine 3 sampling periods. The breeding season (1 Jan–30 Apr) consisted of breeding, parturition, and nursing young. The post-parturition season (1 May–31 Aug) included the period kittens would require prey captured by the adult female. The fall season (1 Sep–31 Dec) was the period that kittens would be traveling with the adult female. The total sampling period extended from January 1989 through December 1991. For convenience, seasons were numbered consecutively 1–9 (season 1 = breeding 1989; season 2 = post-parturition 1989; season 3 = fall 1989; season 4 breeding 1990; etc.). Systematic monitoring was performed to insure locations were equally distributed throughout a diel period.

Seasonal and composite (HR's calculated using all locations obtained for the animal) 95% convex polygon HR's (Bekoff and Mech 1984, Samuel et al. 1985) were determined using program HOME RANGE (Ackerman et al. 1990). This HR model was chosen because omitting the outermost 5% of the telemetry locations minimized the number of locations that could be termed extraterritorial forays (Knick 1990). Differences in HR size between sexes and seasons were tested using a 2-way analysis of variance on rank transformed data (Conover and Iman 1981, Zar 1984). Mean separation was accomplished using least significant differences (Steel and Torrie 1981).

Seasonal HR overlap was determined for each bobcat by superimposing HR's of overlapping bobcats and determining area of shared space; this area was reported as a percentage of the animals' HR. Both inter- and intra-sexual HR overlap was assessed.

Minimum winter bobcat densities were estimated by delineating the area encompassing all bobcat HR's and then dividing the number of bobcats known to exist on the study area during trapping seasons by the area within that boundary (Lawhead 1984, Rucker et al. 1989). Number of bobcats known to exist on the study area during trapping seasons was calculated as the sum of animals captured and number of radio monitored individuals not captured.

Four vegetative types (habitats) were delineated on the study area: pine plantation, mature pine, hardwood bottom, and agricultural (crop lands and pasture). Habitats were digitized into PC ARC/INFO (ESRI 1989) to create a habitat map. Bobcat locations were intersected with the habitat map to determine habitat use. Preference (use > availability) and avoidance (use < availability) of habitats was assessed using a goodness of fit test and Bonferroni confidence intervals (protected at alpha = 0.10) around percent use of the vegetative type (Neu et al. 1974). Seasonal habitat use statistics were calculated separately for each sex.

Results

Fifteen bobcats (10 females, 5 males) were monitored. Two females were subadults and no kittens were monitored. Seasonal HR's and habitat use statistics were calculated using 5–9 bobcats (depending upon season). Numbers of locations were not homogeneous between seasons (range 117–617; $P < 0.001$; chi-square test).

Male composite HR's ($\bar{X}$ = 36.5; SE = 12.7 km^2) were greater than females ($\bar{X}$ = 20.6; SE = 7.7 km^2) (P = 0.03) (Table 1). There was no sex by season interaction (P = 0.91); thus allowing us to examine each of the main effects (season and sex) separately by averaging over the other main effect (Zar 1984). Male seasonal HR's ($\bar{X}$ = 13.1 km^2; SE = 1.5) were greater than females ($\bar{X}$ = 8.3 km^2; SE = 1.4) ($P < 0.001$). HR sizes differed seasonally (P = 0.03). Season 3 HR's were larger than all seasons except seasons 2 and 6 ($P < 0.05$). Season 2 HR's were larger than seasons: 5, 7, 8, and 9 ($P < 0.05$).

Table 1. Seasonal and composite home range sizes (km^2) of adult bobcats on Tallahala Wildlife Management Area, Mississippi, 1989–1991, determined by the 95% convex polygon method.

N	Season[a]									
Bobcat	1	2	3	4	5	6	7	8	9	Composite
Female										
2	12.6	14.9	17.2	10.9						17.7
	(54)[b]	(121)	(105)	(92)						(388)
5	4.1	8.3	8.9	6.9	3.6					9.5
	(58)	(122)	(143)	(113)	(58)					(494)
10	3.7	21.7	31.4	4.4	4.7					35.9
	(53)	(101)	(123)	(62)	(26)					(424)
17								5.1	4.6	6.4
								(59)	(42)	(123)
18[c]					3.3	4.3	38.6			84.8
					(53)	(74)	(104)			(237)
20				3.0	2.0	1.5	1.7	0.9	1.3	3.4
				(31)	(84)	(99)	(27)	(61)	(27)	(330)
22					10.6	6.4	1.6	8.5		15.4
					(77)	(95)	(22)	(42)		(253)
24								4.8	2.9	7.4
								(23)	(26)	(49)
27								6.0	7.7	9.2
								(47)	(40)	(98)
32[c]								15.6	7.4	16.4
								(54)	(42)	(103)
Mean	6.8	15.0	19.2	5.7	5.0	15.5	2.7	6.5	5.2	20.6
Male										
4			8.5	11.9	8.4					19.5
			(82)	(60)	(28)					(233)
8	8.4	13.3	15.4							19.2
	(51)	(125)	(123)							(309)
13	17.0	18.3	38.9	15.6						86.6
	(35)	(33)	(85)	(67)						(257)
15				13.6	14.7	17.3	8.5	19.5	9.0	27.0
				(82)	(56)	(87)	(29)	(39)	(25)	(327)
16				8.9	11.2	6.6	9.3	8.7	5.1	30.3
				(65)	(58)	(93)	(20)	(46)	(25)	(303)
Mean	12.7	15.8	21.0	12.5	11.4	11.9	8.9	14.1	7.1	36.5
Tot. Mean	9.2	15.3	20.0	8.7	7.5	14.1	5.2	8.4	5.9	23.5

[a] Season 1 = breeding 1989; season 2 = post-parturition 1989; season 3 = fall 1989; season 4 breeding 1990; etc.
[b] Number of telemetry locations used to derive home range polygon.
[c] Sub-adults.

Mean female-female seasonal HR overlap ranged from 0%–32% with overlap occurring during 3 seasons (Table 2). Average male-male seasonal HR overlap ranged from 0%–15% and occurred during 2 seasons. Mean intersexual HR overlap ranged from 0%–14% for both sexes and occurred during 5 seasons.

Thirty-one bobcats were known to have been present on the area during the study. Estimates of minimum winter populations were stable: 13 for 1989 and 1990 and 15 for 1991 ($\bar{X}$ = 13.7). The effective study area size was estimated to be 143 km^2. Winter minimum density estimates were 1 bobcat/11.0 km^2 during 1989 and 1990 and 1 bobcat/9.5 km^2 in 1991 ($\bar{X}$ = 1 bobcat/10.4 km^2).

Both sexes consistently used pine plantations and agricultural areas greater than availability and mature pine stands less than availability ($P < 0.10$). Males used bottomland hardwoods in proportion to availability during all seasons; however, females avoided hardwoods during 5 seasons ($P < 0.10$). Females showed more habitat preferences and avoidances than males (Table 3).

Discussion

Composite female bobcat HR sizes for TWMA were among the largest reported in the Southeast while male HR's were within the limits of previous studies (Marshall and Jenkins 1966, Hall and Newsom 1976, Buie et al. 1979, Kitchings and Story 1979, Miller and Speake 1979, Hamilton 1982, Lancia et al. 1982, Shiflet 1984, Whitaker et al. 1987, Wassmer et al. 1988, Rucker et al. 1989). However, care should be taken when comparing HR's derived using different delineation methodologies (White and Garott 1991). Eight of the aforementioned studies (Marshall and Jenkins 1966, Kitchings and Story 1979, Miller and Speake 1979, Hamilton 1982, Lancia et al. 1982, Shiflet 1984, Wassmer et al. 1988, Rucker et al. 1989) described the model used to determine HR as either the "convex polygon" or "minimum area" method. These techniques differ only semantically (Kenward 1987). Both methods calculate the area of the smallest convex polygon containing all animal locations. Because we chose to omit 5 percent of locations before calculating convex polygon HR's our HR's were conservatively small when compared to these

Table 2. Percentage of average seasonal inter- and intrasexual home range overlap for bobcats on Tallahala Wildlife Management Area, Mississippi, 1989–1991.

	Season[a]								
Type of overlap	1	2	3	4	5	6	7	8	9
Female by female	0	0	0	0	32	28	0	0	17
Male by male	0	0	0	2	0	0	15	0	0
Female by male	0	1	6	14	0	0	0	10	1
Male by female	0	3	5	14	0	0	0	10	1

[a] Season 1 = breeding 1989; season 2 = post-parturition 1989; season 3 = fall 1989; season 4 breeding 1990; etc.

Table 3. Habitat use versus availability[a] for male and female bobcats on the Tallahala Wildlife Management Area, Mississippi, 1989–1991.

		Habitat[b]							
		PP		P		H		A	
Season[c]	Sex:	Male	Female	Male	Female	Male	Female	Male	Female
1		=[d]	>[e]	<[f]	<	=	=	>	>
2		>	>	<	<	=	=	=	>
3		>	>	<	<	=	=	>	>
4		>	>	<	<	=	=	>	>
5		>	>	<	<	=	<	>	>
6		>	>	<	<	=	<	>	>
7		>	>	<	<	=	<	=	>
8		>	>	<	<	=	<	=	>
9		>	>	<	<	<	<	=	>

[a] Protected for simultaneous inference at alpha = 0.10.
[b] PP = pine plantation; P = mature pine; H = bottomland hardwood; A = agriculture.
[c] Season 1 = breeding 1989; season 2 = post-parturition 1989; season 3 = fall 1989; season 4 breeding 1990; etc.
[d] Habitat use = availability.
[e] Habitat use > availability.
[f] Habitat use < availability.

studies. For instance, composite minimum area HR's averaged 52.42 km^2 (SE = 14.2) for males and 38.8 km^2 (SE = 15.1) for females. Using the minimum area method, our estimates of female HR size is the largest ever reported in the Southeast. Of the remaining papers reviewed, 1 study (Whitaker et al. 1987) reported 95 percent convex polygon home ranges (the same as used here), while the remaining authors (Hall and Newsom 1976, Buie et al. 1979) chose to use the modified minimum area method (Harvey and Barbour 1965). Our HR estimates would have been smaller had the modified minimum area method been used for HR delineation.

Conner (1991) found prey abundance [white-tailed deer (*Odocoileus virginianus*), rabbits (*Sylvilagus* spp.), and small mammals] to be lower in mature stands than in pine plantations. The larger HR's observed in this study were likely a result of low prey abundance from high proportion (84%) of mature stands. Bobcat HR sizes on Savannah River Plant in South Carolina increased between 1966 (Marshall and Jenkins 1966) and 1978 (Buie et al. 1979). During this period, early successional habitats (old field and pastures) were converted to pine plantations. As the original area became forested, prey biomass decreased; suggesting HR size to be a function of prey abundance (Buie et al. 1979). Additionally, Knick (1990) found HR sizes increased during a period of prey decline.

The observation that male HR's were larger than female HR's is consistent with findings of other researchers (Hall and Newsom 1976, Buie et al. 1979, Miller and Speake 1979, Shiflet 1984, Wassmer 1988, Rucker et al. 1989). Sex specific differences in HR size are attributable to males attempting to maximize breeding opportunities by overlapping as many female ranges as possible (Anderson 1987, Sandell 1989). Our data does not contradict this hypothesis.

Seasonal differences in HR size cannot be easily explained. The larger HR's of season 2 and 3 are primarily from effects of 1 male and 1 female (nos. 13 and 10, respectively). During seasons 1 and 4 these individuals had HR's considerably smaller than observed during seasons 2 and 3. Habitat related explanations cannot account for increased HR sizes for these animals during seasons 2 and 3. If habitat change had occurred, the animals would have continued to use expanded HR's to meet their needs. This was not the case as both animals subsequently ''settled down'' during season 4 in areas within the previous season's HR. Temporarily increased HR sizes from climatically induced impacts on prey resources also can be discredited as no other bobcats exhibited such pronounced HR expansion. Both sub-adult bobcats (nos. 18 and 32) dispersed during fall seasons. It is possible that unmonitored dispersing individuals temporarily displaced resident adults during season 3; however, this would appear to contradict land tenure theories proposed by Bailey (1974).

Seasonal HR's were considerably smaller than composite HR's. This is expected to some degree; however, the extreme differences indicated by some animals is indicative of seasonal partitioning of composite HR's. Female bobcats were observed to restrict activities to areas near den sites when caring for kittens (Bailey 1974, Knick 1990). We found female HR's were usually slightly smaller during the period females would have been caring for young at the den site (seasons 1, 4, and 7, see Table 1). Unfortunately, no kittens were observed with radio-monitored females during the study. Anderson (1987) stated male HR's were generally larger during breeding seasons to maximize probability of reproduction. This pattern was not observed in our study. Additionally, bobcats may utilize portions of their composite HR's during selected seasons to optimize access to seasonally important habitat resources (e.g., concentrate movements in the vicinity of water during drought).

Female intrasexual HR overlap occurred only during seasons 4, 5, and 8. Major HR overlap of adult (age >1 year) females was not common in other studies (Hall and Newsom 1976, Buie et al. 1979, Miller and Speake 1979, Shiflet 1984); however, it has been previously documented (Kitchings and Story 1984, Knick 1990). A substantial area (>1.50 km^2) was shared by 3 female bobcats (nos. 10, 18, and 20) during seasons 4 and 5. However, 1 of the 3 females was classified as a sub-adult (no. 18) and eventually dispersed and established a new HR. Another of the 3 females (no. 10) left the area during season 6 and possibly established an exclusive HR; however, transmitter failure occurred before the new HR could be documented. Female-female HR overlap during season 8 also occurred between an adult and sub-adult bobcat (nos. 22 and 32, respectively). During season 9, the sub-adult bobcat acquired the HR of the adult when the adult was killed by a predator.

Males tended to have more exclusive HR's than females. This is likely because no sub-adult males were monitored. Home range overlap only occurred during 2 seasons between 2 separate pairs of males. Amount of space shared by each pair was considered too small to be of biological significance. Due to observed dispersals of female sub-adults and lack of observed intrasexual HR overlap by males, the land tenure system proposed by Bailey (1974) appears appropriate on TWMA.

Intersexual HR overlap is generally higher than intrasexual overlap (Anderson

1987). Intersexual HR overlap during this study was more common than data reveals because of the lack of radio-tagged males. Further, males were captured within the HR of all females indicating that our sampling efforts were inadequate to describe intersexual HR overlap.

Our estimates of minimum bobcat density fell within the range of densities reported in other southeastern studies (Hamilton 1982, Wassmer et al. 1988, Rucker et al. 1989). Monitored bobcats on each of the aforementioned studies had HR's that were generally higher than those reported elsewhere in the Southeast (Buie et al. 1979, Miller and Speake 1979, Shiflet 1984). If HR size and density are inversely related (Sandell 1989), our study (as well as the studies of Hamilton 1982, Wassmer et al. 1988 and Rucker et al. 1989) was likely conducted in an area of low bobcat density. It was probable that our estimates were lower than true density as bobcat "sign" was found in areas that contained no monitored or captured bobcats. However, some sign observed in "voids" was likely made by animals that were captured elsewhere on the study area but were not radio-tagged (i.e., males on the study area periphery and sub-adults).

The most widely accepted explanation for differential habitat use among bobcats is prey availability (Bailey 1979, Fuller 1985, Knowles 1985, Litvaitis 1985, Boyle and Fendley 1987, Knick 1990). Habitat usage of our study animals indicated a strong preference for pine plantations and agricultural areas. Also conspicuous was the strong avoidance of mature pine stands. Pine plantations had significantly more prey than mature stands on TWMA (Conner 1991). Intensive use of agricultural habitats occurred on an isolated area that was not clean-farmed. This agricultural area contained numerous brushy fence rows and drainages and provided excellent habitat for bobcat prey. We feel abundance of prey best explained differential habitat use during our study.

Hall and Newsom (1976) and Heller and Fendley (1986) observed bottomland hardwoods to be preferred bobcat habitat. We observed hardwood bottoms were used equal to their availability by males and less than their availability by females (5 of 9 seasons). These observations indicate hardwood bottoms on TWMA were marginal bobcat habitat. Because no mature habitats were preferred, older-aged stands are likely not as important to bobcats as early successional habitats.

Females either preferred or avoided all habitats (with the exception of the hardwood bottom habitat type during seasons 1–4). While males also revealed pronounced habitat preferences and avoidances, they used habitats equal to their availability more often than females. Because females utilized smaller HR's than males, females should have concentrated their activities in habitats more conducive for their survival. If this is the case, females would follow habitat use patterns similar to those observed during this study. Additionally, the lessened affinity for selected habitat types by males may result in decreased intersexual competition.

Bailey (1974) and Sandell (1989) theorized that decreases in prey populations could result in increased wandering of individual bobcats, increased HR size, and a breakdown in land tenure. The relatively large HR's and the variability of HR overlap may be related to low bobcat density and habitat quality on TWMA. Additional evidence supporting the hypothesis of poor habitat quality is reflected in the observation that preferred habitats were the least available habitat types on the study area.

Managers should be cognizant of large HR's and low bobcat densities in areas of predominantly mature forest. Forest management practices conducted by the U.S. Forest Service (USFS) do not differ appreciably throughout the lower Coastal Plain (B. Bradford, pers. commun.). These lands are usually dominated by pine stands, typically burned on a 6–8 year regime, and have small (<0.3 km^2) well dispersed pine plantations. If HR size is indicative of habitat quality (Bailey 1974, Sandell 1989), USFS lands are likely poor bobcat habitat throughout this region. Harvest strategies based on bobcat densities in areas comprised of mature habitats should be conservative to insure "non-detrimental" harvest of this species.

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