ECOLOGY OF BOBCATS ON LAND MANAGED FOR NORTHERN BOBWHITE IN SOUTHWESTERN GEORGIA

by

IVY AYN GODBOIS

(Under the direction of Robert J. Warren)

ABSTRACT

Bobcats are considered a quail predator by many quail managers; therefore, it is important for quail managers to understand bobcat ecology. We examined how quail management practices, such as supplemental feeding, prescribed burning, and creation of food plots, affected bobcat home range, movement, and diet. We found that home range size was affected by food plots, but not supplemental feeding, and that movement rates were highest in the evening. Bobcats were attracted to supplemental feeding, but not recently burned areas. Bobcats selected food plots in their home range, and selected mixed pine/hardwood areas throughout the study site. Bobcat diet was mainly made up of rodent. Scat containing deer degraded faster; therefore, deer may be underestimated in diet studies using scat. Bobcat ecology appears driven by prey availability, and bobcats may be beneficial to quail by preying on nest predators.

INDEX WORDS: Bobcat, *Colinus virginianus*, Diet, Home range, Food plots, *Lynx rufus*, Movement, Prescribed burning, Quail, Scat, Supplemental feeding

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DEDICATION

This thesis is dedicated to all of my family, but especially my grandmother who passed down great strength to all her daughters and grandchildren. She never judged me and always loved me and instilled in me the knowledge that I could do anything.

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CHAPTER 1

INTRODUCTION, STUDY AREA, JUSTIFICATION, AND THESIS FORMAT

Introduction

Apex carnivores have a stabilizing effect on ecosystems by suppressing mesopredator (e.g., mid-sized mammal) populations and allowing for more faunal diversity (Palomares et al. 1995, Rogers and Caro 1998, Courchamp et al. 1999). The bobcat (*Lynx rufus*) is perhaps the apex predator in the coastal plain of Georgia.

Bobcats are solitary mammals, with both sexes maintaining exclusive intrasexual home ranges except when prey availability is very low (Hall and Newsome 1976, Buie et al. 1979, Miller and Speake 1979, Buie 1980, McCord and Cardoza 1982, Shiftlet 1984, Rolley 1985). Bobcat home range sizes are variable and dependant on sex, prey abundance, season, and habitat quality (Hamilton 1982, Shiftlet 1984, Litvaitis 1985, Anderson 1987, Sandell 1989, Rucker et al. 1989). Diversity, stability, and distribution of prey populations may be especially important regulators of female home range size, whereas mating opportunities and female home range size regulate male home ranges (Anderson 1987, Sandell 1989). Male bobcat home ranges are generally twice as large as female home ranges within an area and often overlap two or more female territories (Hall and Newsome 1976, Miller and Speake 1979, Buie et al. 1979, Shiflet 1984, Whitaker et al. 1987). Bobcat home ranges in the Southeast range from 1.1 km^2–24.5 km^2 for females and 2.6 km^2–64.2 km^2 for males (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).

Bobcat home range size is inversely related to prey density (Smith 1968, Hall and Newsom 1976, Mares et al. 1976, Kitchings and Story 1978, Buie et al. 1979, Heller and Fendley 1982, Rucker et al. 1989, Knick 1990, Conner et al. 1992). Supplemental feeding of Northern bobwhite (*Colinus virginianus*; hereafter quail) is a management practice that concentrates small mammal populations (Boutin 1990), which may also concentrate bobcat activity and result in smaller bobcat home range sizes. Buie (1980) and Rucker et al. (1989) found that bobcat home ranges were smaller in the summer and larger in the winter, possibly because prey were more available in summer than in winter.

Bobcat reproduction (breeding, parturition, and nursing young) is variable and is influenced by location, photoperiod, altitude, climate, and prey availability (McCord and Cardoza 1982). Bobcat breeding generally occurs between December and February in the southern United States (Fritts and Sealander 1978) but can start earlier and last longer (Blankenship and Swank 1979). Winegarner and Winegarner (1982) found that the post-parturition season, the period in which kittens require prey taken by the adult female, occurs between April and May. During the reproductive season, females use higher quality habitat than males, possibly because females must obtain more prey in smaller areas near the den site (Bailey 1981). Bailey (1979) stated that the location of den sites may be related to prey availability, and that the physical structure of the den site is not as important as the habitat around the den. Kitchings and Story (1984) found dens at the bases of stumps and in brush piles where timber had been recently harvested. Gashwiler et al. (1961) found bobcats denning in hollow logs and rocky outcrops. Logging practices, such as restoration projects that remove hardwoods may also create stumps and brush piles that are suitable den sites.

Bobcat habitat quality is often defined as the ability of a habitat to produce abundant prey (Fendley and Buie 1986, Boyle and Fendley 1987). Quail management practices (e.g., prescribed burning and creation of food plots), increase herbaceous ground cover and limit shrubby cover, which is beneficial to bobcat prey (Landers and Mueller 1986). The interspersion of shrubby and herbaceous cover is important, but areas that are too shrubby may be less beneficial to bobcat prey (Kitchings and Story 1978). Prey, such as cotton rats (*Sigmodon hispidus*) and other small rodents, are most abundant in areas with a dense herbaceous ground cover interspersed with shrubs and shrubby vines such as trumpet vine (*Bignonia radicans*) and blackberry (*Rubus* spp.) (Golley et al. 1965, Schnell 1968).

Bobcats are opportunistic predators and their diet often reflects prey availability (Latham 1951). In the Southeast, bobcats prey most heavily on small mammals such as rabbits (*Sylvilagus* spp.) and cotton rats (Beasom and Moore 1977, Miller and Speake 1978). Bobcats are also known to consume larger prey items, such as white-tailed deer (*Odocoileus virginianus*), when the opportunity arises. Deer consumption is likely to occur during fall-winter when there is the possibility for hunter-killed deer to be consumed and during spring-summer when there are more fawns available as prey (Buttrey 1979, Story et al. 1982).

Quail management may affect habitat suitability for bobcats. Prescribed burning, spreading supplemental food, and creating food plots are all widely used quail management practices. There has only been one other study that investigated possible effects of quail management on bobcats (Miller and Speake 1978). This project investigates the effects of quail management on bobcat home range, movement, habitat selection, and diet, all of which are of interest to quail managers. Since there have not been any bobcat studies performed in the longleaf pine (*Pinus palustris*)/wiregrass (*Aristida beyrichiana*) ecosystem, any information on bobcat home range, movement, habitat selection, and diet will be of interest to ecologists conducting research within this ecosystem.

Study area

The study took place on Ichauway, the outdoor laboratory facility of the Joseph W. Jones Ecological Research Center, located in Baker County, Georgia. This 11,700-ha facility was found in the Southern Coastal Plain physiographic province. Longleaf pine woodlands dominated the landscape. Slash pine (*P. elliottii*) flatwoods, natural loblolly pine (*P. taeda*) stands, mixed pine hardwoods, creek swamps, and agricultural fields were distributed throughout the area. Old field grasses (e.g., *Andropogon* spp.) and wiregrass dominated the understory (Goebel et al. 1997). However, more than 1,000 vascular plant species were documented on the property (Drew et al. 1998). Ichauway contained 724 km of primary, secondary, and tertiary roads on Ichauway and 980 km of firebreaks and food plot edges.

Elevation ranged from 30-100 m and was characterized by flat to gently rolling karst topography (Goebel et al. 1997). Soils in the Dougherty Plain physiographic province (Beck and Arden 1983) had a high sand content, and overlaid Ocala and Lisbon limestone (Soil Conservation Service 1986). The Flint River formed the eastern boundary of Ichauway, and the Ichawaynochaway Creek flowed through the middle of the property.

Ichauway had a subtropical climate with mild, short, wet winters and hot, humid summers (Lynch et al. 1986). Temperatures averaged 27.5º C in summer and 11º C in winter. Rainfall amounts were relatively evenly distributed throughout the year with annual precipitation averaging 131 cm (Goebel et al. 1997). Summer rainfall was generally associated with frontal systems that tended to be moderate in intensity but long in duration (Christensen 1988).

Ichauway was established in the 1920's as a quail hunting plantation. During the time of my study it was one of the most extensive tracts of privately owned longleaf pine in the United States. Prescribed fire, planting of wildlife food plots, spreading of supplemental food, and light predator control were prominent management practices on Ichauway.

Ichauway was divided into two different management zones: multiple-use and conservation. Multiple-use zones made up approximately 60% of the study area while conservation zones made up the remaining 40%. Quail hunting as well as predator management and supplemental feeding took place in multiple-use zones. No quail hunting, predator management or supplemental feeding occurred in the conservation zones. However, longleaf pine restoration occurred more often in conservation zones. Prescribed burning was equally common in both zones. Ichauway employed dormant and growing season burns in a 2-year rotation on approximately 4,000–6,000 ha annually. Multiple-use zones tended to be more heavily managed for wildlife, whereas conservation zones tended to mimic pristine conditions. Although these two zones were managed differently, there were no physical boundaries separating the two, and animals were free to move between zones.

To keep areas productive for quail, fields at Ichauway were disked to increase food and cover. Disking removed thicker vegetation and allowed establishment of plants such as ragweed (*Ambrosia artemisiifolia*) and partridge pea (*Chamaecrista fasciculata*) (Landers and Mueller 1986). Widely scattered wildlife food plots consisting 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*) constituted about one-fifth of the property. These food plots occurred mostly in the multiple-use zones. To supplement quail food, grain consisting of corn, grain sorghum, soybean (*Glycine max*) and sunflower (*Helianthus* sp.) seed was spread throughout the multiple use zones in 2-week intervals from November–May. Supplemental food was spread in thickets, along field edges, and in food plots within multiple-use zones.

Predator control occurred after the quail-hunting season, primarily in the multiple-use zones, from March–July. Target animals were opossum (*Didelphis virginiana*), armadillo (*Dasypus novemcinctus*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), red fox (*Vulpes vulpes*) and bobcat. During my study, no bobcats were harvested; however, other predators were harvested within the multiple-use zones.

There was a wide variety of potential prey for bobcats. White-tailed deer occurred at a relatively low density on Ichauway (approximately 4/km^2). There were 4 squirrel species on Ichauway including Eastern chipmunk (*Tamias striatus*), Southern flying squirrel (*Glaucomys volans*), Eastern gray squirrel (*Sciurus carolinensis*), and Sherman's fox squirrel (*S. niger*). There were 2 species of rabbit on Ichauway including Eastern cottontail (*Sylvilagus floridanus*) and marsh rabbit (*S. palustris*). Small mammals on Ichauway included cotton rat, Eastern harvest mouse (*Reithrodontomys humulis*), oldfield mouse (*Peromyscus polionotus*), house mouse (*Mus musculus*), golden mouse (*Ochrotomys nuttalii*), cotton mouse (*P. gossypinus*), Eastern woodrat (*Neotoma *floridana*), marsh rice rat (*Oryzomys palustris*), Southern short-tailed shrew (*Blarina carolinensis*), Southeastern shrew (*Sorex longirostris*), least shrew (*Cryptotis parva*), and Southeastern pocket gopher (*Geomys pinetis*). There were numerous ground-nesting birds such as quail, wild turkey (*Meleagris gallopavo silvestris*), rufus-side towhee (*Pipilo erythrophthalmus*), and Bachman's sparrow (*Aimophila aestivalis*). Ichauway also had various reptiles and amphibians including gopher tortoises (*Gopherus polyphemus*) and numerous species of snakes.

Justification

Passage of the Endangered Species Conservation Act of 1969 ended the supply of large cats that were in demand by the fur trade. Demand for non-endangered cats of North America increased as a result. Bobcats and lynx (*Lynx lynx*) were highly targeted for their fur (Anderson 1987). Concern regarding over-exploitation of bobcats caused them to be listed in the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). Each state is now obligated to monitor bobcat populations and to ensure that bobcat harvest is nondetrimental (Anderson 1987). Because bobcat home ranges, density, and habitat use are variable (Hamilton 1982, Shiftlet 1984, Litvaitis 1985, Rucker et al. 1989) and because bobcats tend to be targeted for removal as part of quail management, research is needed to better understand the effect of quail management on bobcats.

Many quail management practices, such as prescribed burning, creation of food plots, and supplemental feeding, may benefit bobcats. Prescribed burning creates an herbaceous understory that supports a dense prey base (Golley et al. 1965). Burning also creates thickets and hollow stumps which are considered ideal denning habitat for bobcats (Young 1958, Miller 1980, Kitchings and Story 1984). Small agricultural fields and food plots provide edge and increase prey availability (Hall and Newsom 1976, Miller and Speake 1978). Boutin (1990) concluded that supplemental feeding increases reproduction, decreases home range, and increases density of potential prey, which may attract predators.

Bobcats have been considered detrimental to game populations since their predatory behavior was first noted (Seton 1929). However, the true effects of bobcats on game populations are unknown. Bobcats are often harvested on quail-managed land because they are considered to be a predator of quail. However, bobcats may also benefit quail if they prey on mesomammals that in turn would have preyed on quail or quail nests. Therefore, more should be known about the effects of quail management on bobcats and the ecological role of bobcats on quail plantations.

Objectives

The objectives of this study were to determine the home range, habitat use, movement, and diet of bobcats in a longleaf pine/wiregrass ecosystem as well as how home range size was affected by quail management practices such as supplemental feeding and creation of food plots. I wanted to determine habitat use by bobcats seasonally and how habitat use was affected by quail management practices, such as prescribed burning, creation of food plots, and supplemental feeding. I also wanted to measure movement rates of bobcats seasonally and within different time intervals. Finally, I wanted to determine seasonal diets of bobcats in a longleaf pine/wiregrass ecosystem.

Thesis format

This thesis is written in manuscript format with chapters 2, 3, and 4 as separate manuscripts. Chapter 1 is a general review of bobcat ecology and an introduction to the thesis. Chapter 2 describes bobcat movement patterns, habitat selection, and home range including how each is affected by food plots, supplemental food, and prescribed burning. Chapter 3 describes bobcat diet. Chapter 4 reports how prey composition of scat affects decomposition of the scat in the environment. Chapter 5 is a summary of all findings and presents conclusions of the study.

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CHAPTER 2

MOVEMENT PATTERNS, HABITAT SELECTION, AND EFFECTS OF FOOD PLOTS, SUPPLEMENTAL FEEDING OF NORTHERN BOBWHITE, AND PRESCRIBED BURNING ON BOBCAT HOME RANGE SIZE[1]

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Abstract: Creation of food plots, supplemental feeding, and prescribed burning are prominent Northern bobwhite (*Colinus virginianus*; hereafter quail) management practices that affect bobcat (*Lynx rufus*) ecology. Therefore, it is important for wildlife managers to understand these effects. We monitored 21 radio-collared bobcats during 2001–2002 in southwestern Georgia to determine their movement patterns, home range size, and habitat use. We also monitored the effects of supplemental quail feeding and prescribed burning on bobcat home range size and habitat selection. Bobcats moved more during the evening and males had larger home ranges than females. Habitat composition within the home range differed from habitat composition throughout the study area during the spring and summer. For home ranges, bobcats most preferred mixed pine/hardwood, mature pine, hardwood, food plot, and wetland areas and least preferred shrub/scrub, pine regeneration, and 'other' during spring. They most preferred mixed pine/hardwood, food plot, mature pine, and hardwood areas and least preferred 'other' and pine regeneration during summer. Bobcats used habitat disproportionately to availability within their home range during all seasons. Bobcats most preferred food plot, hardwood, mature pine, mixed pine/hardwood, and pine regeneration areas and least preferred wetlands, 'other', and shrub/scrub during fall. They most preferred food plots and least preferred shrub/scrub, pine regeneration, and 'other' during winter. They most preferred food plot, mature pine, mixed pine/hardwood, and hardwood areas and least preferred shrub/scrub, wetlands, pine regeneration, and 'other' during spring. They most preferred hardwood, mature pine, mixed pine/hardwood, and food plots and least preferred pine regeneration, wetlands, and shrub/scrub during summer. The amount of food plots within the home range affected home range size. Bobcats were found closer to supplemental quail food than expected during the winter, but supplemental quail food did not affect home range size. Finally, bobcats used recently burned areas similar to unburned areas. Thus, some quail management practices appear beneficial to bobcats, but whether this positive impact on bobcats enhances or reduces the impact of bobcats on quail remains unanswered.

Key Words: bobcat, *Colinus virginianus*, food plots, habitat selection, home range, *Lynx rufus*, movement, prescribed burning, quail, southwestern Georgia, supplemental quail feeding

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Bobcats are considered a predator of quail by quail managers. Therefore, it is important to understand the interaction between bobcats and quail. Many quail management practices, such as prescribed burning, creation of food plots, and supplemental feeding of quail, may benefit bobcats. Prescribed burning creates an herbaceous understory that supports a dense prey base (Golley et al. 1965). Burning also creates thickets and hollow stumps which are considered good denning habitat for bobcats (Young 1958, Miller 1980, Kitchings and Story 1984). Food plots provide edge and increase prey availability (Hall and Newsom 1976, Miller and Speake 1978). Boutin (1990) concluded that supplemental quail feeding increases breeding, decreases home range, and increases density of potential prey, which may attract predators.

Bobcats are most commonly considered nocturnal, but are actually most active at sunrise and sunset (Hall and Newsom 1976, Buie et al. 1979). Miller (1980) found that bobcats are most active around 0300–0500 and 1700–1900. Shiftlet (1984) and Buie

(1980) found that males and females were most active from 0400–1000 and from 1800–2400. These periods generally coincide with peak prey activity periods (Anderson 1987).

Bobcats are solitary mammals, and both sexes maintain exclusive intrasexual home ranges unless prey availability is very low (Hall and Newsom 1976, Buie et al. 1979, Miller and Speake 1979, Buie 1980, McCord and Cardoza 1982, Shiftlet 1984, Rolley 1985). Bobcat home range sizes are variable and dependant on bobcat sex, prey abundance, season, and habitat quality (Hamilton 1982, Shiftlet 1984, Litvaitis 1985, Anderson 1987, Sandell 1989, Rucker et al. 1989). Diversity, abundance, stability, and distribution of prey populations may be especially important regulators of female home range size, whereas mating opportunities and female home range size regulate male home ranges (Anderson 1987, Sandell 1989). Male bobcat home ranges are generally twice as large as female home ranges and often overlap two or more female territories (Hall and Newsom 1976, Miller and Speake 1979, Buie et al. 1979, Shiflet 1984, Whitaker et al. 1987). Bobcat home ranges in the Southeast range from 1.1 km^2 to 24.5 km^2 for females and 2.6 km^2 to 64.2 km^2 for males (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).

The bobcat habitat suitability index model (Boyle and Fendley 1987) suggests that habitat suitability is defined by the ability of habitats to support prey. Prey, such as cotton rats (*Sigmodon hispidus*) and other small rodents, are most dense in areas with dense herbaceous ground cover interspersed with shrubs and shrubby vines (Golley et al. 1965). The shrubby structure provides cover that is essential to bobcat prey (Schnell 1968), while the grass/forb-shrub habitat meets nutritional needs of prey. The interspersion of shrubby and herbaceous cover is important, but areas that are too shrubby may be less beneficial to bobcat prey (Kitchings and Story 1978). Prescribed burning can increase the abundance of herbaceous ground cover and limit the presence of shrubby cover (Landers and Mueller 1986).

Burning, spreading supplemental food, and creating food plots are all widely used quail management practices, yet there has only been one other study that investigated the possible effects of quail management on bobcats (Miller and Speake 1978). Our objective is to investigate bobcat movement patterns, home range, and habitat selection with special reference to specific quail management practices. We hypothesize that quail management practices benefit other potential prey species thus affecting how bobcats respond to these practices.

STUDY AREA

The study took place on Ichauway, the 11,700-ha outdoor laboratory facility of the Joseph W. Jones Ecological Research Center, located in Baker County, Georgia. Longleaf pine (*Pinus palustris*) woodlands dominated the landscape. Slash pine (*Pinus elliottii*) flatwoods, natural loblolly pine (*P. taeda*) stands, mixed pine hardwoods, and agricultural fields were distributed throughout the area. Old field grasses (e.g., *Andropogon* spp.) and wiregrass (*Aristida beyrichiana*) dominated the understory (Goebel et al. 1997). However, more than 1,000 vascular plant species existed on the property (Drew et al. 1998).

Ichauway is managed with dormant and growing season burns in a 2-year rotation on approximately 4,000–6,000 ha annually. To keep areas productive for quail, fields were disked to increase food and cover. Disking removed thicker vegetation and allowed seeding of plants such as ragweed (*Ambrosia artemisiifolia*) and partridge pea (*Chamaecrista fasciculata*) (Landers and Mueller 1986). Widely scattered wildlife food plots consisting 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*) made up 20% of the property. To supplement quail food, 300 tons of grain consisting of corn, grain sorghum, soybeans (*Glycine max*) and sunflower (*Helianthus* spp.) seed was spread over 7,020 ha throughout the areas managed for quail from November–May. Supplemental food was spread along edges of thickets, fields, and in food plots.

METHODS

Bobcat capture and monitoring

We trapped bobcats using #3 Victor Soft Catch traps (Woodstream Corp., Lititz, PA). Trapping began in December 2000 and continued through August 2002. We trapped less intensively during the fall and winter of 2001. We checked traps daily and restrained captured bobcats with a large net and wooden pole, which we used to pin the animal. Once the animal was restrained, we injected ketamine hydrochloride (10 mg/kg body weight) intramuscularly (Seal and Kreeger 1987). Once sedated, we recorded sex, body weight, total length, tail length, hind foot length, and ear length. We used weight and total body length as well as characteristics of teeth, teats, and scrotum to determine if the animal was an adult or juvenile (Crowe 1975). We attached a radio-collar (Advanced Telemetry Systems, Isanti, MN) on all adult bobcats. We tattooed a unique number in the ears of all bobcats. We monitored bobcats for 24 hours and then released them at the capture site. All trapping procedures were approved by the University of Georgia Institutional Animal Care and Use Committee (IACUC #A990159).

We initiated radio-tracking 7 days after bobcat release, but intensive monitoring began on 24 September 2001 and ended on 20 September 2002. We used a hand-held, 3-element yagi (Sirtrak, New Zealand) and a hand-held receiver (Wildlife Materials, Carbondale, IL) to locate bobcats using triangulation from known reference points.

For home range data, we obtained locations twice a day, three times a week allowing 8 hours between locations to ensure independence between locations. Each week, we shifted the starting time of tracking 2 hours later to ensure equal sampling throughout the diel period. For movement data, we obtained locations for each animal every hour for 24 hours during each calendar season. The 24-hour period was divided into three 8-hour periods.

Data analysis

Home range.--To calculate home range (HR), we converted telemetry bearings to Universal Transverse Mercator (UTM) coordinates using the FORTRAN program EPOLY (L. M. Conner, Joseph W. Jones Ecological Research Center, unpublished data). We then used program HOMERANGER (Hovey 1997) to derive 95% adaptive kernel (Worton 1989) HR estimates. We converted HR into Arc/Info (ESRI, Inc. 2002) coverages for further analysis. We calculated HR seasonally. We used a mixed model repeated over season (e.g., fall, winter, spring, summer, annual) (Littell et al. 1999) of sex and season and the interaction in SAS (SAS Institute, Inc. 1992) to predict home range size.

Movement.--To evaluate movement rates, we used EPOLY to create UTM coordinates as above. After obtaining coordinates we used the FORTRAN program MOVEMENT (L. M. Conner, Joseph W. Jones Ecological Research Center, unpublished data) to calculate movement rates (m/hr). We calculated movement rates for 4 time intervals: afternoon (1100–1659), evening (1700–2259), midnight (2300–0459), and morning (0500-1059). We then used a mixed model (Littell et al. 1999) of sex, season, time interval, and all the interactions in SAS (SAS Institute, Inc. 1992) to predict movement rates.

Habitat selection.--We assessed habitat selection at 2 different spatial scales, second order (2º) and third order (3º), which we modified from Johnson (1980), using compositional analysis (Aebischer et al. 1993). First, we compared habitat composition of HR to habitat composition of the study site (i.e., 2º). Next, we compared the habitat associated with bobcat locations to habitat composition of HR (i.e., 3º). We also determined if habitat selection differed between sexes in the multivariate analysis of variance (MANOVA) component of compositional analysis. If there was no difference between sexes, we pooled all the animals. We analyzed each season separately and ranked habitats in order of preference using ranking matrices (Aebischer et al. 1993). We then did a composite annual analysis, again using the above procedures, of habitat selection for all animals that were located for at least 6 months of the entire year. For our analyses we partitioned habitat into 8 categories: food plots, shrub/scrub, hardwood, pine regeneration, mature pine, mixed pine hardwood, wetland, and other (e.g., barren land, urban build-up).

Supplemental feed and food plots.--We used tractor-mounted global positioning system (GPS) units to determine location of supplemental food. Tractor-mounted spreaders spread seed at a constant rate. GPS locations were taken every 5 seconds along each feeding trail. Each point represented a volume of food that was spread. We then created random points in Arc/Info (ESRI, Inc. 2002) throughout the study area. Actual bobcat locations were also overlaid in Arc/Info (ESRI, Inc. 2002). We then used the Arc/Info (ESRI, Inc. 2002) NEAR function to determine the distance from random points and bobcat locations to the nearest supplemental food that had been placed prior to obtaining the location. Although feeding actually started on 5 November 2001, we allowed a week for the bobcats to find any prey that may be attracted to the food. For analysis, we also used the NEAR function in Arc/Info (ESRI, Inc. 2002) to determine the nearest food plot edge to the bobcat locations or random points. This was done because most feeding occurred on field edges and we wanted to ensure that any bobcat attraction to food was independent of attraction to field edges. We separated bobcat locations into male and female to determine if there was a difference between sexes.

To determine if bobcats were attracted to supplemental feeding, we used an analysis of covariance (ANCOVA) within a general linear model (GLM) (Dowdy and Wearden 1991) in SAS (SAS Institute, Inc. 1992) to examine the effects of the type of location (e.g., male, female or random), the amount of field edge, as well as the interaction of the 2 on the distance to food.

To determine how HR size was affected by food plots and supplemental feeding, we overlaid seasonal HR onto a habitat map using Arc/Info (ESRI, Inc. 2002) and determined the percent of the HR occupied by food plots as well as the index of supplemental food found within the HR. The index used for supplemental food was the number of GPS locations found within each HR divided by the area of the HR. For supplemental feeding, we used sex, percent food plots, food index, and all the interactions to predict HR size using a regression analysis within a GLM (Dowdy and Wearden 1991) in SAS (SAS Institute, Inc. 1992). For food plots, we then used sex, season, percent food plots found in HR, and all their interactions to predict HR size using a mixed model repeated over season (Littell et al. 1999) in SAS (SAS Institute, Inc. 1992).

Prescribed burning.--Ichauway was partitioned into 177 burn units. After each prescribed burn, the burn unit was given a date of burn. We overlaid HR onto the burn units in Arc/Info (ESRI, Inc. 2002). We determined number of locations within each burn unit 30 days before and then 30 days after the burn. For this analysis, burn units were considered our experimental unit, not the bobcats. We used a Wilcoxon signed rank univariate analysis (Dowdy and Wearden 1991) in SAS (SAS Institute, Inc. 1992) to compare the number of locations in burn units before and after burning in forested areas.

RESULTS

Home range

Number of bobcats tracked seasonally varied from 13 (5 M, 8 F) to 21 (6 M, 15 F) (Table 2.1). Males had larger home ranges ($F_{1,31}$ = 6.20, P = 0.02, 4.99 $\pm$ 0.81 km²; km² $\pm$ SE) than females (2.47 $\pm$ 0.61 km²). There was no seasonal difference in home range size between the sexes ($F_{4,61}$ = 0.67, P = 0.61). The interaction between the percent food plots in the home range and sex affected home range size ($F_{1,54}$ = 4.16, P = 0.046). Female home range size was not affected ($F_{1,36}$ = 0.02, P = 0.88) by the percent food

Table 2.1. Seasonal adult bobcat captures by sex that were radio-collared and tracked on Ichauway, Georgia, 2001–2002.

Season	**Sex**	**N**
Fall 2001	Male	5
	Female	8
Winter 2002	Male	6
	Female	10
Spring 2002	Male	8
	Female	12
Summer 2002	Male	6
	Female	15
Annual	Male	8
	Female	13

plots in the home range, while male home range size was affected ($F_{1,18}$ = 4.46, *P* = 0.049) by the percent food plots in the home range (Figure 2.1). Supplemental feeding of quail had no effect on home range size during the winter ($F_{1,9}$ = 0.26, *P* = 0.622), the only season when supplemental food was available.

Movement

None of the interactions between sex, season, and time interval affected movement rate (*P* > 0.05). Males and females had similar ($F_{1,55}$ = 1.89, *P* = 0.175) movement rates, and movement rates were similar ($F_{3,65}$ = 0.70, *P* = 0.557) seasonally. However, movement rates differed among time intervals ($F_{3,55}$ = 4.82, *P* = 0.005, afternoon = 213.08 $\pm$ 20.39 m/hr, evening = 314.54 $\pm$ 20.92, midnight = 248.13 $\pm$ 19.20, morning = 225.20 $\pm$ 19.75; m/hr $\pm$ SE) (Figure 2.2).

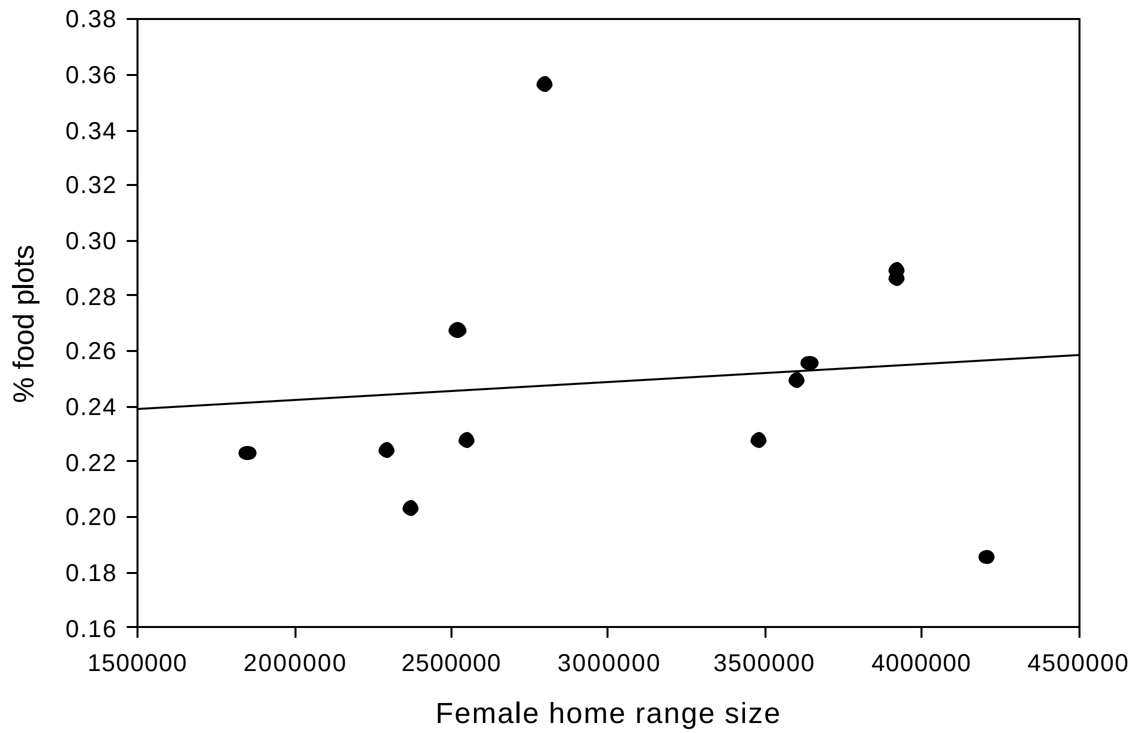
Habitat Selection

2º selection.--There was no difference (*P* > 0.05) in habitat selection between sexes during the fall and winter, and there was no difference (*P* > 0.05) in habitat composition of the home range and the study site during the fall and winter (Table 2.2).

There was no difference between the sexes ($F_{7,12}$ = 0.59, *P* = 0.751) in habitat selection during the spring. The habitat composition of the home range differed ($F_{7,13}$ = 6.81, *P* = 0.002) from the habitat composition of the study site. Bobcats most preferred mixed pine/hardwood, mature pine, hardwood, food plot, and wetland areas and least preferred shrub/scrub, pine regeneration, and 'other'.

There was no difference ($F_{7,13}$ = 0.98, *P* = 0.486) in habitat selection between sexes during the summer. The habitat composition of the home range differed ($F_{7,14}$ = 4.44, *P* = 0.009) from the habitat composition of the study site. Bobcats most preferred

Figure 2.1. Regression of male and female bobcat home range size and the amount of food plots found within the home range on Ichauway, Georgia, 2001–2002.


0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
% food plots
1500000
2000000
2500000
3000000
3500000
4000000
4500000
Female home range size

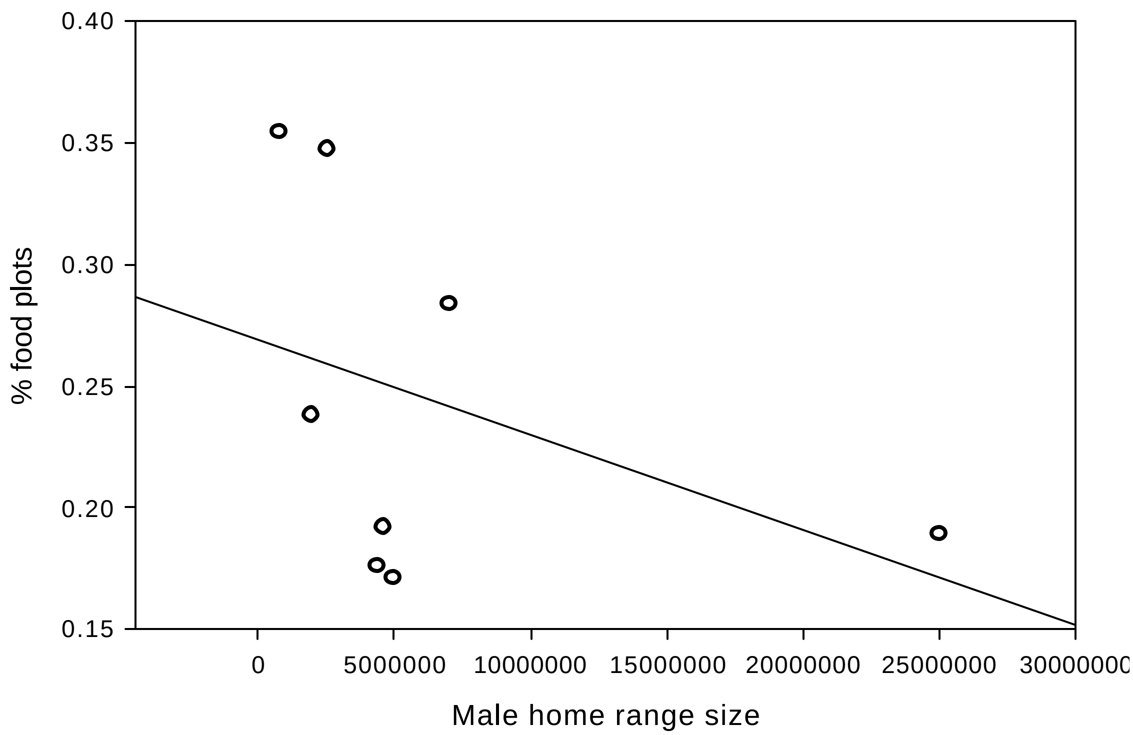
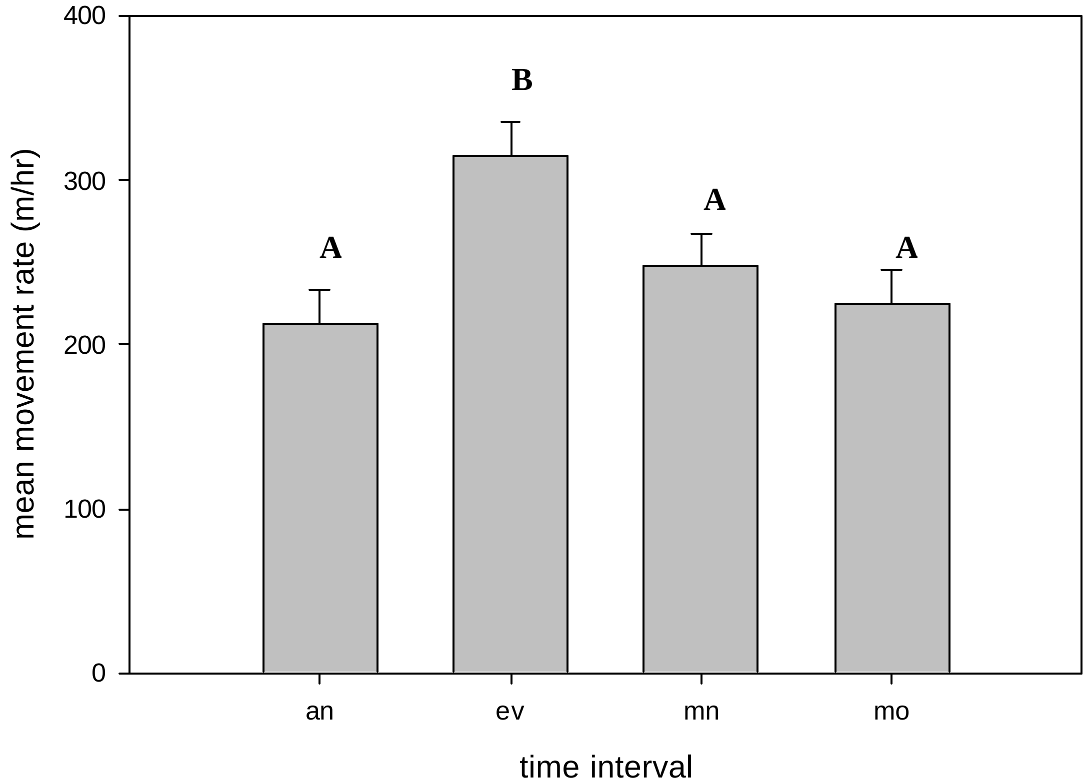

0.40
0.35
0.30
0.25
0.20
0.15
% food plots
0
5000000
10000000
15000000
20000000
25000000
30000000
Male home range size

Figure 2.2. Mean bobcat movement rates (m/hr) during time periods: afternoon (an) = 1100–1659, evening (ev) = 1700–2259, midnight (mn) = 2300–0459, morning (mo) = 0500–1059. Bars with differing letters are significantly different from each other.



400
300
200
100
0
mean movement rate (m/hr)
B
A
A
A
an
ev
mn
mo
time interval

Table 2.2. Seasonal and annual bobcat habitat selection throughout the study site (2º) and within the home range (3º) on Ichauway, Georgia, 2001–2002.

Season	**Level**	**n**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Fall	2º	13	ns	ns	ns	ns	ns	ns	ns	ns
	3º		F_a	H_a	MP_a	P/H_a	PR_{ab}	W_{bc}	O_c	S/S_c
Winter	2º	16	ns	ns	ns	ns	ns	ns	ns	ns
	3º		F_a	MP_b	H_b	P/H_b	W_b	S/S_{bc}	PR_{bc}	O_c
Spring	2º	20	P/H_a	MP_a	H_a	F_a	W_a	S/S_b	PR_b	O_b
	3º		F_a	MP_a	P/H_a	H_{ab}	S/S_{bc}	W_{bc}	PR_c	O_c
Summer	2º	21	P/H_a	F_a	MP_a	H_{ab}	W_b	S/S_b	O_{bc}	PR_c
	3º		H_a	MP_a	P/H_{ab}	A/F_{ab}	PR_{bc}	O_c	W_c	S/S_c
Annual	2º	21	MP_a	H_a	P/H_a	F_a	W_{ab}	S/S_b	O_b	PR_b
	3º		F_a	H_a	MP_a	P/H_b	PR_{bc}	S/S_{bc}	W_c	O_c

habitats with the same subscripts are similar to each other

n = number of animals in analysis, sexes pooled

ns = non significant, F = food plot, S/S = shrub/scrub, H = hardwood, PR = pine regeneration, MP = mature pine, P/H = mixed pine/hardwood, W = wetlands, O = other mixed pine/hardwood, food plot, mature pine, and hardwood areas and least preferred ‘other’ and pine regeneration.

3º selection.--There was no difference between sexes ($F_{6,6} = 0.73$, $P = 0.641$) in habitat selection during the fall. Bobcats used habitat disproportionately ($F_{6,7} = 3.61$, $P = 0.059$) relative to habitat composition of the home range. Bobcats most preferred food plot, hardwood, mature pine, mixed pine/hardwood, and pine regeneration areas and least preferred wetlands, ‘other’, and shrub/scrub (Table 2.2).

There was no difference between sexes ($F_{6,9} = 0.41$, $P = 0.855$) in habitat selection during the winter. Bobcats used habitat disproportionately ($F_{6,10} = 10.38$, $P = 0.001$) relative to habitat composition of the home range. Bobcats most preferred food plots and least preferred shrub/scrub, pine regeneration, and ‘other’.

There was no difference ($F_{6,13} = 0.80$, $P = 0.584$) in habitat selection between sexes during the spring. Bobcats used habitat disproportionately ($F_{6,14} = 6.02$, $P = 0.003$) relative to habitat composition of the home range. Bobcats most preferred food plot, mature pine, mixed pine/hardwood, and hardwood areas and least preferred shrub/scrub, wetlands, pine regeneration, and ‘other’.

There was no difference between sexes ($F_{6,14} = 0.64$, $P = 0.698$) in habitat selection during the summer. Bobcats used habitat disproportionately ($F_{6,15} = 8.84$, $P \leq 0.001$) relative to habitat composition of the home range. Bobcats most preferred hardwood, mature pine, mixed pine/hardwood, and food plot areas and least preferred pine regeneration, wetlands, and shrub/scrub.

Composite.--There was no difference in 2º or 3º habitat selection between sexes during the entire year ($F_{7,13}$ = 0.69, *P* = 0.683, and $F_{6,14}$ = 1.78, *P* = 0.174 respectively). The habitat composition of home ranges differed ($F_{7,14}$ = 4.45, *P* = 0.009) from the habitat composition of the study site. Bobcats most preferred mature pine, hardwood, mixed pine/hardwood, and food plot areas and least preferred wetlands, shrub/scrub, 'other', and pine regeneration (Table 2.2). Bobcats used habitat disproportionately ($F_{6,15}$ = 3.60, *P* = 0.021) relative to habitat composition of the home range. Bobcats most preferred food plot, hardwood, and mature pine areas and least preferred pine regeneration, shrub/scrub, wetland, and 'other'.

Feeding and prescribed fire

There was no interaction between distance to food plot and type of location (e.g., random, male, or female) ($F_{2,3599}$ = 0.00, *P* =0.995). Male and female bobcats were located closer ($F_{2,3599}$ = 220.98, $P \leq 0.001$, M = 232.50 $\pm$ 86.43 m, F = 349.50 $\pm$ 61.35 m; m $\pm$ SE) to supplemental food than random locations (2240.56 $\pm$ 49.96 m; Figure 2.3).

There were no short-term effects of fire on bobcat habitat use. Bobcat locations in the areas burned 30 days before the burn and 30 days after the burn were not significantly different (S = -23, *P* = 0.622).

DISCUSSION

Bobcat home ranges during our study were smaller than in most Southeastern U.S. studies (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 2.3). Small home

Figure 2.3. Mean distance (m) of male and female bobcat locations vs. random locations to supplemental Northern bobwhite food on Ichauway, Georgia, 2001–2002. Bars with the same letter are not significantly different.

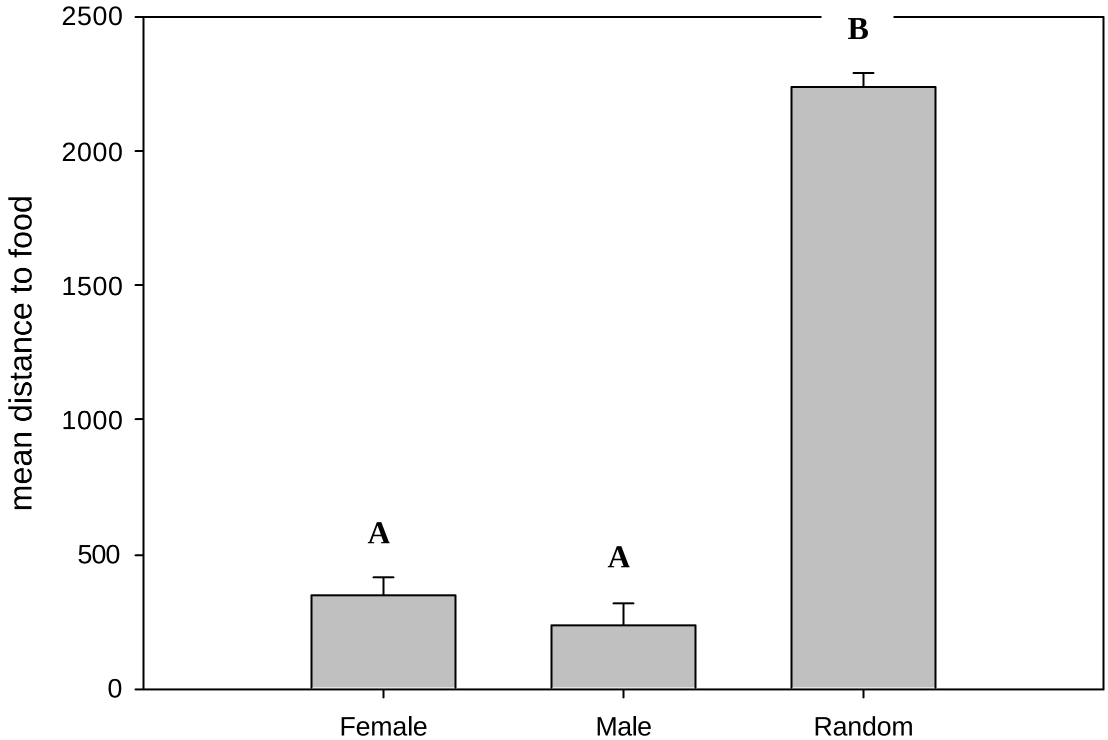

2500
2000
1500
1000
500
0
mean distance to food
B
A
A
Female
Male
Random

Table 2.3. Studies that examined bobcat home range sizes (km^2) and movement rates (km/h) in the Southeast.

Reference	State	Sample Size	Home range M	Home range F	Movement M	Movement F
Hall and Newsom 1976[a, g]	LA	6	4.9	1.0	0.19	0.15
Kitchings and Story 1979[f]	TN	5	42.9	11.5		
Miller and Speake 1979[h]	AL	20	2.6	1.1		
Buie et al. 1979[b, g]	SC	6	20.8	10.3		
Hamilton 1982[h]	MO	30	60.4	16.1		
Kitchings and Story 1984	TN	5			0.20	0.11
Shiftlet 1984[g]	MS	7	10.1	5.9	0.13	0.16
Fendley and Buie 1986[h]	SC	7	3.2	1.6	0.32	0.24
Lancia et al. 1986[a, f]	NC	8[d]	37.7	22.1	0.17	0.22
James 1992[c]	GA	32			0.41	0.34
Rucker et al. 1989[h]	AR	6	64.2	24.5	2.2[e]	
Conner et al. 1992[f]	MS	15	36.5	20.6		
Sullivan 1995	MS	12			0.37	0.34
Griffin 2001[i]	SC	8	10.5-16.7	3.5-10.5	0.02-0.5	0.04-0.2
This Study[i]	GA	21	4.91	2.28	0.19 - 0.34[e]	

[a] = only used summer data, [b] = only used fall and winter data, [c] = only used spring and winter data, [d] = only used 3 bobcats for movement data, [e] = used pooled sex data for average home range or movement rate, [f] = used 95% convex polygon method, [g] = used a modified minimum area method, [h] = used minimum area method, [i] = used adaptive kernal

ranges during our study are likely the result of habitat quality and prey availability as well as a dense bobcat population on Ichauway relative to other study sites.

We found that male bobcat home range sizes were affected by the percent of food plots found in their home range, while female home range sizes were not affected. It is generally accepted that male bobcats are more habitat generalists than female bobcats (Bailey 1979, Anderson 1987, Sandell 1989), but we found the opposite to be true on our study site. We believe that this may be because females had smaller home ranges with high proportions of food plots in them, while males had larger home ranges that contained at least 1 female home range. The male bobcats that had only 1 female within their home range had smaller home ranges and the amount of food plots within the home range may have been greater than male bobcats that may have had 2 or more females within their home range with more corridor area that may not have been prime habitat. However, we do not have enough data to support this hypothesis.

Bobcat movement rates on Ichauway were within the ranges of movement rates in other studies (Hall and Newsom 1976, Kitchings and Story 1984, Lancia et al. 1986, James 1992, Griffin 2001) (Table 2.3). We would expect the movement rates to be greater in home ranges that are larger. The similarity in movement rates could be a result of how the data was collected. We obtained a telemetry location at least every hour, while most of the other studies obtained locations every 2 hours (Hall and Newsom 1976, Kitchings and Story 1984, Fendley and Buie 1986, James 1992, Griffin 2001). Some studies obtained locations every 10 or 15 minutes (Rucker et al. 1989, Sullivan 1995), and one study compared daily locations (Lancia et al. 1986). This could affect the reported movement rate and the subsequent comparison since bobcats don't usually move in a straight line.

Also, the similar movement rates and smaller home range sizes could be attributed to bobcats having constant movement rates overall (Schoener 1969), but their foraging behavior could be affected by prey density (Huey and Pianka 1981). Predators are constantly maintaining territories, looking out for competitors, and monitoring potential mates as well as hunting (Schoener 1969). Many predators exhibit nonrandom foraging which is the tendency of predators to restrict their foraging activity to areas of a recent capture before continuing wide-range foraging again (Curio 1976, Hassell 1978, Kareiva and Odell 1987). With a dense prey base, wide-range foraging could be at a minimum (Holling 1966, Curio 1976) thus affecting home range size.

Bobcats used habitat differently from availability within their home range. Bobcats preferred food plot, mixed pine/hardwood, mature pine, and hardwood areas. Other studies in the Southeast had similar results (Zwank et al. 1985, Rucker et al. 1989, Conner et al. 1992, Conner and Leopold 1996). Bobcats use food plot for hunting because prey (e.g., cotton rats and other small mammals) are also commonly found near agriculture (Cummings and Vessey 1994). Mature pine areas have a dense herbaceous ground cover that would also benefit bobcat prey (Golley et al. 1965). Hardwood and mixed pine/hardwood areas are most commonly associated with wet areas on our study site. The change in habitat selection in the home range from food plots to hardwood and mixed pine/hardwood areas in the summer suggests that bobcats may have hunted less and sought out cooler, shadier areas along the creek and river.

Habitat composition within the home range differed from habitat composition over the study area during the spring and summer. Bobcats preferred mixed pine/hardwood, mature pine, food plot, and hardwood areas. Mixed pine/hardwood and hardwood areas are used for staying cool by escaping heat, or as travel corridors (Rolley 1983, Shiflet 1984, Zwank 1985), while mature pine and food plot areas are productive for prey (Golley et al. 1965, Cummings and Vessey 1994). All these habitats are essential in bobcat ecology for their home range.

Bobcats are attracted to areas supplementally fed for quail. Although supplemental feeding most commonly occurred on food plot edges, we found that supplemental feeding attracted bobcats when controlling for proximity to food plot. This could be because other bobcat prey are also attracted to supplemental food (Boutin 1990). The amount of supplemental feeding did not affect bobcat home range size. Supplemental feeding was so dense throughout the study site that it probably was present in all home ranges at very high densities.

Bobcats did not respond to prescribed fire. We believe that the question of whether or not burning attracts bobcats could better be answered with a more intensive monitoring regime (e.g., locating bobcats more often than every other day) before and after burns.

MANAGEMENT IMPLICATIONS

Quail management practices such as creation of food plots, spreading supplemental food, and prescribed burning are beneficial to quail (Stoddard 1931). Bobcats are attracted to food plots as well as supplemental food, but so are many other species (e.g., cotton rats) that can be detrimental to quail as nest predators (Boutin 1990, Cummings and Vessey 1994). Simpson (1976) found that some quail management practices increased cotton rat densities and that cotton rats could be detrimental to quail populations. Cotton rats compete with quail, eating or damaging plants that are beneficial to quail, and can destroy nests and eggs (Stoddard 1931, Staller 2001).

Although bobcat home ranges were not affected by supplemental food, supplemental food will increase rodent populations (Boutin 1990, L. M. Conner, Joseph W. Jones Ecological Research Center, unpublished data). Dense rodent populations not only attract bobcats but can also attract other predators that prey on quail, such as snakes and birds of prey. Bobcats may benefit quail because they consume other quail predators and may help keep rodent populations in check.

Although bobcats were not directly attracted to recently burned areas, they still probably benefit from the long-term effects of burning on the ecosystem as a whole because prescribed burning enhances prey habitat by suppressing shrubby vegetation and maintaining a dense herbaceous layer (Landers and Mueller 1986).

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CHAPTER 3

BOBCAT DIET IN SOUTHWESTERN GEORGIA ON AN AREA MANAGED FOR NORTHERN BOBWHITE[1]

[1]Godbois, I. A., L. M. Conner, and R. J. Warren. 2003. To be submitted to the Southeastern Association of Fish and Wildlife Agencies.

Abstract: We quantified bobcat (*Lynx rufus*) diet on a longleaf pine (*Pinus palustris*) dominated area managed for Northern bobwhite (*Colinus virginianus*), hereafter quail. We also sorted prey items to species when possible, but for analysis we categorized them into 1 of 5 classes: rodent, bird, deer, rabbit, and other. Bobcat diet did not differ seasonally (χ^2 = 17.82, p = 0.121). Most scats (91%) contained rodent, 14% contained bird, 9% contained deer (*Odocoileus virginianus*), 6% contained rabbit (*Sylvilagus* spp.), and 12% contained other. Because rodents were by far the most important prey item, and because quail management practices create habitat favorable for rodents and other small mammals, which are known predators of quail nests, bobcats may play a key role in controlling rodent populations on land managed for quail.

INTRODUCTION

Bobcats are considered by many land managers to be major predators of quail. Therefore, the interaction between bobcats and quail is important to quail managers. Bobcats are opportunistic predators, and their diet often reflects prey availability (Latham 1951). In the Southeast, bobcats prey most heavily on small mammals such as rabbits and cotton rats (*Sigmodon hispidus*) (Davis 1955, Beasom and Moore 1977, Miller and Speake 1978, Maehr and Brady 1986, Baker et al. 2001). In some regions, bobcats also consume deer. Deer consumption is often highest during fall-winter when there is the possibility for hunter-killed deer to be consumed and during spring-summer when there are more fawns available as prey (Buttrey 1979, Story et al. 1982). Bobcat food habits on lands managed for quail have only been addressed in one other study (Miller and Speake 1978). Food habits of bobcats in a longleaf pine/wiregrass (*Aristida beyrichiana*) ecosystem have never been studied. Therefore, the objective of this study was to quantify bobcat diet on a longleaf pine-dominated area managed for quail and to test for seasonal differences in bobcat diet.

METHODS

The study took place on Ichauway, the 11,700-ha outdoor laboratory facility of the Joseph W. Jones Ecological Research Center, located in Baker County, Georgia. Longleaf pine woodlands dominated the landscape. Slash pine (*Pinus elliottii*) flatwoods, natural loblolly pine (*P. taeda*) stands, mixed pine-hardwood stands, creek swamps, and food plots were distributed throughout the area. Old field grasses (e.g., *Andropogon* spp.) and wiregrass dominated the understory (Goebel et al. 1997). However, more than 1,000 vascular plant species existed on the property (Drew et al. 1998). There were 724 km of primary, secondary, and tertiary roads on Ichauway, as well as 980 km of firebreaks and food plot edges.

Ichauway is managed with dormant and growing season burns in a 2-year rotation on approximately 4,000–6,000 ha annually. To keep areas productive for quail, fields were disked to increase food and cover. Disking removed thicker vegetation and allowed seeding of plants such as ragweed (*Ambrosia artemisiifolia*) and partridge pea (*Chamaecrista fasciculata*) (Landers and Mueller 1986). Widely scattered wildlife food plots consisting 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*) made up 20% of the property. To supplement quail food, grain consisting of corn, grain sorghum, soybeans (*Glycine max*) and sunflower (*Helianthus* spp.) seed was spread throughout the areas managed for quail from

November–May. Supplemental food was spread in thickets and along field edges and food plots.

There was a wide variety of potential prey for bobcats. White-tailed deer occurred at a relatively low density (approximately 4/km^2) on Ichauway (J. Adkins, Joseph W. Jones Ecological Research Center, personal comm.). There were 4 species of squirrel on Ichauway: the Eastern chipmunk (*Tamias striatus*), Southern flying squirrel (*Glaucomys volans*), Eastern gray squirrel (*Sciurus carolinensis*) and fox squirrel (*S. niger*). Two species of rabbits occurred on Ichauway: Eastern cottontail (*Sylvilagus floridanus*), and marsh rabbit (*S. palustris*). Small mammals on Ichauway included mice (e.g., harvest mice [*Reithrodontomys humulis*] and old field mice [*Peromyscus polionotus*]), rats (e.g., cotton rats [*Sigmodon hispidus*] and Eastern wood rats [*Neotoma floridana*]), and insectivorous mammals (e.g., Southern short-tailed shrew [*Blarina carolinensis*] and least shrew [*Cryptotis parva*]). Ground and shrub-nesting birds and herpetofauna were plentiful.

We searched for scat on 30 sections of secondary or tertiary roads, each 1 km in length. We checked each section monthly (21 Jun 2001–24 Jun 2002). We also picked up scat opportunistically. Once located, we placed scats in brown paper bags. Bags were then labeled with the date and location and placed in a freezer. We collected approximately 30 scats each season.

Prior to analysis, we removed scats from the freezer and allowed them to thaw for 24 hours (Griffin 2001). We oven-dried the scats at 60º C for $\geq$ 72 hours (Baker et al. 1993). We weighed dried scats and separated them with forceps. We used hair characteristics (Stains 1958), bone, and teeth to identify prey remains. We identified prey to species when possible, but we placed prey into 5 categories (deer, rodent, rabbit, bird and other) for analysis.

We calculated frequency of occurrence for each prey category, defined as the number of occurrences of a prey category divided by the total number of scats, seasonally. We used a chi-square test (Dowdy and Wearden 1991) to determine if diet was independent of season in SAS (SAS Institute, Inc. 1992).

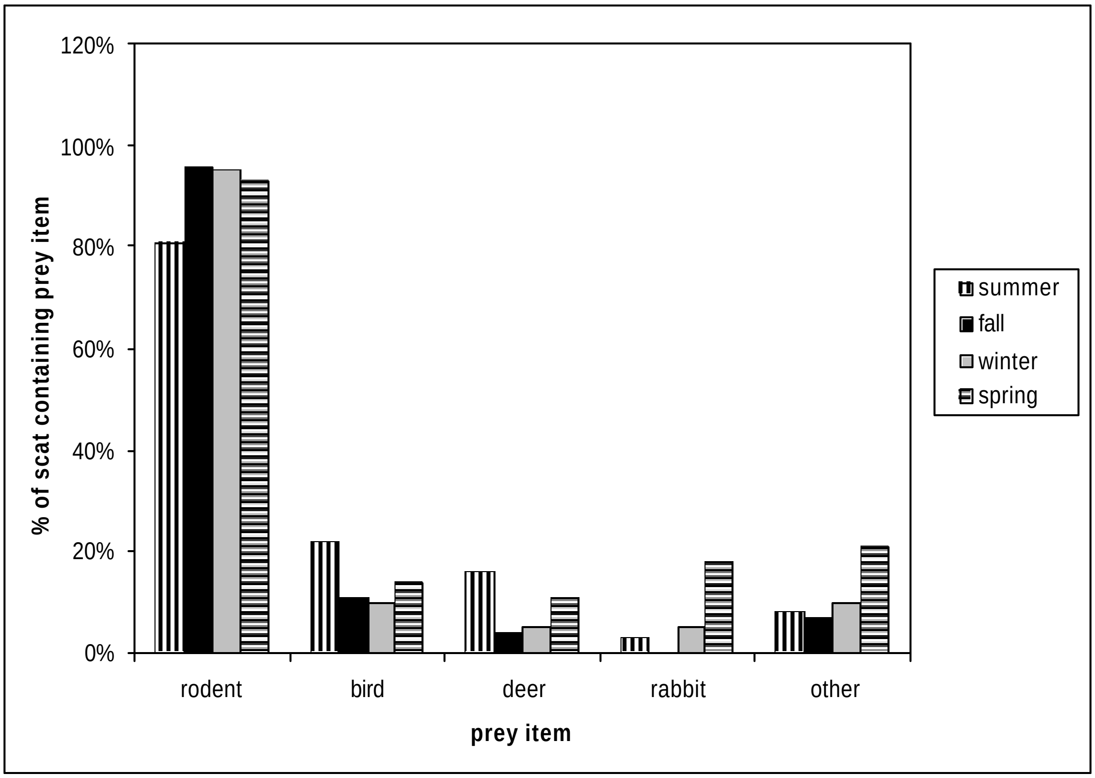
RESULTS

We collected 135 scats between 21 June 2001 and 24 June 2002. Diet did not vary seasonally (χ^2 = 17.82, p = 0.121). Most scats (91%) contained rodent, 14% contained bird, 9% contained deer, 6% contained rabbit, and 12% contained other (Figure 3.1). We identified most of the rodent remains (70%) as cotton rat; 20% were mouse (*Peromyscus* sp.), and 10% were other. Quail made up 10% of the bird remains. We identified 12% of the other remains as armadillo (*Dasypus novemcinctus*), 12% were opossum (*Didelphis virginiana*), 18% were snake, 6% were raccoon (*Procyon lotor*), 6% were skunk (*Mephitis mephitis*), 6% were bobcat, and 40% was vegetation.

DISCUSSION

Bobcat diet has been studied extensively in the Southeast. Most of these studies found that rabbit was the most common prey item (Davis 1955, Progulske 1955, Fitts and Sealander 1978, Kitchings and Story 1979, Story et al. 1982, Maehr and Brady 1986, Nelms 1999, Baker et al. 2001). However, a few studies found that smaller mammals were the most common prey item (Beasom and Moore 1977, Miller and Speake 1978, Buttrey 1979, Griffin 2001), and 1 study found white-tailed deer to be the most common

Figure 3.1. Percent of seasonal prey items in 135 bobcat scats found on Ichauway, Georgia, 2001–2002.



120%
100%
80%
60%
40%
20%
0%
% of scat containing prey item
rodent
bird
deer
rabbit
other
prey item
summer
fall
winter
spring

prey (Fox and Fox 1982). Nine of these 13 studies found that the top 3 prey items were rabbit, rodent, and deer.

Rodents were overwhelmingly the most commonly consumed prey in our study. Rodents often respond favorably to many quail management practices. For example, Boutin (1990) found that supplemental feeding increased small mammal populations. Further, prescribed fire increases herbaceous cover (Landers and Mueller 1986). Prey, such as cotton rats and other small rodents, are most dense in areas with herbaceous cover (Golley et al. 1965). Finally, small mammals are often abundant along agricultural edges (Cummings and Vessey 1994) and food plots associated with game management. We suggest that habitat management on our study area resulted in increased availability of rodents and that bobcats opportunistically fed on small mammals (Latham 1951).

The amount of bird remains, especially quail, found in scats was of particular interest because quail management was an objective for the site. Although birds were the second most common prey they contributed little to the overall diet relative to rodents, occurring in only 19 of the 135 scats. Quail occurred in only 2 of the 135 scats collected. Only 1 other study was conducted on quail managed land (Miller and Speake 1978). They found birds to be the third most common prey with cotton rat being most common. Interestingly, they also observed bobcat consumption of quail to be very low, 2 of 511.

MANAGEMENT IMPLICATIONS

Bobcat prey, particularly small rodents, are positively affected by quail management practices. Although bobcats are considered by managers to be a major quail predators, we found very little predation on quail. Similarly, Miller and Speake (1978) and Maehr and Brady (1986) found bobcats seldom prey on quail (0.9% and 1%

occurrence respectively). Therefore, based on our work and the work of Miller and Speake (1978) and Maehr and Brady (1986), bobcats appear nondetrimental to quail.

Simpson (1976) noticed dense cotton rat populations on quail plantations, and suggested that cotton rats could be detrimental to quail populations. Cotton rats compete with quail, eating or damaging plants that are beneficial to quail, or can even destroy nests and eggs (Stoddard 1931, Staller 2001). Further, dense rodent populations attract other predators that may be efficient predators of quail and quail nests, such as snakes and birds of prey. Because bobcats prey heavily on rodents, they may benefit quail by keeping rodent populations in check. Bobcats also seem to eat more potential quail predators than they do quail.

Apex predators have a stabilizing effect on the ecosystem because they suppress mesopredator populations, allowing for more faunal diversity (Palomares et al. 1995, Rogers and Caro 1998, Courchamp et al. 1999). Bobcats are an apex predator in the Southeast, and thus may serve to suppress other more damaging predators.

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CHAPTER 4

BOBCAT SCAT DEGRADATION: EFFECT OF PREY COMPOSITION ON DIET ANALYSES[1]

[1]Godbois, I. A., L. M. Conner, B. D. Leopold, and R. J. Warren. 2003. To be submitted to the Wildlife Society Bulletin.

***Abstract*:** Many studies have related predator diet to prey detectability in scats, however no studies have examined effects of diet on the persistence of scat in the field. Therefore, we assessed persistence of bobcat (*Lynx rufus*) scats from captive animals fed one of 3 diets; mice (*Mus musculus*)/rats (*Rattus norvegicus*), rabbit (*Oryctolagus cuniculus*), and deer (*Odocoileus virginianus*). Diet affected ($P < 0.001$) degradation. Degradation of scats containing mice/rat was similar ($P > 0.05$) to degradation of scats containing rabbit, but degradation of scats containing deer was greater ($P < 0.05$) than scats containing mice/rat or rabbit. Thus, importance of deer in bobcat diet may be under-represented. We suggest that diet-specific degradation of scats may occur in other species and that research is needed to evaluate this possibility. Studies are also needed to determine adequate sampling intervals to eliminate effects of degradation bias.
Key words: bobcat, captive, degradation, diet-analysis, persistence, scat degradation

Introduction

Carnivore food habits are primarily studied by collecting and sorting scat (Miller and Speake 1978, Buttrey 1979, Johnson and Hansen 1979, Story et al. 1982, Bowyer et al. 1983, Ackerman et al. 1984, Corbett 1989, Baker et al. 1993, Kelly and Garton 1997, Sovada et al. 2001, Baker et al. 2001, Neale and Sacks 2001). Because this is an accepted form of determining food habits, several studies have focused on improving this process. Prey digestibility and detectability have received the most study (Floyd et al. 1978, Weaver and Hoffman 1979, Meriwether and Johnson 1980, Johnson and Aldred 1982). Floyd et al. (1978) found that larger prey were more digestible and therefore underestimated in scat, whereas Weaver and Hoffman (1979), Meriwether and Johnson (1980), and Johnson and Aldred (1982) found that smaller prey were more likely to be completely digested, and therefore, would be underestimated in scat. Kelly and Garton (1997) examined the indigestible matter in scat and linked it back to the representation of prey in scat. They found that amount of bone and teeth of small mammals, digested by coyotes (*Canis latrans*), was determined by meal size, prey size, and meal composition, but the amount of hair digested was not affected by these factors.

Although much research has been done on digestibility of prey items, no research has examined persistence of scats containing different prey. Therefore, we assessed the persistence of bobcat scats containing 3 prey items: mice/rats, rabbit, and deer. If scats containing a particular prey item are less likely to persist, then that prey item may be underestimated in the diet of that animal, with obvious implications for diet analysis.

Methods

Bobcat feeding

We fed captive bobcats housed at the Mississippi State University bobcat research facility located on the Forest and Wildlife Center's Blackjack research site in Starkville, Mississippi. We housed each bobcat, except for 2 kittens, individually in outdoor pens approximately 6 x 6 x 3 m in size. We placed food bowls and water buckets in each pen. All housing facilities were approved by the Mississippi State University Institutional Animal Care and Use Committee (IACUC #96-008).

We obtained frozen mice, rats, and rabbits from The Gourmet Rodent™ (Archer, FL) and Perfect Pets, Inc. (Belleville, MI). Mice weighed 23–35 g, rats weighed 100–150 g, and rabbits weighed 928–1560 g. We obtained the deer diet from hunters.

We used 12 bobcats in the feeding trials, 6 males and 6 females, and all but 2 (1 male and 1 female) were adults. Both juveniles were approximately 6 months old. We fed bobcats 1 whole chicken and then fasted them for 24 hours. We then fed each cat a trial diet for 5 days and scats were collected daily before the pens were cleaned. Feedings occurred from 3 March 2002 until 8 March 2002. Water was provided *ad libitum*.

Diets were assigned randomly to each bobcat. Each mouse/rat diet consisted of an average of 432.2 $\pm$ 13.9 g per day. Each deer diet consisted of an average of 807 $\pm$ 101.8 g of scrap meat (e.g., meat, hide, and bone). Each rabbit diet consisted of half a rabbit, an average of 580.7 $\pm$ 97.4 g. Rabbit diets were alternated between head half and tail half to ensure that each animal got the same amount of hair and bone (Van Domelen et al. 1992).

We placed scats in paper bags labeled with the date, diet, weight of scat and animal identification. They were then placed in a plastic container and stored for approximately 1 week.

Scat decomposition

Once all scats were collected, they were assigned a number and divided into 2 sections. To standardize size of scats, we broke each scat along natural breaks of the scat to minimize disturbance on resulting segments.

We placed scat samples in a small, fallow food plot on Ichauway, the research facility of the Joseph W. Jones Ecological Research Center, located in Baker County, Georgia, USA. Elevation ranged from 30–100 m and was characterized by flat to gently rolling karst topography (Goebel et al. 1997). Soils were in the Dougherty Plain physiographic province (Beck and Arden 1983). Soils had a high sand content and overlaid Ocala and Lisbon limestone (Soil Conservation Service 1986). The climate was subtropical with mild, short, wet winters and hot, humid summers (Lynch et al. 1986). Temperatures averaged 27.5º C in summer and 11º C in winter. Rainfall amounts were relatively evenly distributed throughout the year with annual precipitation averaging 131 cm (Goebel et al. 1997). Summer rainfall was generally associated with frontal systems that tended to be moderate in intensity but long in duration (Christensen 1988).

We placed scats in the selected field and grouped by date of collection. We placed them in a grid of 6–8 lines with 2–3 scats/line. Each scat group was placed 5 meters apart and each scat was placed 0.3 m from each other. We collected and weighed half of the scats in each group after 3 weeks, on 3 April 2002, and the other half after 6 weeks, on 24 April 2002. The average maximum temperature for the first 3 weeks was 26.28º C, the average minimum temperature was 10.56º C, and the average rainfall was 10 cm. The average maximum temperature for the entire 6 weeks was 27.06º C, the average minimum temperature was 12.67º C, and the average rainfall was 13.77 cm. We used an analysis of variance (ANOVA) within a general linear model (GLM) (Dowdy and Wearden 1991) to determine if weight loss varied as a function of exposure time, diet, and their interaction with SAS (SAS Institute, Inc. 1992).

Results

Diet and exposure time did not interact ($F_{2, 83} = 0.34$, $P = 0.713$) to affect decomposition. Scat decomposition varied as a function of diet ($F_{2, 83} = 27.58$, $P \leq 0.001$). Weight loss of scats consisting of mouse/rat (6.1 $\pm$ 0.6 g; $\bar{x} \pm$ SE) and rabbit (4.89 $\pm$ 0.4 g) was similar ($P > 0.05$), but weight loss in scats containing mice/rat or rabbit was less ($P < 0.05$) than weight loss in scats containing deer (9.4 $\pm$ 0.5 g). (Figure

4.1) Scats picked up after 3 weeks (4.8 $\pm$ 0.4 g; $\bar{x} \pm$ SE) lost less ($F_{1, 83}$ = 42.80, $P \leq$ 0.001) weight than scats picked up after 6 weeks (8.6 $\pm$ 0.4 g). (Figure 4.1)

Discussion, research implications, and future studies

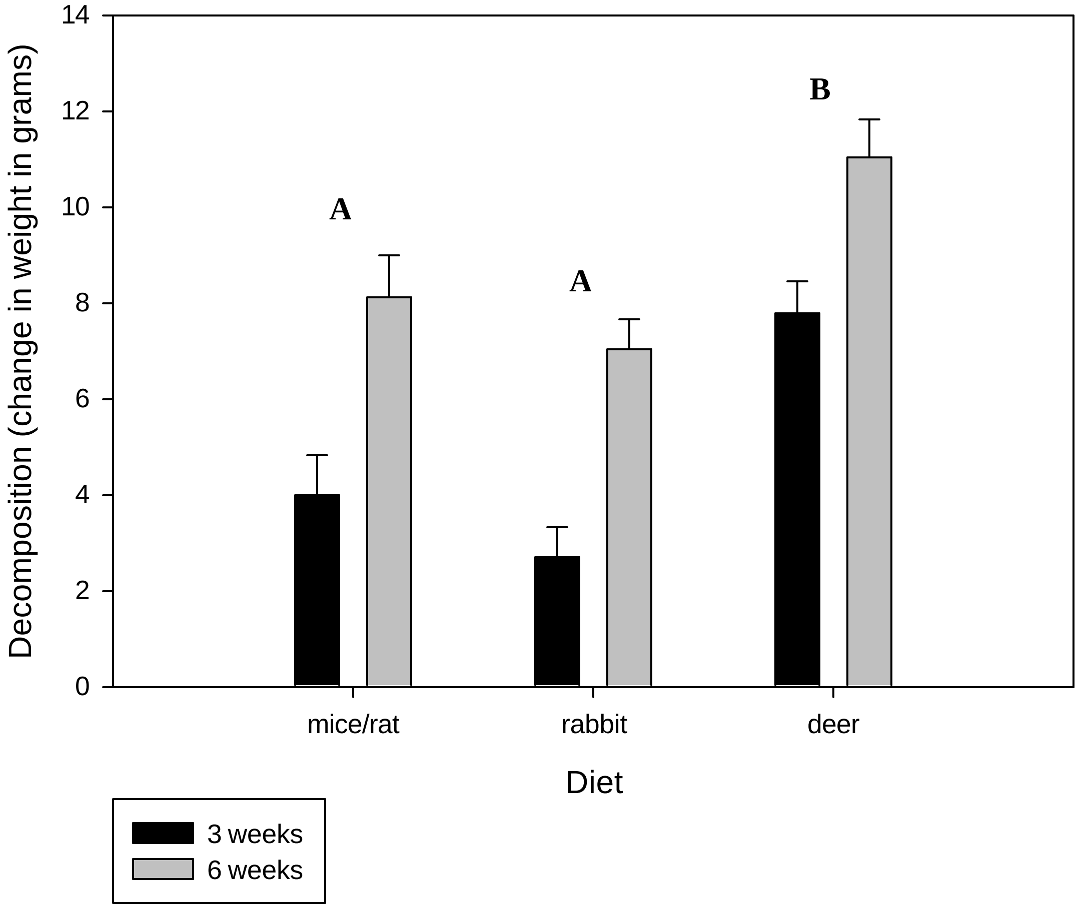
Knowledge of scat persistence is important to researchers for 2 reasons. First, identifying the species that deposited a scat is most easily done when the scat is intact. Second, because many diet studies are conducted using scat, prey-specific persistence presents a potential source of bias.

Scats containing deer lost more weight than scats containing mice/rat and rabbit. Therefore, we suggest that importance of deer in the diet of bobcats may be under represented. Similar studies should be done on other predators to determine if this is a common bias.

Although we fed a limited number of experimental diets, we believe prey size and digestibility may explain our results. Weaver and Hoffman (1979), Meriwether and Johnson (1980) and Johnson and Aldred (1982) found smaller prey were more likely to be completely digested. We found that scat containing deer lost more weight than scat containing smaller mammals. This may occur because small prey is more completely digested (Weaver and Hoffman 1979, Meriwether and Johnson 1980, Johnson and Aldred 1982) and there is less undigested material to attract decomposing organisms that degrade scat.

The longer scats were left in the field, the more they degraded. This is not surprising because there is more time for invertebrates to find and consume any undigested material in the scat. However, this is an important factor in deciding when to do routine searches for scats when conducting a diet study. Because we only looked at 2

Figure 4.1. Decomposition (change in weight) of scat (mean $\pm$ SE), by exposure time and diet. Scats deposited by captive bobcats at the Mississippi State carnivore unit that were fed a diet of deer, rabbit, or mice/rat. Scats were left in a fallow field on Ichauway to degrade. Diets with differing letters were significantly different in decomposition.


Decomposition (change in weight in grams)
14
12
10
8
6
4
2
0
A
A
B
mice/rat
rabbit
deer
Diet
3 weeks
6 weeks

time intervals, it is not possible to specify the optimum time to search for scats. To ensure scats are available and not decomposed, searches should be done at least every month, but more detailed studies should be done to determine the most efficient time interval.

Although we only looked at degradation during spring, we suggest that prey-specific degradation of scats would be similar during other seasons. The absolute rate of degradation, however, may vary seasonally or under different climatic conditions. Studies should be conducted throughout the year to determine if our results are applicable to other seasons.

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CHAPTER 5

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Although bobcats (*Lynx rufus*) have long been considered a predator of Northern bobwhite (*Colinus virginianus*), hereafter quail, by quail managers, their effect on quail numbers seems to be benign. I collected scat throughout the study site, 60% of which is managed for quail, and found that rodents (e.g., cotton rats [*Sigmodon hispidus*], mice [*Peromyscus* sp.]) were the most common prey item. Although bird was the second most common prey item, quail made up a very small proportion of the bird remains I found in scats. In fact, bobcats seemed to prey on other quail predators such as snakes, raccoons (*Procyon lotor*), and armadillos (*Dasypus novemcinctus*) more than they preyed on quail. In order to do a proper diet study in which scat was the unit studied, I found that the more often scat was picked up the better, decreasing the likelihood that the scat would be too degraded to identify and to insure that there were no prey composition biases. Scats containing deer degraded more quickly than those containing mice/rats and rabbit (*Sylvilagus* spp.), and the amount of degradation that occurred was related to time left in the field as well.

Quail management practices such as creation of food plots, burning, and supplemental feeding affect many species in addition to quail by increasing the quality of the habitat available. Small mammals are especially known to respond to these management practices (Boutin 1990, Cummings and Vessey 1994). Bobcats most commonly selected mature pine, hardwood, mixed pine/hardwood, and food plot areas for their home range. Mature pine and hardwood areas are seen as travel corridors (Rolley 1983, Shiflet 1984, Zwank 1985) as well as cool areas to escape the heat. Bobcats most commonly selected food plots, hardwood areas, and mature pine stands within their home ranges. Food plots and mature pines offer better hunting grounds

(Golley et al. 1965, Cummings and Vessey 1994) while hardwood areas offer a cool retreat during the hot summer.

I found that male bobcat home range sizes are affected by the amount of food plots found in them. This leads me to believe that food plots were important to bobcat ecology, although this is not certain without doing more in depth comparisons between areas with food plots and areas without food plots. I found that home range size and movement rates were not affected by the amount of supplemental food found in the home range, but that bobcats were more likely to be found near supplemental food. This is probably due to cotton rats and other rodents that are bobcat prey and are also attracted to supplemental food (L. M. Conner, Joseph W. Jones Ecological Research Center, unpublished data).

Bobcats on Ichauway had smaller home range sizes than found in other southeastern U.S. studies (Hall and Newsom 1976, Miller and Speake 1979, Kitchings and Story 1979, Buie et al. 1979, Hamilton 1982, Shiftlet 1984, Lancia et al. 1986, Fendley and Buie 1986, Rucker et al. 1989, Conner et al. 1992, Griffin 2001). Seasonal home ranges were not different, suggesting that prey was readily available throughout the year. Although I did not investigate denning behavior and fecundity rates directly, the ratio of juvenile bobcat captures to adult bobcat captures suggests that the bobcat population was healthy and stable.

Quail management practices such as creation of food plots and spreading supplemental food are beneficial to quail (Stoddard 1931). Bobcats are attracted to food plots as well as supplemental food, but so are many other species (e.g., cotton rats) that can be detrimental to quail (Boutin 1990, Cummings and Vessey 1994). Simpson (1976) also found that some quail management practices increase cotton rat densities and that cotton rats could be detrimental to quail populations. Cotton rats compete with quail, eating or damaging plants that are beneficial to quail, or can even destroy nests and eggs (Stoddard 1931, Staller 2001). Although bobcat home ranges were not affected by supplemental food, that food will increase rodent populations (Boutin 1990). Dense rodent populations not only attract bobcats but can also attract other predators that prey on quail, such as snakes and birds of prey. Bobcats may benefit quail because they consume other quail predators and may help keep rodent populations in check.

Bobcat mortality on Ichauway and the surrounding areas was mostly caused directly by humans. Of the 5 bobcat mortalities, 3 were trapped and killed on surrounding quail management areas, 1 was hit by a truck, and 1 was killed by another felid. I believe that this was a fair representation of mortality of bobcats in the Southeast especially in areas that have a high concentration of quail-managed land (Hamilton 1982, Zwank et al. 1985, Knick 1990, Fuller et al. 1995, Chamberlain et al. 1999).

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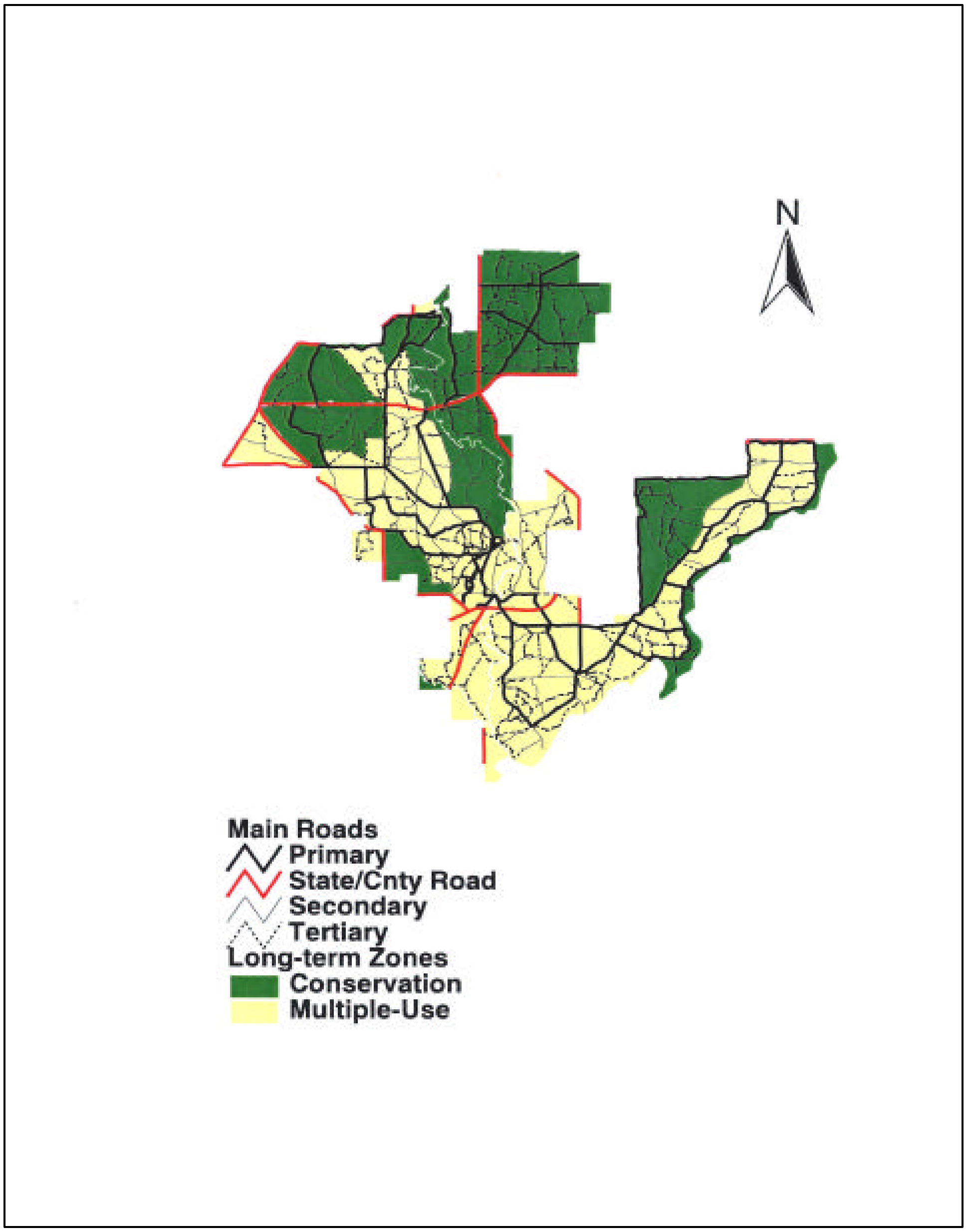
APPENDIX 1

MANAGEMENT ZONES ON ICHAUWAY, GEORGIA, 2000–2002

Conservation zones are areas that are managed to mimic more pristine conditions.

Multiple-use zones are areas that are more heavily managed for wildlife.



APPENDIX 2

DATA COLLECTED ON 27 BOBCATS CAPTURED BETWEEN DECEMBER 2000 AND JULY 2002, ICHAUWAY, GEORGIA

Data collected on 27 bobcats between December 2000 and June 2002 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

APPENDIX 3

INDIVIDUAL HOME RANGE SIZE (KM^2) OF BOBCATS USING THE ADAPTIVE KERNAL (AK) METHOD BY SEX AND SEASON ON ICHAUWAY, GEORGIA, 2001–2002

Individual adaptive kernal home ranges (km²) of 24 bobcats by sex and seasons on Ichauway, Georgia, 2001-2002

Animal Number	Sex	Fall 2001	Winter 2002	Spring 2002	Summer 2002
1	Female	1.455	0.036	0.49	1.229
4	Female	2.802	3.337	2.235	3.282
5	Male	2.278	1.792	2.697	
6	Female				3.281
10	Female	3.651	1.702	0.873	1.518
15	Female	2.326	1.356	2.244	1.296
16	Male	5.683	3.486	2.047	5.181
18	Female	1.885	0.563	1.66	3.898
23	Female	5.025	2.795	3.193	1.482
25	Female	0.846	1.603	2.123	1.502
27	Female	5.457	1.637	0.102	2.522
30	Male	4.908	28.916	10.859	3.918
34	Male	5.304	2.044	5.282	3.377
36	Male		0.367	2.286	4.572
37	Female		1.854	2.837	1.984
39	Female		4.748	4.575	1.809
40	Female				6.392
41	Male		4.456	5.116	7.068
42	Female				2.453
45	Male			3.042	1.710
46	Male			0.317	
47	Female			1.253	1.616
48	Female			1.294	
51	Female				0.828

APPENDIX 4

RANKING MATRICES FOR BOBCAT HABITAT SELECTION BOTH WITHIN THE HOME RANGE (3º) AND THROUGHOUT THE SITE (2º) FOR EACH SEASON AND FOR THE WHOLE YEAR ON ICHAUWAY, GEORGIA, 2001–2002

2º and 3º habitat selection ranking matricies for each season and the whole year on Ichauway, Georgia, 2001–2002. F = food plot, S/S = shrub/scrub, H = hardwood, PR = pine regeneration, MP = mature pine, P/H = mixed pine/hardwood, W = wetland, O = other. $P < 0.05$

Fall Matrix (3º)

	F	S/S	H	PR	MP	P/H	W	O
F		**3.99**	0.75	1.12	1.37	1.56	**2.29**	**4.30**
S/S	**-3.99***		**-3.7**	**-2.49**	**-3.72**	**-3.46**	-0.88	-0.20
H	-0.75	**3.73**		0.80	0.06	0.50	2.00	**3.87**
PR	-1.12	**2.49**	-0.80		-0.84	-0.63	1.53	**2.70**
MP	-1.37	**3.72**	-0.06	0.84		0.66	**2.20**	**4.25**
P/H	-1.56	**3.46**	-0.50	0.63	-0.66		**2.26**	**4.12**
W	**-2.29**	0.88	-2.00	-1.53	**-2.20**	**-2.26**		0.88
O	**-6.91**	0.20	**-3.87**	**-2.70**	**-4.25**	**-4.12**	-0.88	

Winter Matrix (3º)

	F	S/S	H	PR	MP	P/H	W	O
F		1.80	**3.25**	1.98	**2.79**	**4.22**	1.65	**3.74**
S/S	-1.80		-0.79	0.04	-0.92	-0.82	-0.29	0.86
H	**-3.25**	0.79		0.81	-0.38	0.22	0.57	**2.41**
PR	-1.98	-0.04	-0.81		-1.04	-0.88	-0.33	1.19
MP	**-2.79**	0.92	0.38	1.04		0.65	0.92	**3.18**
P/H	**-4.22**	0.82	-0.22	0.88	-0.65		0.52	**2.30**
W	-1.65	0.29	-0.57	0.33	-0.92	-0.52		1.84
O	**-6.33**	-0.86	**-2.41**	-1.19	**-3.18**	**-2.30**	-1.84	

* bold numbers $p < 0.05$

Spring Matrix (3º)

	F	S/S	H	PR	MP	P/H	W	O
F		**2.24**	1.18	**3.71**	0.42	1.22	**2.54**	**4.35**
S/S	**-2.24**[*]		-1.13	1.34	**-2.16**	-1.91	0.23	1.47
H	-1.18	1.13		**2.54**	-0.97	-0.55	1.86	**3.56**
PR	**-3.71**	-1.34	**-2.54**		**-3.94**	**-3.88**	-0.91	0.34
MP	-0.42	**2.16**	0.97	**3.94**		1.27	**2.44**	**4.20**
P/H	-1.22	1.91	0.55	**3.88**	-1.27		**2.07**	**3.97**
W	**-2.54**	-0.23	-1.86	0.91	**-2.44**	**-2.07**		**2.22**
O	**-7.41**	-1.47	**-3.56**	-0.34	**-4.20**	**-3.97**	**-2.22**	

Spring Matrix (2º)

	F	S/S	H	PR	MP	P/H	W	O
F		**3.62**	-0.21	**2.30**	-1.35	-1.83	1.00	**2.49**
S/S	**-3.62**		**-4.14**	0.09	**-3.83**	**-3.64**	**-2.20**[*]	0.41
H	0.21	**4.14**		**2.33**	-0.67	-1.11	1.34	**2.48**
PR	**-2.30**	-0.09	**-2.33**		**-2.38**	**-2.74**	-1.07	0.22
MP	1.35	**3.83**	0.67	**2.38**		-0.68	1.40	**2.97**
P/H	1.83	**3.64**	1.11	**2.74**	0.68		1.46	**3.30**
W	-1.00	**2.20**	-1.34	1.07	-1.40	-1.46		1.23
O	**-2.49**	-0.41	**-2.48**	-0.22	**-2.97**	**-3.30**	-1.23	

Summer Matrix (3º)

	F	S/S	H	PR	MP	P/H	W	O
F		**3.41**	-1.32	1.20	-1.02	-0.59	**2.45**	**2.31**
S/S	**-3.41**		**-4.48**	-1.27	**-4.08**	**-3.65**	-0.40	-0.46
H	1.32	**4.48**		**2.20**	0.67	1.88	**4.02**	**3.97**
PR	-1.20	1.27	**-2.20**		**-2.05**	-1.72	0.86	0.81
MP	1.02	**4.08**	-0.67	**2.05**		1.80	**3.59**	**3.96**
P/H	0.59	**3.65**	-1.88	1.72	-1.80		**3.49**	**3.77**
W	**-2.45**	0.40	**-4.02**	-0.86	**-3.59**	**-3.49**		-0.20
O	**-6.99**	0.46	**-3.97**	-0.81	**-3.96**	**-3.77**	0.20	

Summer Matrix (2º)

	F	S/S	H	PR	MP	P/H	W	O
F		**2.60**	0.31	**4.03**	0.03	-0.21	1.84	**2.12**
S/S	**-2.60**		**-2.10**	**2.83**	**-2.28**	**-2.30**	-0.40	0.92
H	-0.31	**2.10**		**3.82**	-0.23	-0.35	1.61	**2.00**
PR	**-4.03**	**-2.83**	**-3.82**		**-3.61**	**-4.01**	**-2.88**	-1.40
MP	-0.03	**2.28**	0.23	**3.61**		-0.21	**2.24**	**2.39**
P/H	0.21	**2.30**	0.35	**4.01**	0.21		1.83	**2.41**
W	-1.84	0.40	-1.61	**2.88**	**-2.24**	-1.83		1.27
O	**-2.12**	-0.92	**-2.00**	1.40	**-2.39**	**-2.41**	-1.27	

* bold numbers $p < 0.05$

Annual Matrix (3º)

	F	S/S	H	PR	MP	P/H	W	O
F		1.99	0.06	1.98	0.72	**2.41**	**2.90**	**3.66**
S/S	-1.99		-1.91	-0.63	-1.89	-1.59	0.71	0.94
H	-0.06	1.91		**2.17**	0.44	1.48	**2.80**	**3.39**
PR	-1.98	0.63	**-2.17**		-1.91	-1.41	1.13	1.57
MP	-0.72	1.89	-0.44	1.91		**2.10**	**2.59**	**3.55**
P/H	**-2.41***	1.59	-1.48	1.41	**-2.10**		**2.34**	**3.19**
W	**-2.90**	-0.71	**-2.80**	-1.13	**-2.59**	**-2.34**		0.46
O	**-6.87**	-0.94	**-3.39**	-1.57	**-3.55**	**-3.19**	-0.46	

Annual Matrix (2º)

	F	S/S	H	PR	MP	P/H	W	O
F		**4.33**	-0.20	**2.52**	-0.44	-0.01	1.41	**2.28**
S/S	**-4.33**		**-3.69**	1.19	**-3.99**	**-4.00**	-0.28	1.14
H	0.20	**3.69**		**2.63**	-0.20	0.15	1.59	**2.37**
PR	**-2.52**	-1.19	**-2.63**		**-2.29**	**-2.36**	-1.09	-0.02
MP	0.44	**3.99**	0.20	**2.29**		0.32	1.67	**2.60**
P/H	0.01	**4.00**	-0.15	**2.36**	-0.32		1.47	**2.66**
W	-1.41	0.28	-1.59	1.09	-1.67	-1.47		1.31
O	**-2.28**	-1.14	**-2.37**	0.02	**-2.60**	**-2.66**	-1.31	

* bold numbers $p < 0.05$

APPENDIX 5

MEANS AND STANDARD DEVIATIONS OF MOVEMENT RATES (M/HR) OF MALE AND FEMALE BOBCATS DURING THE AFTERNOON = 1100–1659, EVENING = 1700–2259, MIDNIGHT = 2300–0459, AND MORNING = 0500–1059 BY SEASON ON ICHAUWAY, GEORGIA, 2001–2002

Means and standard deviations of movement rates (m/hr) of male and female bobcats during meaningful time periods by season on Ichauway, 2001–2002

Season	Sex	N	Time	Mean	SD
Fall	Female	8	afternoon	223.97	148.45
		8	evening	269.56	198.43
		6	midnight	338.16	205.85
		7	morning	203.23	99.86
	Male	5	afternoon	174.82	81.91
		5	evening	241.17	126.39
		5	midnight	251.94	136.87
		5	morning	156.41	55.80
Winter	Female	10	afternoon	191.37	169.54
		10	evening	337.95	287.17
		10	midnight	285.52	128.98
		10	morning	201.14	89.84
	Male	6	afternoon	209.47	158.11
		6	evening	375.98	248.91
		5	midnight	491.89	448.50
		4	morning	210.29	85.58

Season	Sex	N	Time	Mean	SD
Spring	Female	12	afternoon	226.99	123.77
		12	evening	202.85	107.16
		12	midnight	196.68	97.53
		11	morning	290.07	266.21
	Male	8	afternoon	228.6	128.14
		7	evening	311.11	186.50
		6	midnight	983.85	1783.26
		6	morning	653.59	952.62
Summer	Female	12	afternoon	257.519	172.53
		13	evening	299.897	215.78
		14	midnight	231.030	112.57
		15	morning	311.749	233.09
	Male	4	afternoon	395.478	266.74
		6	evening	351.712	244.42
		6	midnight	308.081	242.41
		4	morning	311.528	232.47

APPENDIX 6

DESCRIPTION OF BOBCAT MORTALITIES IN SOUTHWESTERN GEORGIA, 2001 AND 2002

Five bobcat mortalities occurred during the course of this study. One was hit by a truck, 3 were killed by trappers, and 1 was killed by another felid. An adult female (B007) was hit by a truck on Ichauway on 21 June 2001. It was last located on 19 June 2001. The carcass was immediately recovered. It was found to be in good body condition.

An adult male (B003) was trapped on Pinebloom Plantation, 5-10 miles from Ichauway, on 27 Sep 2001. It was initially caught on 4 Jan 2001, but never located with telemetry. The carcass was not recovered.

An adult male (B014) was trapped on Longleaf Plantation, neighboring quail managed land, on 29 Oct 2001. It was last located on 5 Oct 2001, 5 miles away from the capture location. The carcass was immediately recovered. It was found to be in good body condition.

An adult male (B026) was killed on Ichauway by another felid on 28 Jan 2002. It was last located on 27 Jan 2002. The carcass was cached and had extended front claws. No bite marks or other wounds were visible. We opted to leave the carcass there as bait surrounding it with 3 leg hold traps and a video camera in hopes of catching the animal that may have killed it.

An adult male (B032) was trapped near the Baker County/Miller County line, about 10 miles from Ichauway, on 28 Jun 2002. It was last located on 19 May 2001. It was found to be in good body condition.