

ECOLOGY OF BOBCATS IN A LONGLEAF PINE FOREST  
IN SOUTHWESTERN GEORGIA

by

JESSICA CHOTARD COCHRANE

(Under the direction of Robert J. Warren)

ABSTRACT

There is little known about bobcat ecology within longleaf pine forests. Therefore, I examined home range size, home range and core area overlap, habitat selection, and diet of bobcats within a longleaf pine forest in southwestern Georgia. Male and female home range sizes varied seasonally. Intersexual home range and core area overlap was greater than intrasexual overlap. Across the entire study site, bobcats selected certain habitats within the study site when establishing their home range; habitat selection within the home range was much less prominent. Habitat selection at the home range scale did not vary among sexes or seasons. However, female bobcats selected habitats within their home range seasonally. Bobcat diet was predominately composed of rodents throughout the 2-year study, but there was some variation between years. Our results suggest that bobcats select habitat for establishing a home range based on prey availability.

INDEX WORDS: Bobcat, Home range, Home range overlap, core area overlap, *Lynx rufus*, Habitat use, Scat, Longleaf Pine, southwestern Georgia

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## DEDICATION

This thesis is dedicated to all those who have supported me along the way, but especially my parents and sister. They gave me their unconditional love and support.

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## CHAPTER 1

### INTRODUCTION, STUDY AREA, JUSTIFICATION, AND THESIS FORMAT

## INTRODUCTION

Little is known about bobcats (*Lynx rufus*) in longleaf pine (*Pinus palustris*) forests. Therefore, this study will focus on home range, habitat use, and diet of bobcats within a longleaf pine/wiregrass (*Aristida beyrichiana*) ecosystem.

In many forested habitats the bobcat (*Lynx rufus*) is an apex predator (Henke and Bryant 1999, Conner et al. 2000) and bobcats represent an apex predator in the longleaf pine forests of southwestern Georgia. Apex predators have the ability to regulate other predator populations, thus keeping ecosystems in equilibrium. Apex predators may even help increase the survival of prey species by preying upon mesopredators (Courchamp et al. 1999, Rogers et al. 1998, Palmores et al. 1995, Conner et al. 2000).

### **Bobcat Home Range**

The bobcat is one of the most widely distributed predators in the United States (Buie 1980). It is a solitary mammal (Anderson 1987) with a variable home range in the Southeast, ranging from 1.1 - 24.5 km<sup>2</sup> for females and 2.6 - 64.2 km<sup>2</sup> for males (Miller and Speake 1978, Rucker et al. 1989). Male home ranges are typically 2-3 times larger than females (Hall and Newsome 1976, Buie et al. 1979, and Whitaker et al. 1987). Bailey (1974) determined that female bobcats used their home ranges more intensively than did male bobcats. Home ranges of female bobcats are thought to be regulated by diversity, abundance, stability, and distribution of prey populations, whereas the male bobcat home ranges are regulated by opportunities for breeding, and the size of female home ranges (Anderson 1987, Sandell 1989). Male bobcat home ranges typically overlap several female bobcat home ranges (Hall and Newsome 1976, Miller and Speake 1978, Buie et al. 1979, and Whitaker et al. 1987).

Common Northern bobwhite quail (*Colinus virginiana*) management practices such as supplemental feeding, prescribed burning, and creation and maintenance of food plots may influence home range size of bobcats. These quail management practices may benefit bobcats as well as quail. Supplemental feeding may cause an increase in prey populations and a corresponding decrease in a predator's home range size by concentrating prey species and bobcats in the same area (Boutin 1990). Prescribed burning maintains excellent habitat for prey by creating and maintaining a herbaceous understory (Golley et al. 1965). Food plots create edge that provides both food and cover for bobcat prey species (Landers and Mueller 1986).

Bobcat home ranges fluctuate seasonally and these fluctuations may be linked to seasonal availability of prey. For example, two studies found that bobcats maintained smaller home ranges during the summer and winter season than during other seasons, and researchers suggest that prey is most abundant during the summer and winter seasons (Buie 1980, Rucker et al. 1989).

Habitat quality is considered a major determinant of bobcat home range size, and habitat quality is strongly linked to prey availability (Fendley and Buie 1986). Bobcat home range sizes are assumed to be inversely correlated to prey density (Smith 1968, Mares et al. 1976, Buie et al. 1979, and Knick 1990).

### **Habitat Use**

Bobcats prefer early successional (Kitchings and Story 1978), bottomland hardwoods in mid-successional stages (Hall and Newsome 1976), mature bottomland hardwoods, old fields, 1-4 year old pine plantations (Heller and Fendley 1982) and agricultural areas (Lancia 1982, Conner et al. 1992). Although superficially these habitats appear drastically different, researchers generally suggest that these habitats represent the most prey rich habitats on their

study areas. Prey abundance and distribution are the main factors that determine habitat use by bobcats (Pollack 1951, Bailey 1974, Litvaitis 1984, Anderson 1987). Habitat quality is determined based on the ability of the habitat to produce abundant prey (Fendley and Buie 1986, Boyle and Fendley 1987). Habitats with high stem density (Litvaitis et al 1986), vertical vegetation cover (Knowles 1985), and horizontal and vertical understory cover (Leopold et al 1995) are typically linked to areas of optimal bobcat prey habitat, which would also be linked to optimal bobcat habitat (Kolowski and Woolf 2002). Habitat use within the longleaf pine/wiregrass ecosystem by bobcats may be influenced by management practices such as prescribed fire and the creation and maintenance of food plots. These practices help to create habitat for bobcat prey species by maintaining a herbaceous understory (Golley et al. 1965). Bobcats typically use habitats characterized by a dense growth of briars, vines and grasses, which usually support high prey populations (Rolley and Warde 1985). Protection from severe weather, access to resting and denning sites, cover for hunting and escape, and freedom from disturbances may also influence habitat use by bobcats (Pollack 1951, Bailey 1974, and Anderson 1987). In the Southeast, where the climate is relatively moderate, thickets, hollow stumps, and logging debris provide adequate cover for resting and denning (Miller 1980, Kitchings and Story 1984, Boyle and Fendley 1987). Bottomland hardwoods are used for loafing and travel in the Southeast (Hall and Newsome 1976, Buie 1980, Boyle and Fendley 1987).

Male and female bobcats select habitats differently. One study found that female bobcats selected old fields more frequently than male bobcats (Fendley and Buie 1986). Typically, female bobcats use better quality habitats than males because female bobcats require more prey from within smaller home ranges, especially during physiologically demanding periods like

kitten rearing (Bailey 1981 and Anderson 1987). The availability of den sites may influence habitat use of female bobcats (Bailey 1974). Den sites may be increased by prescribed fire performed within longleaf pine forests. Prescribed burning creates hollow logs and stumps that are used for denning (Gashwiler et al. 1961). Also, prescribed burning helps to maintain the herbaceous layer, which can cause an increase in prey densities (Landers and Mueller 1986). Thus, the increase in prey density may influence the female choices of den sites. However, the difference in habitat use by the sexes may be due to niche segregation (Rolley and Warde 1985).

### **Diet**

In the South, bobcats primarily consume mammals, especially rabbits (*Sylvilagus* spp.) and cotton rats (*Sigmodon hispidis*) (Beasom and Moore 1977, Miller and Speake 1978, Boyle and Fendley 1987). Bobcats are also thought to be a major predator of quail, but this contention is unsubstantiated. However, data from a study conducted in Alabama, where quail were present in abundance, suggested quail were not an important prey species in bobcat diets (Miller and Speake 1978).

Bobcats may exhibit a functional response to prey by altering their diets based on the relative density of prey in the area (Boutin 1990). For instance, deer consumption by bobcats increases during late fall to early winter when there is the possibility of consuming hunter-killed deer, and in late spring to early summer when fawns are available (Buttrey 1979). Conversely, bobcats may specialize in different sizes of prey based on bobcats' body size, which would help reduce intraspecific competition (Rosenzweig 1966). For example, in Arkansas, female bobcats consumed more rats and mice than males (Fritts and Sealander 1978). In New Hampshire, male bobcats consumed more white-tailed deer (*Odocoileus virginianus*) and fewer cottontails than

females (Livaitis et al. 1984). Both these studies suggest that female bobcats, the smaller sex, selected smaller prey or utilized the more abundant prey than males (Fritts and Sealander 1978).

### **Reproduction and Denning**

Breeding, parturition, and nursing young comprise the reproductive season for female bobcats. In the southern United States, bobcats typically breed between December and February (McCord and Cardoza 1982); however, their breeding is not limited to this time period. Blankenship and Swank (1979) suggest that in southern latitudes breeding begins earlier and may last longer. Post-parturition is the period when kittens require prey captured by an adult female. Kittens will remain with the adult female during the fall season (Conner et al. 1992). Timing of reproduction varies based on a number of factors including prey availability, location, and climate (McCord and Cardoza 1982).

Bobcats den in hollow logs, rock ledges (Gashwiler et al. 1961), stumps from recent timber harvests (Kitchings and Story 1984), thickets, and brush piles (Anderson 1987). Logging may increase available den sites for bobcats by creating brush piles and stumps. Also, prescribed burning may increase availability of den sites for bobcats by creating hollow logs and stumps (Gashwiler et al. 1961). Another benefit of prescribed burning is that it maintains the herbaceous layer which can cause an increase in prey densities (Landers and Mueller 1986). This increase in prey density may influence a female's choice of den sites.

### **STUDY AREA**

This study was conducted in Baker County, Georgia, on Ichauway. Ichauway was a former quail hunting plantation but currently serves as an outdoor laboratory for the Joseph W. Jones Ecological Research Center (JWJERC). Ichauway consists of 11,700 ha located

approximately 16 km south of Newton, Georgia. Ichauway is one of the largest privately held tracts of longleaf pine forest remaining in Georgia. The Flint River forms 21.6 km of the eastern boundary of Ichauway. The Ichauwaynohaway Creek flows through 24 km of the site. A flat to rolling landscape characterizes the topography, with the elevation ranging between 27 - 200 m above sea level. There is an average temperature of 27.5 ° C in the summer months and 11° C in the winter months. The general climate at Ichauway is subtropical with hot, humid summers and mild, wet short winters (Lynch et al. 1986). The average annual precipitation is 131 cm (Goebel et al. 1997). The area consists of a conglomeration of habitats, but longleaf pine forests dominate the landscape. Ichauway also contains mixed hardwoods, slash pine flatwoods, natural loblolly pine stands, riparian hardwood hammocks, oak barrens, grassy limesink ponds, cypress-gum limesink ponds, creek swamps, agricultural fields, food plots, and riverine habitats. The dominant understory species are old field grasses (e.g., *Andropogon* spp.) and wiregrass (*Aristida beyrichiana*) (Goebel et al. 1997). There are more than 1,000 vascular plant species documented on site (Drew et al. 1998).

Prescribed fire is the most dominant habitat management tool employed on Ichauway. Prescribed burning takes place throughout the year but is more prevalent during the late winter and early spring. Prescribed burning is used to reduce hardwoods and to promote herbaceous vegetation, which in turn may increase prey for bobcats. Burning typically occurs on a 2-year rotation with 4,000 - 6,000 ha being burned annually.

Ichauway is divided into multiple-use (approximately 60% of the site) and conservation zones. In addition to prescribed fire, management in multiple-use zones includes food plots and supplemental feeding. Wildlife food plots consist of grain sorghum (*Sorghum vulgare*), Egyptian wheat (*Sorghum* spp.), brown top millet (*Brachiaria ramosa*), cowpea (*Vigna* spp.),



corn (*Zea mays*), and winter wheat (*Triticum aestivum*). Although food plots occur within conservation zones, they are less abundant than in the multiple-use zones, and food plots within conservation zones are typically planted for white-tailed deer instead of quail. Grain, consisting of corn, grain sorghum, soybean (*Glycine max*) and sunflower (*Helianthus* spp.), is spread on 2-week intervals from November-May to supplement quail food. Supplemental feeding does not occur in conservation zones. Quail hunting only occurs in the multiple-use zone. Longleaf pine restoration is performed in the conservation zone. Conservation zones tend to emphasize restoration, while multiple-use zones are more heavily managed for quail. There are no physical boundaries separating the two zones, thus animals are free to move between the two zones.

Limited predator removal occurs annually within multiple use zones as part of quail management. Quail management focuses on regulating populations of opossum (*Didelphis virginiana*), armadillo (*Dasypus novemcinctus*), raccoon (*Procyon lotor*), and striped skunk (*Mephitis mephitis*), a few coyotes (*Canis latrans*), gray foxes (*Urocyon cinereoargenteus*), and red foxes (*Vulpes vulpes*) are harvested annually as well. Bobcats have not been harvested on site since 1999.

## **JUSTIFICATION**

The Endangered Species Conservation Act of 1969 prohibited the import of fur from endangered cats, which increased the demand for fur from the non-endangered bobcat and lynx (*Lynx lynx*). Due to the increased harvest of bobcats during the 1970s and 1980s, concern of over-exploitation developed. This concern resulted in the addition of bobcats to Appendix II of the Convention on International Trade in Endangered Species of Flora and Fauna (CITES) (Anderson 1987). As a consequence of this listing, each state was required to monitor bobcat populations to ensure that harvest of bobcats was not “detrimental to the survival of that species”

(Anderson 1987). Bobcat natural history is relatively unstudied within the longleaf pine/wiregrass ecosystem; thus, research is needed to identify factors that influence bobcat ecology within a longleaf pine/wiregrass ecosystem. This information will prove valuable to other researchers and will permit managers to make better-informed management decisions regarding bobcats.

### **OBJECTIVES**

To better understand the role of bobcats within the longleaf pine ecosystem and to understand how various land management practices might affect bobcats, I established the following objectives.

1. Determine if home range size and home range overlap varies by season and sex.
2. Determine if diet of bobcats varies seasonally.
3. Determine habitat use of bobcats and compare habitat use to habitat availability within each bobcat home range.
4. Compare bobcat habitat use between sexes and among season.

### **THESIS FORMAT**

This thesis was written in manuscript format in which chapters 2, 3 and 4 represent manuscripts to be submitted for publication. Chapter 1 is an overall description of bobcat ecology and an introduction to the thesis. Chapter 2 describes home range size and overlap between sexes and will be submitted to the Southeastern Naturalist. Chapter 3 describes habitat selection and will be submitted to the Journal of Wildlife Management. Chapter 4 pertains to bobcat diet and will be submitted to the Southeastern Naturalist. Chapter 5 is a summary of all findings and the conclusions of this study.

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CHAPTER 2

BOBCAT HOME RANGE SIZE AND HOME RANGE OVERLAP IN A LONGLEAF  
PINE/WIREGRASS ECOSYSTEM

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<sup>1</sup>Cochrane, J. C., L. M. Conner, and R. J. Warren. 2003. To be submitted to the Southeastern Naturalist.

**ABSTRACT:** Little is known about bobcat home ranges or home range overlap within longleaf pine (*Pinus palustris*) ecosystems. Therefore, we examined home range sizes as well as home range overlap of bobcats in southwestern Georgia. We monitored 32 radio-collared bobcats from 21 September 2001 until 21 June 2003 in southwestern Georgia. Average home range size for female bobcats was  $2.76 \text{ km}^2$  and  $5.95 \text{ km}^2$  for male bobcats. There was a significant sex  $\times$  season interaction ( $F_{6,105} = 4.32$ ,  $P=0.0006$ ). Both female ( $F_{6,71.8}=2.77$ ,  $P=0.0176$ ) and male ( $F_{6,31.3}=1.98$ ,  $P=0.0989$ ) home range sizes varied seasonally. Seasonal home ranges for males averaged  $5.95 \pm 0.804 \text{ km}^2$  with the smallest home range ( $2.51 \pm 2.01 \text{ km}^2$ ) occurring during fall 2001 and the largest home range ( $12.76 \pm 1.65 \text{ km}^2$ ) occurring during summer 2002. Female seasonal home ranges averaged  $2.76 \pm 0.564 \text{ km}^2$  with the smallest home range ( $1.46 \pm 1.17 \text{ km}^2$ ) occurring during spring 2002 and the largest home range ( $4.49 \pm 1.05 \text{ km}^2$ ) occurring during winter 2003. There was more home range overlap ( $F_{1,209}=14.54$ ,  $P=0.0002$ ) intersexually than intrasexually, with overlap between bobcats of different sexes being 2.74 times greater than for the same sex. Similarly, there was a difference ( $F_{1,207}=6.99$ ,  $P=0.0088$ ) between intersexual and intrasexual core area overlap. The average home range sizes for male and female bobcats in this study were smaller than the home range sizes reported by others in the southeastern United States. Further investigation into home range and core area overlap is needed to consider the effect of density on these variables.

## INTRODUCTION

Bobcats are one of the most widely distributed predators in the United States (Buie 1980). They are solitary mammals (Anderson 1987), with variable home range sizes in the Southeast, ranging from  $1.1 - 24.5 \text{ km}^2$  for females and  $2.6 - 64.2 \text{ km}^2$  for males (Miller and Speake 1978, Rucker et al. 1989). Male home ranges are typically 2-3 times larger than females

(Hall and Newsome 1976, Buie et al. 1979, and Whitaker et al. 1987). Bailey (1974) determined that female bobcats used their home ranges more intensely than male bobcats. Home ranges of female bobcats are thought to be regulated by diversity, abundance, stability, and distribution of prey populations, whereas male bobcat home ranges are regulated by opportunities for breeding, and the size of female home ranges (Anderson 1987 and Sandell 1989). Male bobcat home ranges typically overlap several female bobcat home ranges (Hall and Newsome 1976, Miller and Speake 1978, Buie et al. 1979, and Whitaker et al. 1987). Habitat quality is considered a major determinant of bobcat home range size, and habitat quality is strongly linked to prey availability (Fendley and Buie 1986). Therefore, prey abundance is generally considered the dominant factor influencing home range size (McNab 1963, Harestad and Bunnell 1979, Boutin 1990). However, experience may also play a role (Conner et al. 1999). Bobcat home range sizes are assumed to be inversely correlated to prey density (Smith 1968, Mares et al. 1976, Buie et al. 1979, and Knick 1990).

Bobcat home ranges fluctuate seasonally and these fluctuations may be linked to seasonal availability of prey. For example, two studies found that bobcats maintained smaller home ranges during the summer and winter season when prey was most abundant (Buie 1980, Rucker et al. 1989).

Typically, intersexual overlap in bobcats is higher than intrasexual overlap (Anderson 1987). Most studies suggest that female bobcat home ranges are exclusive of other female home ranges. However, male bobcats typically overlap females as well as other males (Bailey 1974, Hall and Newsome 1976, Miller and Speake 1978, Buie et al. 1979, Schwartz and Schwartz 1981, Lawhead 1984, Anderson 1987, Whitaker et al. 1987). However, a few studies have found intrasexual overlap occurs with female bobcats as well. In California, female bobcat home

ranges overlapped up to 36%, while male bobcat home ranges were exclusive of other male bobcats (Zezulak and Schwab 1979). In situations where there was extensive overlap between female bobcats, Zeulak and Schwab (1979) observed that the female bobcats used common areas at different times. Kitchings and Story (1984) noted that 2 adult females with kittens in Tennessee used the same territory. While it is an accepted fact that subadults are often tolerated in adult home ranges (Provost et al. 1973, McCord 1974, Miller and Speake 1979), a long-term study in Mississippi found that adult female and male bobcats maintained overlapping home ranges in all seasons (Chamberlain and Leopold 2001). There is nothing known about home range overlap for bobcats in southwestern Georgia. Therefore, the objective of our research was to determine if home range size and home range overlap for bobcats in southwestern Georgia varied by season, sex, or if an interaction occurred between season and sex.

## **STUDY AREA**

The study was conducted in Baker County, Georgia, on Ichauway Plantation. Ichauway was a former hunting plantation, but it currently serves as a research site for the Joseph W. Jones Ecological Research Center (JWJERC). Ichauway consists of 11,700 ha located approximately 16 km south of Newton, Georgia. Approximately half of the site was managed for quail hunting. The area consists of a conglomeration of habitats, but longleaf pine forests dominant the landscape. However, Ichauway also contains mixed hardwoods, slash pine flatwoods, natural loblolly pine stands, riparian hardwood hammocks, oak barrens, grassy limesink ponds, cypress-gum limesink ponds, creek swamps, agricultural fields, food plots, and riverine habitats. Prescribed fire is the most dominant habitat management tool employed on Ichauway.

Prescribed burning may take place at any time but is typically more prevalent during late winter and early spring.

In addition to prescribed fire, management includes planting food plots and supplemental feeding. Twenty percent of the property is made up of food plots that consisted of grain sorghum (*Sorghum vulgare*), Egyptian wheat (*Sorghum* spp.), brown top millet (*Brachiaria ramosa*), cowpea (*Vigna* spp), corn (*Zea mays*), and winter wheat (*Triticum aestivum*). The supplemental feed is a mixture of corn, grain sorghum, soybeans (*Glycine max*), and sunflower seeds (*Helianthus* spp.). It is spread in thickets, along field edges, and food plots during November-May.

## METHODS

### Bobcat capture and monitoring

We used #3 Victor Soft Catch Traps (Woodstream Corp., Litiz, PA) to trap bobcats. Trapping occurred from December 2000 until June 2003. However, trapping was sporadic after July 2001, focusing on individual animals. Captured animals were netted and restrained them with a wooden pole. Once animals were restrained, they were injected intramuscularly with ketamine hydrochloride (10mg/kg body weight) (Seal and Kreeger 1987). We recorded basic measurements (sex, body weight, total body length, tail length, hind-foot length, and ear length) and determined age (juvenile or adult) following Crowe (1975). To determine age we also examined pelage, teeth, teats, scrotum, etc. as suggested by Crowe (1975), but size was a dominant factor. A radio collar (Advanced Telemetry Systems, Isanti, MN) was attached to most adult cats weighing more than 5.5 kg. A unique number was tattooed in both ears of all captured bobcats. Captured bobcats were monitored for approximately 24 hours to ensure full

recovery from sedation and then released at their capture site. All trapping and handling procedures were approved by the University of Georgia Institutional Animal Care and Use Committee (IACUC #A990159).

Radio tracking began 7 days after release to ensure bobcats had recovered from the stress of capture. Locations were obtained by triangulation from known reference points using a 3-element Yagi antenna (Sirtrack, New Zealand) and hand-held radio telemetry receiver (Wildlife Materials, Carbondale, IL).

We located bobcats 6 times/week with = 8 hours between locations to ensure independence. To minimize effects of animal movement on telemetry accuracy, less than 15 minutes were allowed between bearings (Cochran 1980, Kenward 1987, and White and Garrott 1990). We ensured locations were obtained equally throughout the diel period.

### **Data Analysis**

We converted telemetry bearings to Universal Transverse Mercator (UTM) coordinates using the program EPOLY (L. M. Conner, Joseph W. Jones Ecological Research Center, unpublished data). We then used CALHOME (Kie et al. 1996) to generate 95% minimum convex polygon (MCP Mohr 1947) home range estimates and 50% MCP core area estimates for each season as well as composite home ranges for all bobcats that were tracked for a minimum of 6 months. We also generated 95% adaptive kernel estimates for comparison with other studies (Worton 1989). We used a repeated measure Analysis of Variance (ANOVA) using a PROC MIXED (SAS institute, Inc. 1992) to determine whether home ranges varied as a function of sex, season, and an interaction of sex and season. We used locations as the subject repeated over seasons. Covariance structure was estimated using autoregressive, order 1 modeling

approach (Littlell et al. 1996). We used calendar seasons (summer, fall, winter, and spring). Using PROC GLM we determined if composite home ranges varied as a function of sex.

Overlap of home ranges and core areas were generated by first intersecting all overlapping home ranges to determine the common area. From this we calculated percent area overlap of each home range (common area/home range area). We then calculated percent point overlap by extracting all the locations for a bobcat falling within a common area and dividing this number of locations by the total number of locations on that animal. We then calculated an index of overlap which was calculated as the product of the percent area overlap and the percent point overlaps for all overlapping bobcats. For example, assume bobcats A and B have overlapping home ranges. The index of overlap for bobcat A would be the percent area overlap A times percent point overlap A times percent point overlap B. Because the index of overlap ranged between 0 and 1, we used an arcsine square root transformation on index of overlap prior to analysis (Zar 1996). We then used ANOVA to determine if overlap varied by type (i.e., intrasexual or intersexual), season, and their interaction. This analysis was performed for both home ranges and core areas. We considered statistical significance at  $\alpha = 0.10$ .

## RESULTS

The number of bobcats tracked each season ranged from 13 (5 M, 8 F) to 23 (7 M, 16 F). Male bobcats ( $5.95 \pm 0.804 \text{ km}^2$ ) had an average composite home range that was approximately 2 times larger than females ( $2.76 \pm 0.564 \text{ km}^2$ ). There was no significant difference ( $F_{1,27}=2.27$ ,  $P=0.1436$ ) in composite home range sizes between the sexes. There was a significant ( $F_{6,105}=4.32$ ,  $P=0.0006$ ) sex  $\times$  season interaction. Therefore, we examined females throughout

the seasons and males throughout the seasons separately. Home range sizes of both females ( $F_{6,72}=2.77$ ,  $P=0.0176$ ) and males ( $F_{6,31}=1.98$ ,  $P=0.0989$ ) varied seasonally (Figure 2.1). Male home ranges were larger during summer 2002 ( $F_{1,19}=9.21$ ,  $P=0.0068$ ) and spring 2003 ( $F_{1,21}=31.86$ ,  $P=0.0001$ ) (Figure 2.1). Composite home ranges did not vary ( $F_{1,27}=2.27$ ,  $P=0.1436$ ) as a function of sex.

Sex and season did not interact to affect overlap of home ranges ( $F_{6,209}=0.85$ ,  $P=0.5339$ ) or core areas ( $F_{6,207}=1.50$ ,  $P=0.1791$ ). Likewise, home range ( $F_{6,209}=0.31$ ,  $P=0.9331$ ) and core area ( $F_{6,207}=1.24$ ,  $P=0.2852$ ) overlap did not vary seasonally. However, intersexual and intrasexual home range ( $F_{1,209}=18.51$ ,  $P<0.0001$ ) and core area ( $F_{1,207}=11.39$ ,  $P=0.0009$ ) overlap differed. Intersexual home range overlap was 2.5 times greater than intrasexual home range overlap, and intersexual core area overlap was 2.77 times greater than intrasexual core area overlap.

## DISCUSSION

Like most studies (Hall and Newsome 1976, Buie et al. 1979, Whitaker et al. 1987), we found that male bobcat home range sizes were larger than female bobcat home range sizes. However, the average home range size for male bobcats and female bobcats in our study were smaller than the home range sizes reported by others in the southeastern United States (Hall and Newsom 1976, Miller and Speake 1979, Kitchings and Story 1979, Buie et al. 1979, Hamilton 1982, Shiftlet 1984, Fendley and Buie 1986, Lancia et al. 1986, Rucker et al. 1989, Conner et al. 1992, Griffin 2001) (Table 2.1). The small home range sizes we observed probably were due to the quality of the habitat within the study area. Habitat quality for bobcats is determined based on the ability of the habitat to produce abundant prey (Fendley and Buie 1986, Boyle and



Fendley 1987). Land management practices such as prescribed fire and creation of food plots can promote a herbaceous understory while creating edge, ultimately supporting dense prey populations (Golley et al. 1965, Landers and Mueller 1986). This increase in prey may concentrate bobcat use in an area, thus decreasing the home range. Common management practices in the longleaf pine forest may be impacting the home range size of bobcats.

In our study, home range size differed among seasons between sexes. However, there was only a significant difference in home range size between sexes during summer 2002 and spring 2003. Bobcat home range sizes fluctuate seasonally. This fluctuation can be attributed to change in prey availability (Buie 1980, Rucker et al. 1989). Change in home range size could also be associated with reproduction, such as mating opportunities or kitten rearing. During summer 2002, there were 2 male bobcats with extremely large home ranges (Cat #16=24.25km<sup>2</sup> and Cat #30=38.28km<sup>2</sup>). These 2 home ranges probably contributed to the difference within male bobcats and female bobcats during summer 2002. Cat #30 moved from one area of the property to the other end of the property during this season, while Cat #16 apparently expanded his home range to encompass home ranges of 2 female bobcats.

The difference in home range sizes between male bobcats and female bobcats during spring 2003 could possibly be explained by a general decrease in female bobcat home range size and male bobcat home range sizes remaining relatively constant. A possible contributing factor to the change in home range sizes between female and male bobcats could be the fact that 3 females (Cat #6, Cat #23, and Cat #40) substantially decreased their home range size during spring 2003 from the previous season. Cat #6 had a home range of 7.66 km<sup>2</sup> during winter 2003, which was 4.1 times larger than her home range of 1.86 km<sup>2</sup> during spring 2003. Likewise, Cat #23's home range during winter 2003 was (4.41km<sup>2</sup>) 2.35 times larger than during spring 2003

(1.88km<sup>2</sup>). Cat #40's home range during winter 2003 (18.15km<sup>2</sup>) was 3.24 times larger than during spring 2003 (5.60km<sup>2</sup>). Also, the decrease in female bobcat home ranges could be an indication of denning. During this season, 3 dens with kittens were successfully located. It is possible that other bobcats were denning as well.

Similar to other studies of home range overlap among bobcats, we found that there was more intersexual than intrasexual overlap (Anderson 1987). This was, because males and females both seek mating opportunities. Further, morphological differences between sexes is thought to result in sex-specific prey use (Fritts and Sealander 1978), perhaps reducing competition and permitting overlap to occur.

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Figure 2.1. Bobcat seasonal home range sizes (Fall 2001, Winter 2002, Spring 2002, Summer 2002, Fall 2002, Winter 2003, and Spring 2003) on Ichauway, Georgia, 2001-2003



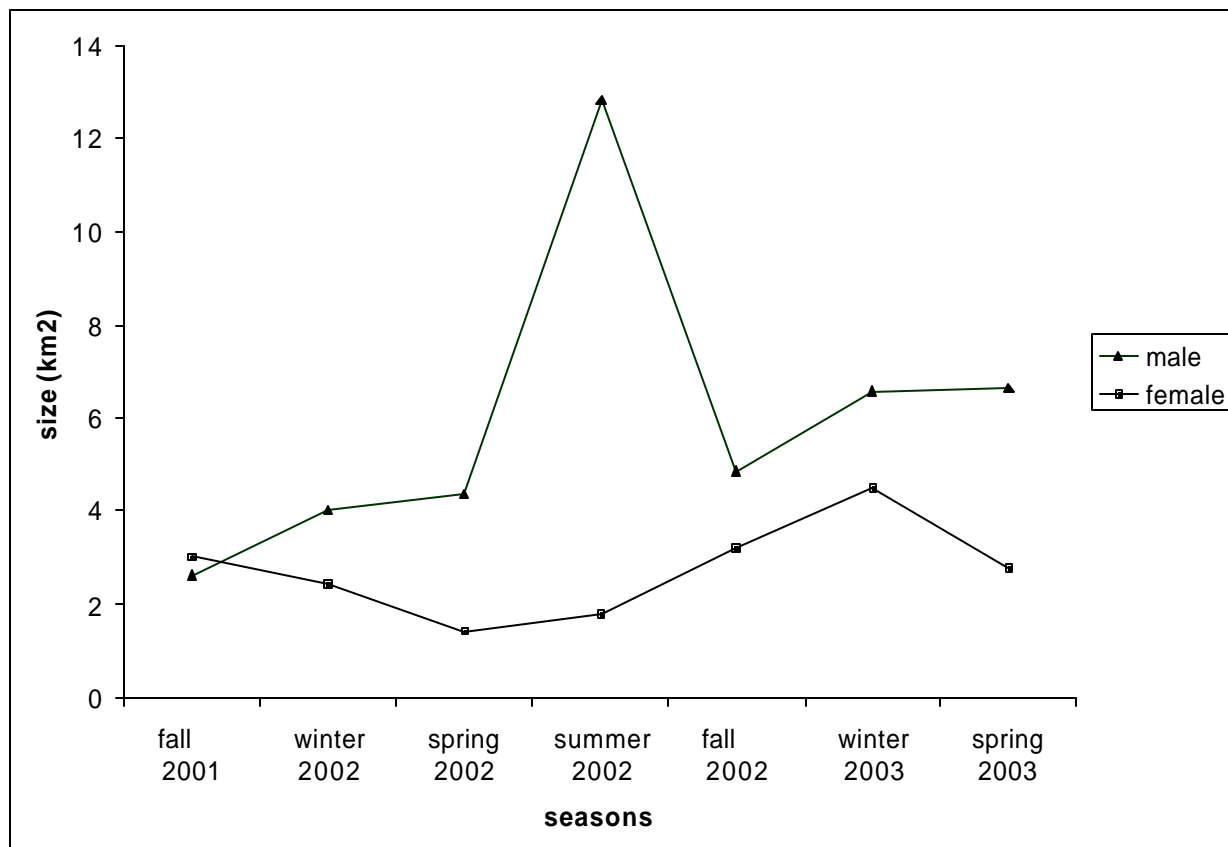


Table 2.1 Summary of 12 studies in the Southeastern U. S. that examined bobcat home range sizes (km<sup>2</sup>).

Reference	State	Sample Size	Home range		Home range model
			M	F	
Hall and Newsom 1976	LA	6	4.9	1.0	MMA <sup>a</sup>
Kitchings and Story 1979	TN	5	42.9	11.5	MCP <sup>b</sup>
Miller and Speake 1979	AL	20	2.6	1.1	MCP
Buie et al. 1979	SC	6	20.8	10.3	MCP
Hamilton 1982	MO	30	60.4	16.1	MCP
Shiftlet 1984	MS	7	10.1	5.9	MCP
Fendley and Buie 1986	SC	7	3.2	1.6	MCP
Lancia et al. 1986	NC	8	37.7	22.1	MCP
Rucker et al. 1989	AR	6	64.2	24.5	MCP
Conner et al. 1992	MS	15	36.5	20.6	MCP
Griffin 2001	SC	8	10.5-16.7	3.5-10.5	ADK <sup>c</sup>
This Study	GA	23	5.95	2.76	MCP

<sup>a</sup> Modified Minimum Area

<sup>b</sup> Minimum Convex Polygon

<sup>c</sup> Adaptive Kernal

CHAPTER 3

HABITAT SELECTION OF BOBCATS IN SOUTHWESTERN GEORGIA

IN A LONGLEAF PINE FOREST

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<sup>1</sup>Cochrane, J. C., L. M. Conner, and R. J. Warren. 2003. To be submitted to the Journal of Wildlife Management.

**Abstract:** An understanding of habitat preferences is vital to managing any species, and little is known regarding habitat selection of bobcats (*Lynx rufus*) in longleaf pine (*Pinus palustris*) forests. Therefore, we initiated a study of bobcat habitat use in a longleaf pine forest in southwestern Georgia. We monitored 32 radio-collared bobcats from 21 September 2001 until 21 June 2003. We analyzed habitat selection at 2 spatial scales: habitat selection of the home range relative to the study area (Johnson's second order habitat selection) and habitat selection within an individual's home range (Johnson's third order habitat selection). There was no sex  $\times$  season interaction ( $F_{6,91}=1.26$ ,  $P=0.2855$ ) for second order habitat selection. Second order habitat selection did not differ between sexes ( $F_{1,30}=2.16$ ,  $P=0.1518$ ) or among seasons ( $F_{6,91}=1.38$ ,  $P=0.2295$ ). However, our analysis of the third order habitat selection revealed a sex  $\times$  season interaction ( $F_{6,91}=2.91$ ,  $P=0.0122$ ). Therefore, we analyzed seasonal habitat selection for each sex. Seasonal habitat selection differed for female bobcats ( $F_{6,64}=2.68$ ,  $P=0.0220$ ) but not for male bobcats ( $F_{6,27}=1.54$ ,  $P=0.2030$ ). Second order habitat selection was much more pronounced than third order habitat selection. At the second order habitat selection level, all habitat types were preferred more than expected, indicating a preference for habitat edge. Agriculture was significantly preferred over all other habitat types followed by: hardwood, mixed pine-hardwood, pine regeneration, wetland, urban/barren, shrub/scrub, and pine. Urban/barren and shrub/scrub were significantly preferred more than expected at the third order habitat selection level for male bobcats followed by wetland, pine, hardwood, and agriculture, whereas pine regeneration and mixed pine-hardwoods were significantly avoided. During fall 2001 and spring 2002 female bobcats preferred the urban/barren habitat type. Pine regeneration was avoided during fall 2002 and spring 2003 at the third order of habitat selection. No habitat types were preferred or avoided during the other 3 seasons. At the third order of habitat

selection, female bobcats preferred the urban/barren habitat over all habitat types followed by pine, hardwood, wetland, mixed pine-hardwood, shrub/scrub, pine regeneration and agriculture.

**Key words:** bobcat, Georgia, habitat selection, Johnson's second order selection, Johnson's third order selection, longleaf pine, *Lynx rufus*

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## INTRODUCTION

Prey abundance and distribution are the main factors that determine habitat use by bobcats (Pollack 1951, Bailey 1974, Litvaitis 1984, Anderson 1987), and habitat quality is often defined by the ability of habitat to produce prey (Fendley and Buie 1986, Boyle and Fendley 1987). Habitats with high levels of stem density (Litvaitis et al 1986), vertical vegetation cover (Knowles 1985), dense growth of briars, vines, and grasses (Rolley and Warde 1985), and ground cover (Leopold et al 1995) are typically linked to areas of abundant prey and excellent bobcat habitat (Kolowski and Woolf 2002). Bobcats prefer the following habitat types in the Southeast: early successional habitat (Kitchings and Story 1978), bottomland hardwoods in mid-successional stages (Hall and Newsome 1976), mature bottomland hardwoods, old fields, 1-4-year-old pine plantations (Heller and Fendley 1982) and agricultural areas (Lancia 1982, Conner et al. 1992).

Protection from severe weather, access to resting and denning sites, cover for hunting and escape, and freedom from disturbances are other factors that influence habitat use by bobcats (Pollack 1951, Bailey 1974, and Anderson 1987). In the relatively moderate climate of the Southeast, thickets, hollow stumps, and logging debris provide cover for resting and denning (Miller 1980, Kitchings and Story 1984, Boyle and Fendley 1987) and bottomland hardwoods are used for loafing and travel (Hall and Newsome 1976, Buie 1980, Boyle and Fendley 1987).

Because there is a lack of information on habitat selection by bobcats within a longleaf pine forest, the objective of this study was to determine habitat selection by bobcats at 2 spatial scales: Johnson's second order habitat selection and Johnson's third order habitat selection. We predicted that bobcats would select habitat types that was early successional or where there was a lot of edge.

## STUDY AREA

The study was conducted in Baker County, Georgia, on Ichauway. Ichauway was a formerly a hunting plantation, but currently serves as a research site for the Joseph W. Jones Ecological Research Center (JWJERC). Ichauway consists of 11,700 ha located approximately 16 km south of Newton, Georgia. Approximately half of the site is managed for quail hunting. The area consists of a conglomeration of habitats, but longleaf pine forests dominant the landscape. Ichauway also contains mixed hardwoods, slash pine flatwoods, natural loblolly pine stands, riparian hardwood hammocks, oak barrens, grassy limesink ponds, cypress-gum limesink ponds, creek swamps, agricultural fields, food plots, and riverine habitats. Prescribed fire is the most dominant habitat management tool employed on Ichauway. Prescribed burning may take place at any time but is typically more prevalent during late winter and early spring.

In addition to prescribed fire, management activities include planting food plots and supplemental feeding. Twenty percent of the property was made up of food plots that consisted of grain sorghum (*Sorghum vulgare*), Egyptian wheat (*Sorghum* spp.), brown top millet (*Brachiaria ramose*), cowpea (*Vigna* spp), corn (*Zea mays*), and winter wheat (*Triticum aestivum*). The supplemental food was a mixture of corn, grain sorghum, soybeans (*Glycine max*), and sunflower seeds (*Helianthus* spp.), which was spread in thickets, along field edges, and food plots during November-May.

## **METHODS**

### **Bobcat capture and monitoring**

We used #3 Victor Soft Catch Traps (Woodstream Corp., Litiz, PA) to trap bobcats. Trapping occurred from December 2000 until June 2003. However, trapping was sporadic after July 2001, focusing on individual animals. Once a bobcat was trapped, we netted and restrained it with a wooden pole. Once restrained, bobcats were injected intramuscularly with Ketamine hydrochloride (10mg/kg body weight) (Seal and Kreeger 1987). We recorded basic measurements (sex, body weight, total body length, tail length, hind-foot length, and ear length) and determined age (juvenile or adult) following Crowe (1975). A radio collar (Advanced Telemetry Systems, Isanti, MN) was attached to all adult females and select larger adult males. A unique number was tattooed in both ears of all bobcats that were captured. Captured bobcats were monitored for about 24 hours to ensure full recovery from the sedative and then released at their capture site. Trapping and handling procedures were approved by the University of Georgia Institutional Animal Care and Use Committee (IACUC #A990159).

Radio tracking began 7 days after release to ensure bobcats had recovered from the capture stress. Locations were obtained by triangulation from known reference points using a 3-element Yagi antenna (Sirtrack, New Zealand) and hand-held radio-telemetry receiver (Wildlife Materials, Carbondale, IL). We located bobcats 6 times/week with = 8 hours between locations to ensure independence. To minimize effects of animal movement on telemetry accuracy, less than 15 minutes were allowed between bearings (Cochran 1980, Kenward 1987, and White and Garrott 1990). We ensured locations were obtained equally throughout the diel period.

## Data analysis

We converted telemetry bearings to Universal Transverse Mercator (UTM) coordinates using the program EPOLY (L. M. Conner, Joseph W. Jones Ecological Research Center, unpublished data). We then used CALHOME (Kie et al. 1996) to generate 95% minimum convex polygon (MCP Mohr 1947) and 95% adaptive kernel home range estimates (Worton 1989). We also calculated a composite 95% MCP for all bobcats that were tracked for = 6 months. We partitioned the tracking periods into calendar seasons.

Eight habitat types (agriculture/food plots, shrub/scrub, hardwoods, pine, pine regeneration, wetlands, mixed pine-hardwoods, and urban/barren) were delineated and digitized into a Geographical Information System (GIS) from aerial photo-interpretation ARC/INFO (ESRI 1997). Animal locations and home ranges were intersected onto the habitat map using ARC/INFO (ESRI 1997). Habitat selection was determined using a Euclidean distance technique that compared the average distance between animal locations and habitat types to expected distances as determined from a null model (Conner and Plowman 2001, Conner et al. 2003). We determined if sex, season, or sex  $\times$  season interaction influenced habitat selection. All habitat analyzes were conducted at 2 spatial scales, Johnson's second (selection of home range) and third (selection within home range) orders (Johnson 1980).

To test for second order habitat selection, random locations were generated throughout the study area. The ARC/INFO (ESRI 1997) NEAR command was used to calculate the average distance from random locations to each habitat type. Eight distance ratios (average distances from random locations within home range divided by the average distances from the random locations throughout the study area) were created for each bobcat.



To determine if habitat selection occurred within the home range (Johnson's third order); we calculated the average distances between bobcat locations within the home range and each habitat type. We then calculated the average distance between random locations within the home range to each habitat type. As above, we calculated 8 distance ratios for each bobcat.

A multivariate analysis of variance (MANOVA) was used to determine if sex  $\times$  season interaction, sex, or season had an effect on habitat selection, and to determine if habitats were used disproportionately. For this analysis, animals were treated as experimental units and seasons were treated as a repeated measure. If habitat use was random (i.e. no selection), we expected the ratio of used distances to random distances to equal 1.0 (Conner and Plowman 2001, Conner et al. 2003). If the ratios differed from 1, we used univariate *t*-tests to determine which habitats were used disproportionately. If the distance ratio was  $<1.0$  (i.e., use distance  $<$  random distance), the bobcat preferred that habitat type; if the distance ratio was  $>1.0$  (i.e., use distance  $>$  random distance), the bobcat avoided that habitat type (Conner and Plowman 2001, Conner et al. 2003). Habitat types were then ranked by forming a ranking matrix using univariate *t*-tests (Conner and Plowman 2001, Conner et al. 2003). This same approach was used to assess habitat selections at Johnson's third order (Johnson 1980). We considered statistical significance at  $\alpha = 0.10$ .

## RESULTS

The number of bobcats tracked each season ranged from 13 (5M, 8F) to 23 (7M, 16F). Sex ( $F_{1,30}=2.16$ ,  $P=0.1518$ ) and season ( $F_{6,91}=1.38$ ,  $P=0.2295$ ) had no significant effect on Johnson's second order habitat selection and there was no sex  $\times$  season interaction ( $F_{6,91}=1.26$ ,  $P=0.2855$ ). Bobcats were found in closer proximity to all habitats greater than expected (Table

3.1) indicating a preference for habitat edges. Agriculture was the most preferred habitat type, followed by hardwood, mixed pine-hardwood, pine regeneration, wetland, urban/barren, shrub/scrub, and pine (Table 3.2).

The sex  $\times$  season interaction ( $F_{6,91}=2.91$ ,  $P=0.0122$ ) was significant with respect to the Johnson's third order habitat selection. Therefore, we examined sex and season separately at this level of selection.

Seasonal habitat selection did not vary ( $F_{6,27}=1.54$ ,  $P=0.2030$ ) for male bobcats. Male bobcats were found closer than expected to shrub/scrub and urban/barren and farther than expected from pine regeneration and mixed pine-hardwood. Urban/barren was the most preferred habitat when compared to all habitat types within the home range and mixed pine-hardwood was the least preferred (Table 3.3).

Seasonal habitat selection varied ( $F_{6,64}=2.68$ ,  $P=0.0220$ ) for female bobcats. During winter 2002, summer 2002, and winter 2003, female bobcats used habitat as expected. Urban/barren was preferred during fall 2001 and spring 2002. Pine regeneration was avoided in fall 2002 and spring 2003. According to the habitat ranking matrix habitats were equally preferred during winter 2002, winter 2003, and spring 2003. In fall 2001, hardwood was the most preferred habitat, but it was only significantly preferred over agriculture, shrub/scrub, and wetland. Urban/barren was the most preferred habitat type during spring 2002 and summer 2002 and it was significantly preferred over pine regeneration, shrub/scrub, wetland, and agriculture. During summer 2002, urban/barren was significantly preferred over pine regeneration, agriculture, and mixed pine-hardwood. Wetland was significantly preferred over pine regeneration and mixed pine-hardwood during fall 2002 (Table 3.4).

## DISCUSSION

On our study site bobcats selected habitats to establish their home range (Johnson's second order) as opposed to selecting habitat types within their home range (Johnson's third order). Bobcats were found closer to all 8 habitat types (agriculture, shrub/scrub, hardwood, pine regeneration, pine, mixed pine-hardwood, wetland and urban/barren) than expected at Johnson's second order of selection. Because bobcats were found closer to all habitats more than expected, we conclude that availability of edge is important to bobcats when establishing a home range (Conner et al. 2000). Edge offers a variety of food and cover for prey, often harboring dense prey populations and attracting bobcats. Edge also provides bobcats with easy travel corridors and hunting areas (Landers and Mueller 1986) .

Agriculture, hardwood, and mixed pine-hardwood habitats were preferred at Johnson's second order habitat selection. These findings are similar to other studies that found bobcats used early successional habitats (Kitchings and Story 1978), bottomland hardwoods in mid-successional stages (Hall and Newsome 1976), mature bottomland hardwoods, old fields, 1-4-year-old pine plantations (Heller and Fendley 1982) and agricultural areas (Lancia 1982, Conner et al. 1992, Godbois et al. 2003). Prey abundance may best explain our observed bobcat habitat preference. Prey species are typically attracted to agricultural areas (Cummings and Vessey 1994). Hardwood and mixed pine-hardwood habitats have a dense herbaceous understory that can support dense prey populations (Golley et al 1965) as well as provide bobcats with cover and denning sites. Habitat types like agriculture, hardwood, and mixed pine-hardwood typically have dense prey populations and may represent excellent habitat for bobcats (Kolowski and Woolf 2002).

Habitat selection of male and female bobcats differed seasonally. Male bobcats did not select habitat within their home range (Johnson's third order). Within their home range, male bobcats preferred shrub/scrub and urban/barren, while avoiding pine regeneration and mixed pine-hardwood. It appeared as though males selected habitat within their home range randomly.

Habitat selection by females varied seasonally. Female bobcats selected habitat within their home range during 4 of 7 seasons. In fall 2001 and spring 2002, they preferred urban/barren habitat type more than expected. Female bobcats may have more pronounced habitat selection than males, because females require more prey from within smaller home ranges than male bobcats, especially during nutritionally demanding periods like kitten rearing (Bailey 1981 and Anderson 1987). Also, the availability of den sites may influence habitat selection by female bobcats (Bailey 1974). Finally, differences in habitat selection between sexes may be due to niche segregation (Rolley and Warde 1985).

Reduced habitat selection within the home range may have occurred because bobcats selected habitats within the study area. Thus, habitat quality within their home range was excellent, resulting in less selection of habitat within the home range.

## **MANAGEMENT IMPLICATIONS**

We suggest that bobcats prefer habitats that produce abundant prey. Management practices should seek to provide dense herbaceous layers in order to increase prey availability. In the longleaf pine forest, prescribed fire can be an instrumental tool in maintaining a dense herbaceous understory. Managing for diverse forest types will improve the habitat quality for bobcats. Having a diversity of forest types should provide bobcats with more areas for loafing and denning. Also, maintaining a mosaic of habitats will increase the amount of edge available, increasing the availability of a valuable habitat component for bobcats.

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Table 3.1. Habitat type distance ratios for second-order selection using composite home ranges for bobcats at Ichauway, Georgia, 2001–2003.

Habitat type	Mean <sup>a</sup>	<i>P</i> <sup>b</sup>
Agriculture	0.6499496	<0.0001
Hardwood	0.8267012	<0.0001
Mixed pine-hardwood	0.8770186	<0.0001
Pine regeneration	0.8986757	0.0555
Wetland	0.9207745	0.0274
Urban/Barren	0.9514403	0.0826
Shrub/Scrub	0.971655	0.5207
Pine	0.9958425	0.9214

<sup>a</sup> Average distance from random locations within home ranges divided by average distance from random locations throughout study area. Mean ratios <1 indicate habitat preference; >1 habitat avoidance

<sup>b</sup> Probability mean ratio = 1.0

Table 3.2. A ranking matrix based on pair-wise comparisons between habitat type distance ratios for second-order habitat selection (average distances from random locations to each habitat type within home range divided by the average random locations within the study area) using home ranges of all bobcats monitored on Ichauway, Georgia, 2001-2003. A plus sign indicates that the row habitat type was closer to preference.

	Agriculture	Hardwood	Mix <sup>b</sup>	Pine Regen <sup>a</sup>	Wetland	Urban/Barren	Shrub/Scrub	Pine
Agriculture		+++ <sup>c</sup>	+++	+++	+++	+++	+++	+++
Hardwood	--- <sup>c</sup>		+	+	+++	+++	+++	+++
Mix	---	-		+	+	+++	+++	+++
Pine Regen	---	-	-		+	+	+	+
Wetland	---	---	-	-		+	+	+
Urban/Barren	---	---	---	-	-		+	+
Shrub/Scrub	---	---	---	-	-	-		+
Pine	---	---	---	-	-	-	-	

<sup>a</sup> Pine Regeneration

<sup>b</sup> Mixed hardwood-pine

<sup>c</sup> Three plus signs indicate row habitat significantly preferred over column and 3 minus signs indicate that the column habitat significantly preferred over row ( $t$  test,  $P > 0.10$ ).

Table 3.3. A ranking matrix based on pair-wise comparisons between habitat type distance ratios for third-order habitat selection (average distances from random locations to each habitat type within home range divided by the average distance from animal locations to each habitat type) using home ranges of male bobcats monitored on Ichauway, Georgia, 2001-2003. A plus sign indicates that the row habitat type was closer to preference.

	Urban/Barren	Shrub/Scrub	Wetland	Pine	Hardwood	Agriculture	Pine Regen <sup>a</sup>	Mix <sup>b</sup>
Urban/Barren		+	+	+	+	+++ <sup>c</sup>	+++	+++
Shrub/Scrub	-		+	+	+	+++	+++	+++
Wetland	-	-		+	+	+	+++	+++
Pine	-	-	-		+	+	+++	+++
Hardwood	-	-	-	-		+	+++	+++
Agriculture	---	--- <sup>c</sup>	-	-	-		+	+
Pine Regen	---	---	---	---	---	-		+
Mix	---	---	---	---	---	-	-	

<sup>a</sup> Pine Regeneration

<sup>b</sup> Mixed hardwood-pine

<sup>c</sup> Three plus signs indicate row habitat significantly preferred over column habitat types and 3 minus signs indicate that the column habitat was significantly preferred over the row ( $t$  test,  $P > 0.10$ ).

Table 3.4. A ranking matrix based on pair-wise comparisons between habitat type distance ratios for third order, seasonal habitat selection (average distances from random locations to each habitat type within home range divided by the average distances from animal locations to each habitat type ) for female bobcats at Ichauway, Georgia, 2001-2003. (1=most preferred, 8=least preferred) Within each row, habitat types with the same superscript do not differ ( $t$  test,  $P>0.10$ ) in relative preference.

Season	Habitat Ranking							
	1	2	3	4	5	6	7	8
Fall 2001 (1)	Hardwood <sup>a</sup>	Mix <sup>a</sup>	Urban/Barren <sup>a</sup>	Pine Regen <sup>a</sup>	Pine <sup>a,b</sup>	Agriculture <sup>b</sup>	Shrub/Scrub <sup>b</sup>	Wetland <sup>b</sup>
Winter 2002 (2)	Urban/Barren <sup>a</sup>	Hardwood <sup>a</sup>	Mix <sup>a</sup>	Pine Regen <sup>a</sup>	Shrub/Scrub <sup>a</sup>	Wetland <sup>a</sup>	Agriculture <sup>a</sup>	Pine <sup>a</sup>
Spring 2002 (3)	Urban/Barren <sup>a</sup>	Mix <sup>a,b</sup>	Pine <sup>a,b</sup>	Hardwood <sup>a,b</sup>	Pine Regen <sup>b</sup>	Shrub/Scrub <sup>b</sup>	Wetland <sup>b</sup>	Agriculture <sup>b</sup>
Summer 2002 (4)	Urban/Barren <sup>a</sup>	Pine <sup>a,b</sup>	Wetland <sup>a,b</sup>	Hardwood <sup>a,b</sup>	Shrub/Scrub <sup>a,b</sup>	Pine Regen <sup>b</sup>	Agriculture <sup>b</sup>	Mix <sup>b</sup>
Fall 2002 (5)	Wetland <sup>a</sup>	Hardwood <sup>a,b</sup>	Agriculture <sup>a,b</sup>	Shrub/Scrub <sup>a,b</sup>	Urban/Barren <sup>a,b</sup>	Pine <sup>a,b</sup>	Pine Regen <sup>a,b</sup>	Mix <sup>b</sup>
Winter 2003 (6)	Mix <sup>a</sup>	Wetland <sup>a</sup>	Shrub/Scrub <sup>a</sup>	Urban/Barren <sup>a</sup>	Agriculture <sup>a</sup>	Pine Regen <sup>a</sup>	Pine <sup>a</sup>	Hardwood <sup>a</sup>
Spring 2003 (7)	Pine <sup>a</sup>	Urban/Barren <sup>a</sup>	Mix <sup>a</sup>	Wetland <sup>a</sup>	Shrub/Scrub <sup>a</sup>	Hardwood <sup>a</sup>	Pine Regen <sup>a</sup>	Agriculture <sup>a</sup>

CHAPTER 4

SEASONAL DIET OF BOBCATS IN SOUTHWESTERN GEORGIA

IN A LONGLEAF PINE FOREST

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<sup>1</sup>Cochrane, J. C., L. M. Conner, and R. J. Warren. 2003. To be submitted to the Southeastern Naturalist.

**ABSTRACT:** It is important to quantify bobcat diets on lands managed for Northern bobwhite (*Colinus virginianus*), because some wildlife managers think bobcats may be detrimental to Northern bobwhite populations. Therefore, we quantified the seasonal diet of bobcats (*Lynx rufus*) in a longleaf pine (*Pinus palustris*)/ wiregrass (*Aristida beyrichiana*) ecosystem managed for Northern bobwhite. We collected 265 scats in between 21 June 2001 and 21 June 2003. We sorted prey items to species, but used 5 prey categories (rodent, bird, deer, rabbit, and other) for analysis. Diet was dependent on year ( $\chi^2_4=18.0343$ ,  $P=0.0012$ ), therefore we looked at seasonal variation for the 2 years separately. There was seasonal variation in year 1 ( $\chi^2_{12}=19.9340$ ,  $P=0.0683$ ) and year 2 ( $\chi^2_{12}=23.8139$ ,  $P=0.0216$ ). Over the 2 years combined rodents were the most common (84.5%) item found in scats, followed by other (18.1%), rabbit (*Sylvilagus* spp. 14%), bird (13.6%), and deer (*Odocoileus virginianus* 7.5%). Only 5 (1.89%) of the 265 scats sorted contained Northern bobwhite. Because rodents are predators of Northern bobwhite nests and considering that Northern bobwhite management practices can improve habitat for rodents and other small mammals, the effect of bobcats on rodent populations and nest success of Northern bobwhite warrants further investigation.

## INTRODUCTION

It is important to understand the impact that bobcats are having on Northern bobwhite in a longleaf pine forest. In the South, bobcats primarily consume mammals, especially rabbits (*Sylvilagus* spp.) and cotton rats (*Sigmodon hispidus*) (Beasom and Moore 1977, Miller and Speake 1978, Boyle and Fendley 1987). Bobcats may exhibit a functional response to prey by altering their diets based on the relative density of prey in an area (Latham 1951, Baker et al. 2001). For example, deer consumption by bobcats increased during late fall and early winter when there is the possibility of consuming hunter-killed deer, and in late spring to early summer

when fawns were available (Buttrey 1979). Similarly when rodent populations are high, birds compose a small proportion of bobcats' diet (Beasom and Moore 1977).

Bobcats may also specialize in different sizes of prey based on bobcats' body size, which would help reduce intraspecific competition (Rosenzweig 1966). In Arkansas, female bobcats consumed more rats and mice than males (Fritts and Sealander 1978). In New Hampshire, male bobcats consumed more deer (*Odocoileus virginianus*) and fewer cottontails than females (Livaitis et al. 1984).

Despite the abundance of Northern bobwhite present on an Alabama plantation, Northern bobwhites were not important in the bobcat's diet (Miller and Speake 1978). Most wildlife managers and landowners believe that bobcats are a major predator of Northern bobwhites. The objective of this study was to quantify seasonal diet of bobcats relative to Northern bobwhite management in a longleaf pine forest.

We predicted that bobcat diets would vary seasonally, reflecting seasonal availability of prey. For example, during the late fall and early winter we predicted that white-tailed deer consumption would increase because of the availability of hunter-wounded deer. Also, we predicted that rodents would be a primary prey species of bobcats, because of their abundance.

## **STUDY AREA**

The study was conducted in Baker County, Georgia, on Ichauway Plantation. Ichauway was formerly a hunting plantation, but it currently serves as a research site for the Joseph W. Jones Ecological Research Center (JWJERC). Ichauway consists of 11,700 ha located approximately 16 km south of Newton, Georgia. Approximately half of the site is managed for quail hunting. The area consists of a conglomeration of habitats, but longleaf pine forests

dominant the landscape. However, Ichauway also contains mixed hardwoods, slash pine flatwoods, natural loblolly pine stands, riparian hardwood hammocks, oak barrens, grassy limesink ponds, cypress-gum limesink ponds, creek swamps, agricultural fields, food plots, and riverine habitats.

Prescribed fire is the most dominant habitat management tool employed on Ichauway. Prescribed burning may take place at any time but is typically more prevalent during late winter and early spring. In addition to prescribed fire, management includes planting food plots and supplemental feeding. During this study, 20% of the property was made up of food plots that consisted of grain sorghum (*Sorghum vulgare*), Egyptian wheat (*Sorghum* spp.), brown top millet (*Brachiaria ramosa*), cowpea (*Vigna* spp), corn (*Zea mays*), and winter wheat (*Triticum aestivum*). The supplemental food is a mixture of corn, grain sorghum, soybeans (*Glycine max*), and sunflower seeds (*Helianthus* spp.). It is spread in thickets, along field edges, and food plots during November-May.

Potential bobcat prey is diverse. There are 2 species of rabbits (Eastern cottontail [*Sylvilagus floridanus*] and marsh rabbit [*S. palustris*] at Ichauway and 4 species of squirrels (Eastern chipmunk [*Tamias striatus*], Southern flying squirrel [*Glaucomys volans*], Eastern gray squirrel [*Sciurus carolinensis*], and fox squirrel [*S. niger*]). Small mammals at Ichauway include mice such as harvest mice (*Reithrodontomys humulis*) and cotton mice (*Peromyscus gossypinus*), cotton rats (*Sigmodon hispidus*), Eastern wood rats (*Neotoma floridana*), and insectivorous mammals such as Southern short-tailed shrew (*Blarina carolinensis*) and least shrew (*Cryptotis parva*).



## METHODS

Scat was collected on 30, 1-km long sections of roads on Ichauway. These were both secondary roads (those that are frequently traveled, dirt roads) and tertiary roads (those that are less frequently traveled and typically are covered in grass). These sections of road were checked monthly (June 2001- June 2003). Scat also was collected opportunistically over the entire property. Scat was placed in a brown paper bag that was labeled with the date and location of collection. The scat was then placed in a freezer until processed. We attempted to collect = 30 scats season.

Scat was allowed to thaw for 24 hours (Griffin 2001) and then it was oven dried at 60 ° C for 72 hours (Baker et al. 1993) before processing. Processing consisted of weighing the scat and separating it into 5 major prey categories—rodent, bird, rabbit, deer, and other. When possible, prey items were identified to species using hair characteristics (Stains 1958), bone, teeth, and feathers.

Seasons based on calendar seasons (summer, fall, winter, and spring) for both years. Percent of occurrence (i.e., the frequency of occurrence of a prey divided by the total number of scats examined within season and year) was calculated for each prey category. A chi-square test of independence (Dowdy and Wearden 1991) in SAS (SAS institute, Inc. 1992) was used to determine if diet was dependent on year and if diet varied seasonally within the individual years. We considered statistical significance at  $\alpha = 0.10$ .

## RESULTS

We collected 265 scats between 21 June 2001 and 20 June 2003 (n=135 year 1, n=130 year 2). Bobcat diet varied between years ( $\chi^2_4=18.0343$ ,  $P=0.0012$ ). There was an increase in the amount of rabbit (21.5%) and other (24.6%) found in scat and a decrease in rodent (77.7%) found in scat in year 2 (Figure 4.1). Most of the rodent remains in first year (70%) and second year (69.2%) were identified as cotton rats. Cotton rat remains were found in 68.3% of all scat sorted. Northern bobwhite only comprised 1.9% of all scat examined. Northern bobwhite comprised 1.5% of remains in year 1 and 2.3% in year 2. Diet varied among seasons in year 1 ( $\chi^2_{12}=19.9340$ ,  $P=0.0683$ ; Figure 4.2) and year 2 ( $\chi^2_{12}=23.8139$ ,  $P=0.0216$ ; Figure 4.3). Species that made up the other category were snake, raccoon, opossum, armadillo (*Dasypus novemcinctus*), skunk (*Mephitis mephitis*), bobcat, and vegetation. Vegetation was the most common item found in the other category for both years (year 1=40%, year 2=32.3%).

## DISCUSSION

The bobcat is opportunistic (Latham 1951). A bobcat's diet is based on both prey abundance and the amount of energy required to capture prey (Latham 1951, Baker et al. 2001). There have been many studies of bobcat diet in the Southeast, and the top 3 prey in most of these studies were rabbit, rodent, and deer (Davis 1955, Progulski 1955, Kight 1962, Beasom and Moore 1977, Miller and Speake 1978, Fritts and Sealander 1978, Kitchings and Story 1979, Buttrey 1979, Fox and Fox 1982, Mahr and Brady 1986, Baker et al. 2001, Griffin 2001, Schoch 2003; Table 4.1).

There was an increase in consumption of rabbit and other along with a decrease consumption of rodent in diet between year 1 and year 2. The increase of rabbit in the diet of

bobcats in year 2 might be correlated to an increase in the overall rabbit population or a decrease in the rodent population on the study site. Therefore, bobcats may have substituted rodents for rabbits during the second year of the study, because rabbits were more readily available.

Unfortunately, there are no data to assess rabbit abundance on the study site.

Seasonal variation in prey consumed during 1 year could be contributed the increase consumption of rabbit and other in the spring and the lack of rabbit present in fall. Also, in the summer more bird and deer were consumed than in any other season. This increase in consumption of bird and deer could be due to the presence of young birds and fawns.

In year 2 seasonal variation prey consumed is probably due to the change in diet during the winter season. During the winter of year 2, no birds were consumed, there was a substantial decrease in the number rodents consumed, and there was an increase in the amount of rabbit and deer consumed. Rabbit and deer may have been more readily available than rodent or bird. The opportunity for bobcats to consume deer that are wounded or unclaimed by hunters increases during the winter season (Anderson 1987). This may account for the increase in consumption of deer. Also, rabbit populations may have increased or rodent populations may have decreased during the winter, thus making rabbit more readily available than rodents.

Throughout both years rodents were the most frequently consumed prey item, while deer were the least frequently consumed prey item. This was likely because rodent populations were high in our study area and deer populations were kept at a low density (approximately 4/km<sup>2</sup>) as well as the fact that deer are harder to catch and kill than rodents. Many Northern bobwhite management practices also improve habitat for rodents. For example, supplemental feeding often causes a two-to-three fold increase in density of small mammals (Boutin 1990). Further, prescribed burning helps maintain excellent habitat for rodents by creating and maintaining

herbaceous understory (Golley et al. 1965). Finally, rodents were commonly found along field edges and food plots (Cummings and Vessey 1994).

Birds were the third most common prey consumed by bobcats throughout the 2 years. Of 265 scats, 36 contained some kind of bird remains. However, only 5 of those 36 bird remains were identified as Northern bobwhite. This is a relatively low number given the density of Northern bobwhite on the study site. There have been 2 diet studies of bobcats conducted on southeastern U.S. Northern bobwhite plantations. One study Miller and Speake (1978) examined bobcat stomachs, large intestines, and scat and found rodents to be the most important prey item; only 2 of 218 scats collected contained remains of quail. The other study examined bobcat stomachs and found that 7 stomachs of the 66 stomachs they examined contained Northern bobwhite or Northern bobwhite eggs (Schoch 2003). Rodents were the most common prey consumed by bobcats in this study as well.

We did not find bobcats to be a primary predator of Northern bobwhite. When rodents, particularly cotton rats, occur in dense populations they can have a negative impact on Northern bobwhite (Stoddard 1931, Schnell 1968, Simpson 1976, Miller and Speake 1978, Staller 2001). Cotton rats not only compete directly with Northern bobwhite for food, they also damage roots of valuable Northern bobwhites food (Stoddard 1931, Schnell 1968, Miller and Speake 1978). Also, cotton rats destroy Northern bobwhite nests and eggs (Stoddard 1931, Simpson 1976). Therefore, bobcats may potentially benefit Northern bobwhite populations by consuming other predators such as raccoon, snakes, and opossums, and cotton rats.

Further studies need to be performed that look at both scat and stomach contents along with density of other potential predators of Northern bobwhite. A study that examines diet and prey densities simultaneously would be beneficial. Looking at the stomach contents allows items

that would be broken down and underrepresented in scats (e.g., egg fragments) to be accounted for in the prey items. It would be interesting to perform a study that looked at bobcat diets on pen-reared operations where birds are released.

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Figure 4.1. Percent occurrence of prey items consumed in year 1 and year 2 based on bobcat scats found on Ichauway, Georgia, 2001-2003

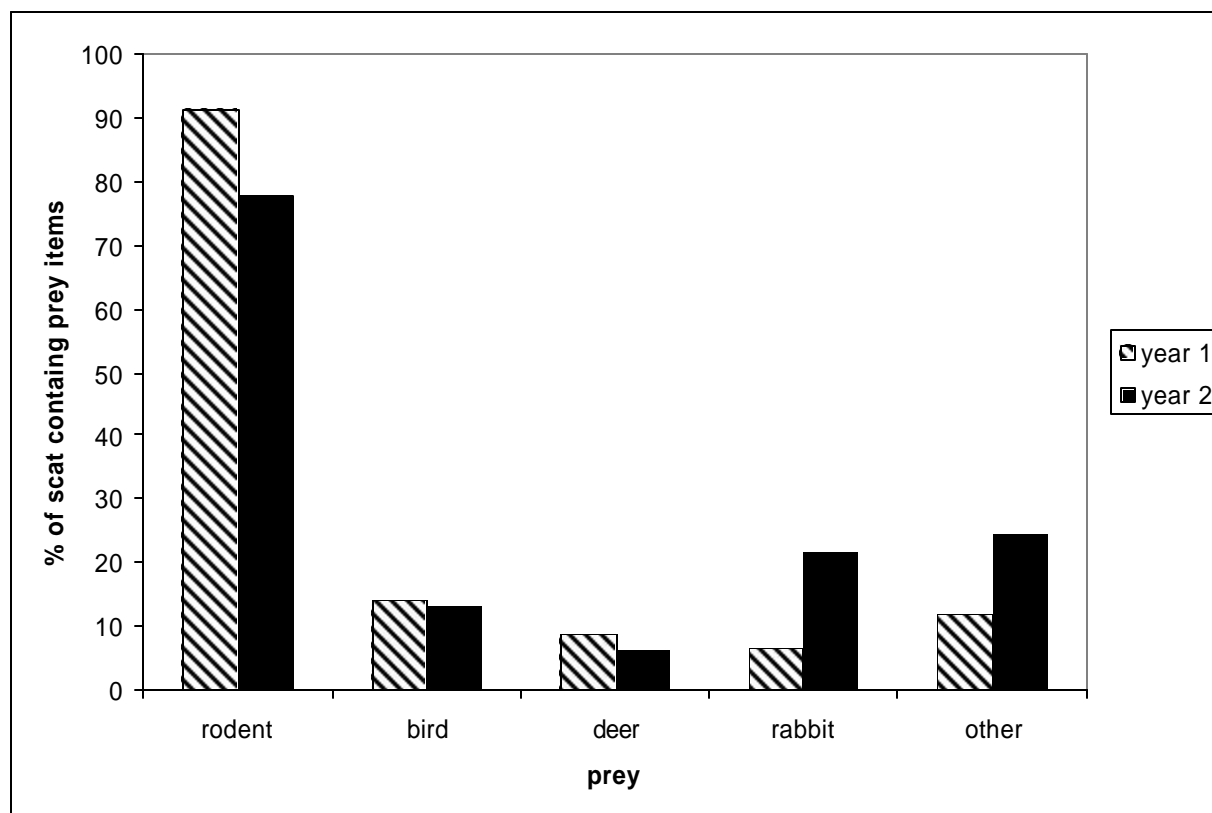


Figure 4.2. Percent occurrence of seasonal prey items in 135 bobcat scats found on Ichauway, Georgia, 2001-2003

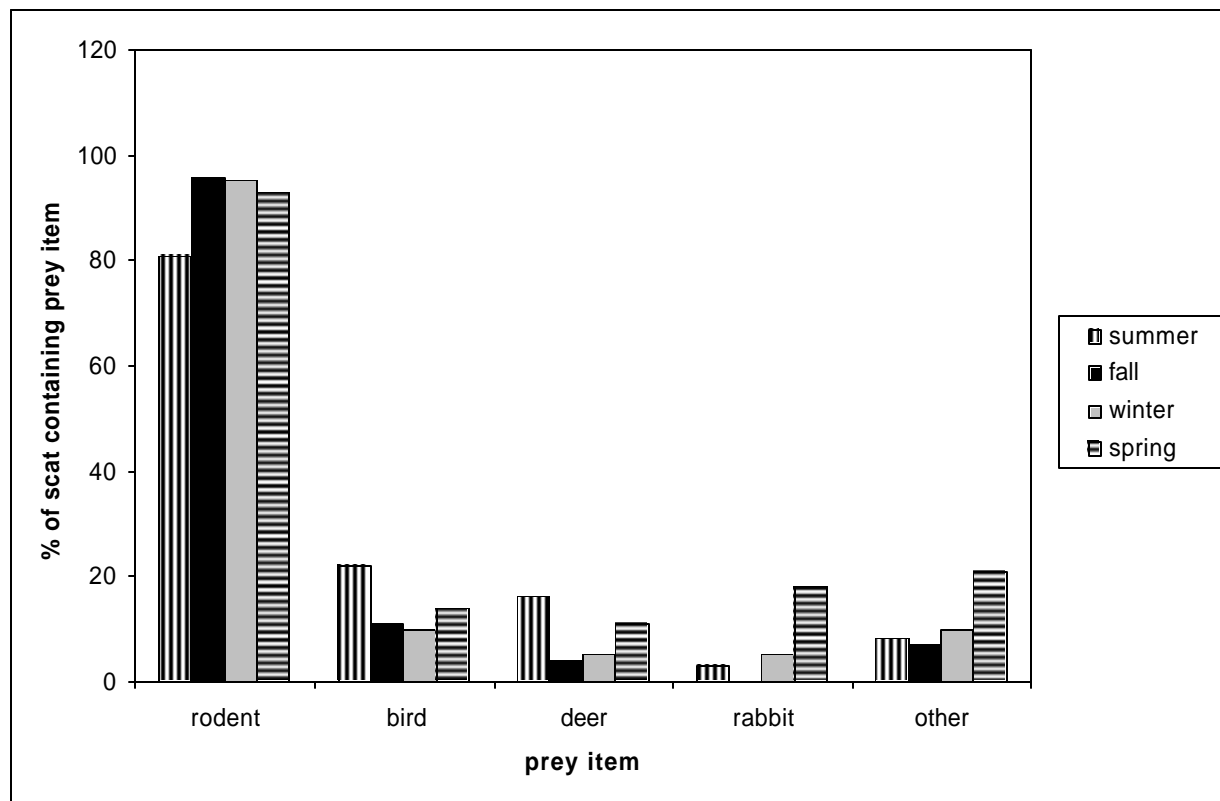


Figure 4.3. Percent occurrence of seasonal prey items in 130 bobcat scats found on Ichauway, Georgia, 2002-2003

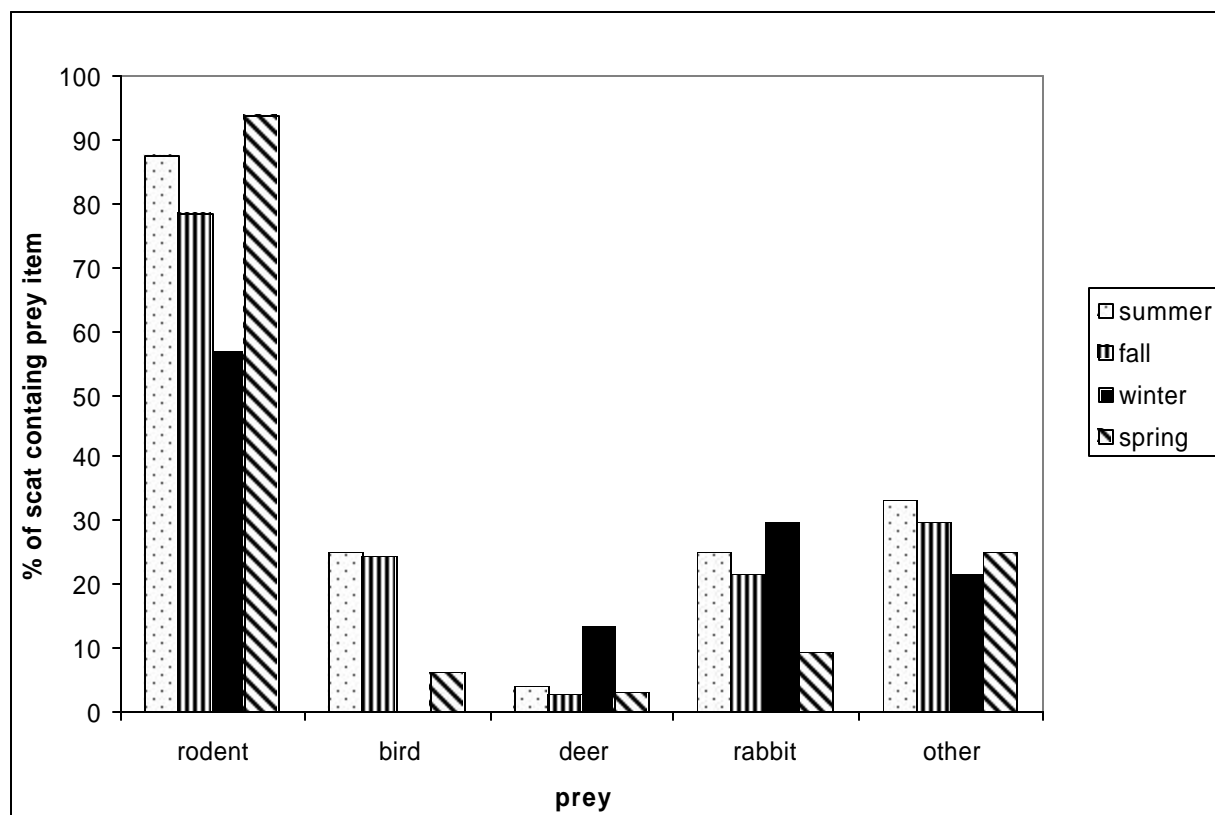


Table 4.1. Summary of percent of occurrence of prey in bobcat diets observed in 14 studies in the southeastern United States.

Study	State	Sample Size	Rodent	Rabbit	Deer	Bird	Other	Analysis <sup>1</sup>
Davis 1955	AL	239	18.8	63.2	10.5	6.9	20.6	GI
Progulske 1955	VA	124	66.9	54.6	9.9	14.9	62.8	Scat
Kight 1962	SC	317	65.6	43.8	0	21.8	29	Scat
Beasom & Moore 1977	TX	125	96.5	23	3	18.5	13	GI
Fritts & Sealander 1978	AR	150	21	39	7	8	52	GI
Miller & Speake 1978	AL	273	49.1	29.3	9.5	10	38.5	GI
Miller & Speake 1978	AL	218	87.2	37.6	1.4	15.6	43.6	Scat
Buttrey 1979	TN	15	23	40	6.7	6.7	.0065	GI
Buttrey 1979	TN	34	47.1	32.4	29.4	14.7	61.8	Scat
Kitchings & Story 1979	TN	31	46.5	68.5	19.5	7	46.5	Scat
Fox & Fox 1982	WV	172	44.1	23.5	50	8.8	25.3	GI
Maehr & Brady 1986	FL	413	42.4	85.5	2.4	18.7	25.7	GI
Baker et al. 2001	GA	357	15.7	46.2	36.4	7.8	13.2	Scat
Griffin 2001	SC	179	43	16	19	13.7	8.7	Scat
Schoch 2003	GA	66	62.1	28.8	9.1	10.6	18.2	GI
Current <sup>**</sup>	GA	265	84	14	7.5	13.6	18.1	Scat

<sup>1</sup>Type of analysis (GI=stomach or intestines and Scat)

<sup>\*\*</sup>Current is the two years combined.

## CHAPTER 5

### CONCLUSION AND MANAGEMENT IMPLICATIONS



Bobcats represent an apex predator, a predator that has the ability to regulate other predator populations, in the longleaf pine (*Pinus palustris*) forest of southwestern Georgia. Many land managers believe that bobcats are detrimental to quail populations, and a large portion of our study site was managed for Northern bobwhite (*Colinus virginianus*). Therefore, we initiated a study of bobcat diets with specific interest in quantifying quail consumption. Scat was collected for 2 years, and only 5 out of 265 scats contained quail remains. Our study was unable to account for any quail eggs that might have been consumed by bobcats due to the fact that we only looked at scat. Similar to other studies in the Southeast, bobcats in my study most frequently consumed rodents and rabbits. Bobcats consumed more rodents and fewer rabbits in Year 1 than in Year 2 of this study. This change in diet suggests that bobcats may have substituted rodents for rabbits in year 2, perhaps because of a change in rabbit abundance. We found little evidence to support the idea that bobcats have a negative impact on quail populations.

Similar to other studies (Hall and Newsome 1976, Buie et al. 1979, Whitaker et al. 1987), we found that male home range sizes were larger than female home range sizes. However, the average home range sizes for male and female bobcats in our study were smaller than the average home range sizes reported elsewhere in the Southeast (Hall and Newsom 1976, Miller and Speake 1979, Kitchings and Story 1979, Buie et al. 1979, Hamilton 1982, Shiftlet 1984, Fendley and Buie 1986, Lancia et al. 1986, Rucker et al. 1989, Conner et al. 1992, Griffin 2001). If home range size is a function of habitat quality as determined by prey abundance (Fendley and Buie 1986, Boyle and Fendley 1987), then our smaller home range sizes may have resulted from higher quality habitat on our study site. Land management practices within our study site, such as prescribed fire and creation of food plots, likely increased quality of habitat for bobcats by

promoting a herbaceous understory that supports dense prey populations (Golley et al. 1965, Landers and Mueller 1986).

Both male and female bobcat home range sizes varied seasonally. These seasonal fluctuations in home range sizes may be due to changes in prey availability, breeding behavior or kitten rearing.

Habitat selection by bobcats during our study occurred at the home range level (i.e., Johnson's second order habitat selection; Johnson 1980). Bobcats were found closer to all 8 habitat types than expected when comparing the home range to the entire study area. This indicates that bobcats are an edge species. Agriculture, hardwood, and mixed pine-hardwood habitat types were the most preferred habitats in our study site. All 3 of these habitat types support dense prey populations, while hardwood and mixed pine-hardwood provide loafing areas for bobcats. Bobcats did not select habitats within their home range (Johnson's third order habitat selection).

Bobcats den in caves, rock shelters, dense brush piles, abandoned buildings, hollow stumps, downed trees, and under trees (Bailey 1974, Kitchings and Story 1984, Anderson 1987, and Griffin 2001). We located 4 dens during our study. The only similarity between previously documented dens and our dens was protection from the adverse weather conditions. Therefore, we suggest that shelter from the elements, and perhaps prey availability, are the determining factors for females when selecting a den.

There were 8 bobcat mortalities during our study. Four of the 8 mortalities were confirmed to be human related. Three were trapped and killed on surrounding plantations, 1 was hit by a vehicle, 1 was killed by another felid, and 3 died from unknown causes.

We encourage land managers to manage for habitat diversity which leads to increased edge. However, the interaction of anthropogenic features such as food plots and maintenance roads should be weighed against potential negative effects of habitat fragmentation.

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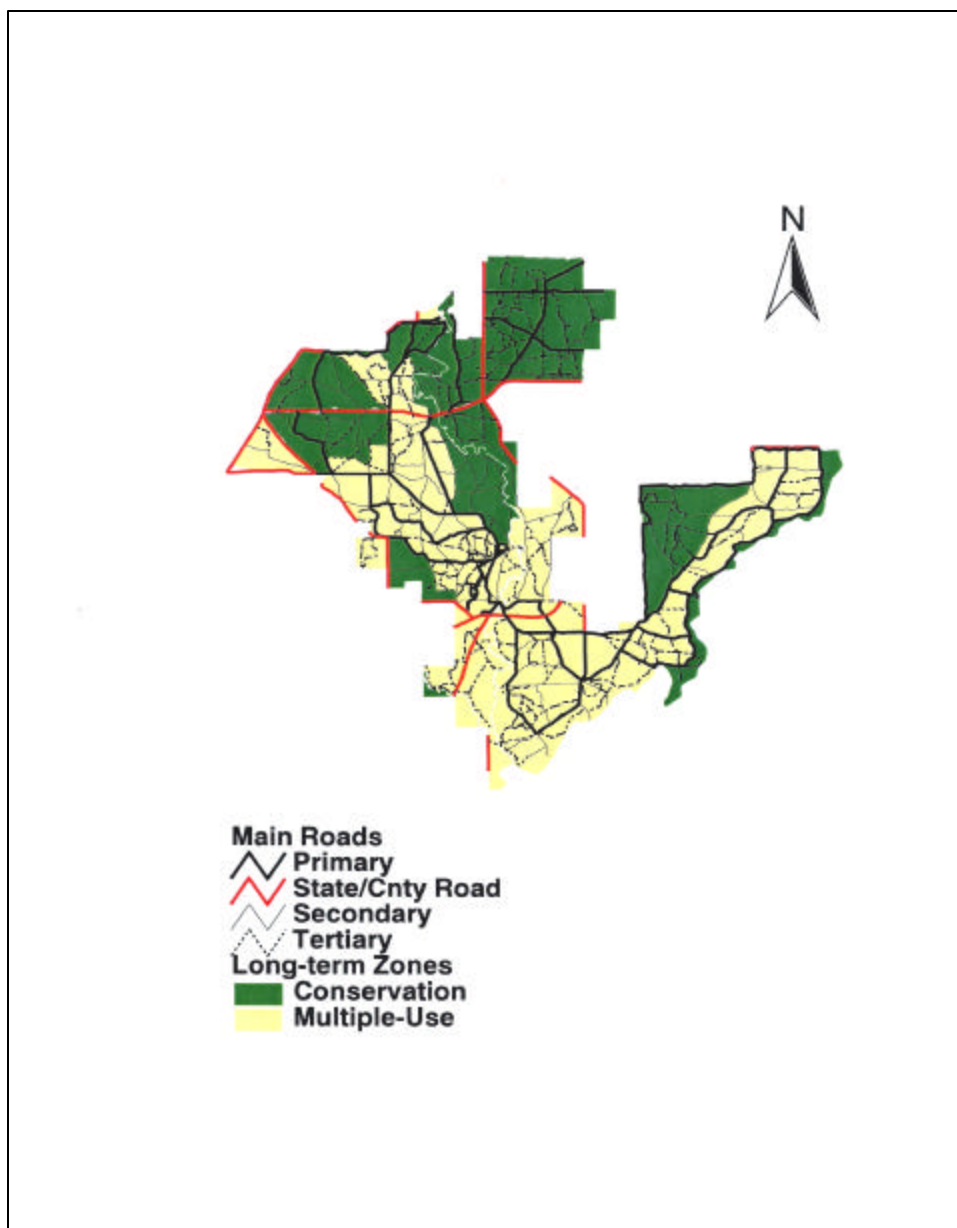
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## APPENDIX 1

### MANAGEMENT ZONES ON ICHAUWAY, GEORGIA, 2000–2003

Conservation zones are areas that are managed to mimic more pristine conditions. Multiple-use zones are areas that are more heavily managed for quail.



## APPENDIX 2

MORPHOLOGICAL DATA COLLECTED ON 36 BOBCATS CAPTURED AND RADIO  
COLLARED BETWEEN DECEMBER 2000 AND MAY 2003, ICHAUWAY, GEORGIA



Morphological data collected on 36 bobcats between December 2000-May 2003 on Ichauway

Date	Cat #	Sex	Weight (kg)	Total length (cm)	Tail length (cm)	Hind foot length (cm)	Front of ear length (cm)
12/13/00	01	female	5.75	860	150	165	65
01/10/01	04	female	6.75	902	143	160	61
01/24/01	10	female	7.33	902	152	164	59
01/25/01	12	male	7	932	125	160	58
02/07/01	15	female	6.25	917	138	154	54
02/07/01	16	male	9.5	941	132	170	62
03/08/01	18	female	6.75	890	135	165	60
03/27/01	23	female	7.25	912	121	168	66
04/08/01	25	female	7.75	880	130	170	70
04/20/01	27	female	7	915	131	170	64
04/24/01	28	female	6.75	890	138	161	62
05/01/01	30	male	7	954	142	179	62
06/03/01	34	male	8.1	1000	170	170	70
06/04/01	05	male	5.6	940	160	160	60
11/16/01	36	male	10.5	1040	160	185	70
12/07/01	37	female	6.5	863	113	150	62
12/19/01	39	female	7.83	850	130	165	70
12/26/01	41	male	10	1010	140	175	70
03/05/02	06	female	7.4	940	145	160	60
03/05/02	45	male	8.5	1040	150	170	70
03/06/02	47	female	7	850	120	160	60
03/07/02	40	female	6.5	905	145	160	65
03/09/02	50	male	7.25	985	160	170	65
03/26/02	46	male	8.45	970	145	165	60
04/30/02	48	female	6.5	870	140	153	68
05/15/02	42	female	6.25	895	140	160	60
06/21/02	51	female	7.25	940	155	170	65
12/04/02	49	female	6.3	860	121	164	57
12/12/02	54	female	6.2	900	130	165	51
12/13/02	57	male	10.2	985	165	180	49
01/30/03	60	female	8.75	844	137	173	52
01/30/03	61	male	6.75	985	145	182	55
02/17/03	65	male	9.95	940	140	173	58
03/04/03	67	female	5.5	908	135	165	51
04/25/03	71	male	9.95	995	155	175	55
05/21/03	72	female	5.5	865	140	155	55

### APPENDIX 3

INDIVIDUAL HOME RANGE SIZE OF BOBCATS USING THE MINIMUM  
CONVEX POLYGON (MCP) AND THE ADAPTIVE KERNEL (ADK) METHOD BY  
SEX AND SEASON ON ICHAUWAY, GEORGIA, 2001-2003

Individual 95% minimum convex polygon home ranges (km<sup>2</sup>) of 32 bobcats by sex and season on Ichauway, Georgia, 2001-2003 (a minimum of 30 locations/bobcat/season were obtained for analysis)

Animal Number	Sex	Fall 2001	Winter 2002	Spring 2002	Summer 2002	Fall 2002	Winter 2003	Spring 2003
1	female	2.46	.801	.731	1.26	2.01	2.77	2.46
4	female	1.95	1.64	2.29	2.44	2.48	2.68	
5	male	2.63	1.26	2.09				
6	female				1.46	1.96	7.66	1.86
10	female	2.45	2.59	.643	1.85	1.73	3.50	6.00
15	female	1.76	1.06	1.39	.769	2.21	2.02	1.88
16	male	3.56	1.76	1.57	24.25	3.22		
18	female	2.77	.960	2.33	2.47	3.03	5.72	2.97
23	female	3.12	3.33	.387	1.30	2.43	4.41	1.88
25	female	.752	1.03	1.69	1.08	3.65	3.97	4.05
26	female	1.28						
27	female	10.71	9.32	.369	4.44	4.65		
30	male	2.16	14.66	5.56	38.28	5.56	5.59	5.19
34	male	3.76	3.92	5.37	3.23	3.60	9.92	7.42
36	male		.665	3.20	6.34	6.91	5.09	4.83
37	female		1.09	1.79	1.38	1.36	1.84	1.08
39	female		3.53	2.92	1.72	1.36	4.40	2.66
40	female				4.08	15.82	18.15	5.60
41	male		3.82	2.54	4.76	7.73	8.49	8.17
42	female				1.61	3.25	2.51	1.87
45	male			1.32	1.71	2.15	2.52	7.45
46	male			.377				
47	female			1.35	1.38	1.39	2.53	2.01
48	female			1.89				
49	female						2.71	1.68
51	female				.456	2.87		
57	male						9.38	
60	female						2.27	4.11
61	male						5.36	4.90
63	female							3.29
67	female							1.83
71	male							7.99

Ichauway, Georgia, Individual 95 %adaptive kernel home ranges (km<sup>2</sup>) of 32 bobcats by sex and season on 2001-2003 (a minimum of 30 locations/bobcat/season were obtained for analysis)

Animal Number	Sex	Fall 2001	Winter 2002	Spring 2002	Summer 2002	Fall 2002	Winter 2003	Spring 2003
1	female	5.00	1.41	1.19	1.81	3.91	5.90	4.27
4	female	3.48	3.13	3.96	3.48	4.32	4.23	
5	male	4.61	3.07	3.00				
6	female				3.06	3.61	17.54	3.08
10	female	3.91	4.30	1.19	3.16	2.70	6.09	7.73
15	female	2.81	1.57	2.73	1.18	3.78	3.35	3.04
16	male	5.61	2.76	3.40	4.28	5.14		
18	female	4.57	1.56	3.81	3.85	5.57	14.02	4.93
23	female	4.50	4.75	5.46	2.04	3.67	9.49	3.03
25	female	1.20	1.68	3.67	1.32	6.55	6.33	7.21
26	female	2.15						
27	female	18.43	14.24	1.01	6.66	7.41		
30	male	3.23	80.95	39.76	-	8.84	8.51	9.01
34	male	5.36	5.65	6.81	4.09	4.26	17.48	10.70
36	male		1.23	5.22	6.82	9.81	8.28	7.94
37	female		2.06	2.67	1.98	1.71	2.65	1.51
39	female		5.65	5.39	2.56	2.36	6.74	4.22
40	female				5.99	30.96	34.70	7.75
41	male		6.20	3.13	6.24	11.88	12.98	13.52
42	female				3.03	5.69	5.27	3.17
45	male			2.43	3.71	3.07	4.32	8.83
46	male			.73				
47	female			3.27	1.98	1.66	4.17	3.11
48	female			6.14				
49	female						3.07	3.12
51	female				.803	3.55		
57	male						16.38	
60	female						3.93	6.94
61	male						10.14	9.15
63	female							6.68
67	female							3.10
71	male							13.38

APPENDIX 4  
DESCRIPTION OF BOBCAT MORTALITIES IN SOUTHWESTERN GEORGIA,  
2001-2003

Eight radio-collared bobcats died during the course of this study. Three were trapped and killed on other plantations, 3 died from unknown causes of death, 1 was hit by a vehicle, and 1 was killed by another felid.

An adult female's (#051) carcass was located off of the study site 11 December 2002. It was last located alive on 27 November 2002. We were unable to determine the cause of death. She was initially caught 21 June 2002. The remains of an adult female (#054) were located on the study site on 30 December 2002. No radio locations were obtained on the bobcat. Cause of death was undetermined. She was initially collared 12 December 2002. An adult male's (#016) carcass was located off of the study site 7 March 2003. He was last located alive on 18 February 2003. Cause of death was undetermined, but we believe he was hit by a vehicle. He was initially captured 7 February 2001.

Three bobcats were trapped and killed on plantations in the surrounding area. An adult male bobcat (#003) was trapped on Pinebloom Plantation on 27 September 2001, approximately 5-10 miles from the study site. The bobcat was initially trapped 4 January 2001 but was never relocated. Bobcat #014, an adult male, was trapped and killed on neighboring Longleaf Plantation 29 October 2001. Bobcat #014 was initially captured 2 February 2001 and last located 5 October 2001. Bobcat #032, an adult male, was trapped and killed on a plantation near the Baker/Miller County line about 10 miles from the study site on 28 June 2002. Bobcat #032 was initially captured 16 May 2001 and last located 19 May 2001.

Bobcat #007, an adult female, was hit by a vehicle on the study site 21 June 2001. She was initially caught 22 January 2001 and last located 19 June 2001.

Bobcat #026, an adult male, was killed on the study site by another felid on 28 January 2002. He was initially caught 19 April 2001 and last located on 27 January 2002.

## APPENDIX 5

DESCRIPTION OF FOUR DENS LOCATED IN SOUTHWESTERN GEORGIA,

2002-2003

Four dens were located on the study site during the course of the study. Den 1 was located 17 April 2002 in a bulldozed pile of trees created as a by-product of logging. We heard at least 2 kittens inside, but were unable to obtain visual confirmation. However, we observed the adult female in the den.

Den 2 was located 17 April 2003 in a bulldozed pile of trees also created as a by-product of logging. We heard at least 2 kittens, but were unable to get visual confirmation on kittens or the adult female.

Den 3 was located 24 April 2003 in a hollowed out water oak in a hardwood bottom near the Flint River. We saw the adult female with two kittens with unopened eyes.

Den 4 was located 24 April 2003 in a downed hollow log surrounded by dense vegetation. We heard at least 2 kittens. The adult female fled from the den as we approached.