SPACE-USE PATTERNS OF BOBCATS RELATIVE TO SUPPLEMENTAL FEEDING OF NORTHERN BOBWHITES

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Abstract: In the southeastern United States, supplemental feeding of northern bobwhites (*Colinus virginianus*) is a common management practice. To determine whether bobcats (*Lynx rufus*) are attracted to supplemental food provided to northern bobwhites and whether this food affects bobcat home-range size, we radiomarked bobcats and assessed space use relative to supplemental feeding. We found little evidence to suggest that bobcat home-range sizes were affected by the supplemental food, but we observed bobcats to be approximately 10 times closer to supplemental food than expected under a null model. Our data suggest that supplemental feeding of prey can result in a spatial response by predators. Further research is needed to determine whether supplemental feeding of prey attracts other top predators and whether supplemental feeding results in decreased prey survival by attracting predators.

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Throughout portions of North America, supplemental feeding of wildlife is commonly used as a management tool, but such artificial feeding is controversial (Dunkley and Cattet 2003). In the southeastern United States, supplemental feeding of the northern bobwhite (hereafter quail) is a widely employed management practice (Landers and Mueller 1997, Townsend et al. 1999, Thackston and Whitney 2001). Supplemental feeding can increase winter survival rates in adult quail (Townsend et al. 1999), provide an important food source in unproductive habitat (Landers and Mueller 1997), and increase body condition of quail (Robel 1969). However, supplemental food also may concentrate prey species (Boutin 1990, Doonan and Slade 1995) and alter the spacing behavior of their predators. If predators alter their behavior and spend more time near supplemental food, then the probability of a predation event occurring will increase.

Supplementally feeding predators directly can cause them to concentrate their activity near the supplemental food and alter their foraging behavior (Crabtree and Wolfe 1988, Gasaway et al. 1992, Vander Lee et al. 1999, Jones et al. 2002), as well as increase their reproduction (Clark et al. 1996). However, we found no studies that have examined the behavioral response of predators to the supplemental feeding of prey (i.e., indirectly feeding predators). Bobcats are a top carnivore that preys on species (e.g., cotton rats [*Sigmodon hispidus*]) attracted to grains used to feed quail (Beasom and Moore 1977, Miller and Speake 1978, Buttrey 1979, Griffin 2001). We therefore studied space use of bobcats to determine whether presence of supplemental food for quail altered bobcat home-range size and bobcat locations relative to the location of supplemental food.

STUDY AREA

We conducted our study on Ichauway, the 11,700-ha outdoor laboratory facility of the Joseph W. Jones Ecological Research Center, located in Baker County, Georgia, USA. 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, >1,000 vascular plant species were present on the property (Drew et al. 1998). Ichauway contains 724 km of primary, secondary, and tertiary roads and 980 km of firebreaks and food-plot edges.

Ichauway personnel employed 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 disced to increase food and cover. Discing removed thicker vegetation and allowed seeding of plants such as ragweed (*Ambrosia artemisiifolia*) and partridge pea (*Chamaecrista fasciculata*; Landers and Mueller 1997). Widely scattered wildlife food plots consisting of grain sorghum (*Sorghum vulgare*), Egyptian wheat (*Sorghum* spp.), brown top millet

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(*Brachiaria ramose*), cowpea (*Vigna* spp.), corn (*Zea mays*), and winter wheat (*Triticum aestivum*) made up 20% of the property. To supplement native quail foods, approximately 270 metric tons of grain sorghum was spread over 7,020 ha throughout the areas managed for quail from November to May. Supplemental food was spread along field edges, food plots, and through upland, pine-dominated forests, resulting in a well-dispersed distribution of food (Fig. 1).

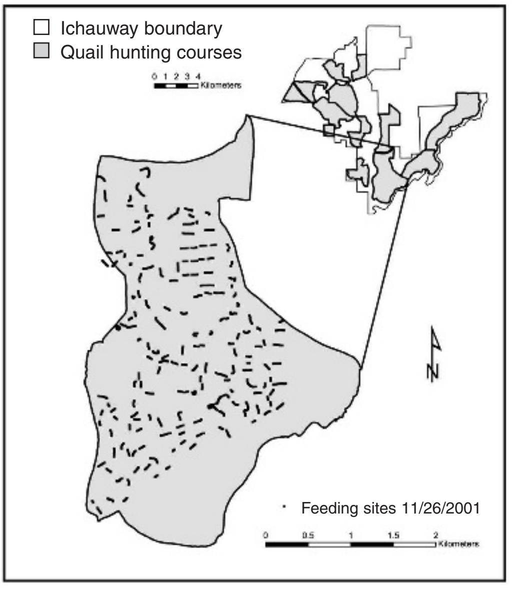

Fig. 1. Map showing supplemental food spread during 1 day in 1 quail course on Ichauway, Georgia, USA, 2001.

METHODS

Bobcat Capture and Monitoring

We trapped bobcats using #3 Victor Soft Catch traps (Woodstream Corporation, Lititz, Pennsylvania, USA) during December 2000–November 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 checked the animal for any injuries or abnormalities. We recorded sex, body weight, total length, tail length, hindfoot length, and ear length of each animal. We used weight and total body length as well as characteristics of teeth, teats, and scrotum to determine whether the animal was an adult or juvenile (Crowe 1975). We placed a 180-g radiocollar (Advanced Telemetry Systems, Isanti, Minnesota, USA) on all adult bobcats. We tattooed a unique number in the ears of all bobcats. We monitored bobcats for 24 hr and then released them at the capture site.

We initiated radiotracking 7 days after bobcat release. We used a hand-held, 3-element yagi antenna (Sirtrak, New Zealand) and a hand-held receiver (Wildlife Materials, Carbondale, Illinois, USA) to locate bobcats using triangulation from known reference points. We obtained locations twice per day, 3 times per week, allowing ≥8 hr between locations. We considered all animal locations to be biologically independent. Each week, we shifted the starting time of radiotracking to 2 hr later. Thus, we ensured that the entire diel period was sampled every 12 weeks. Repeated tests of radiotelemetry accuracy suggested that the standard deviation from the true bearing was approximately 7°.

Data Analysis

To calculate home range, we used the FORTRAN program EPOLY (L. M. Conner, unpublished data) to determine Universal Transverse Mercator coordinates for animal locations obtained from telemetry bearings. We then used program HOMERANGER (Hovey 1997) to derive 95% adaptive kernel (Worton 1989) home-range estimates for all bobcats with ≥40 locations (range = 40–275), exceeding the minimum sampling recommendations of ≥30 locations suggested by Seaman et al. (1999). We converted home ranges into ARC/INFO (Environmental Systems Research Institute 2002) coverages (i.e., digital thematic maps) for further analysis.

We used tractor-mounted Global Positioning System (GPS) units to determine locations of supplemental food. Tractor-mounted spreaders dispersed seed at a constant rate. Therefore, we recorded GPS locations every 5 sec along each feeding trail and used these locations within a bobcat home range as an index of amount of food provided within the home range.

Although feeding started on 5 November 2001, we allowed 1 week for animals to find supplemental food. To assess effect of supplemental feeding on home-range size, we used 2 analytical approaches. First, we calculated home ranges for bobcats from data collected during the period 12 November 2001–31 May 2002, and we counted the number of GPS locations (i.e., index of supplemental food) within the home range using ARC/INFO (Environmental Systems Research Institute 2002). We then used linear regression

(Dowdy and Wearden 1991) in SAS (SAS Institute 1992) to examine the effects of sex (a dummy variable), percent area of the home range occupied by food plots, supplemental food index, and all interactions on bobcat home-range size.

Second, we examined those animals that had received <60 min (i.e., <300 GPS locations) of feeding within their home range during the entire period supplemental food was provided. Bobcats receiving <60 min of feeding within their home range, on average, received <3% of the supplemental food provided within the home ranges of the remaining bobcats. Therefore, we treated bobcats having <60 min of feeding within their home range as control animals. We calculated home ranges for the 2001–2002 winter (i.e., when food was being provided) and for the summer of 2002 (i.e., when food was not being provided). We then used a before-after-control-intervention (BACI) design (Stewart-Oaten and Murdoch 1986) and an analysis of variance, blocking on individual bobcat, to determine whether supplemental feeding of prey affected bobcat home-range size. Here, a significant treatment (fed or control)-by-season (winter or summer) interaction would indicate supplemental food altered home-range size of bobcats.

We used the ARC/INFO (Environmental Systems Research Institute 2002) NEAR function to determine the distance between bobcat locations and the nearest supplemental food that had been placed prior to obtaining the location. Because supplemental feeding occurred on a daily basis, we generated a random location for each bobcat location for each date that bobcats were located. Random locations (n = 1,805) were generated from a uniform distribution and were created such that they fell within the area bounded by a convex polygon encompassing all bobcat locations for the period of interest. Then, for each date of sampling, we calculated the average distance between male, female, and random locations to the nearest supplemental food.

Because supplemental food often was placed along field edges, we also used the NEAR function in ARC/INFO (Environmental Systems Research Institute 2002) to determine the distance between the nearest field edge and male, female, and random locations. Distances to field edges were treated much like distances to supplemental food, but instead of treating distance to field edge as a dependent variable, we treated distance to field edge as a covariate. We used analysis of covariance (ANCOVA) to examine the effects of the type of location (e.g., male, female, or random), the distance to field edge, and their interaction on distance to food. We used least-squared means in SAS (SAS Institute 1992) to estimate means and standard errors of distance to food for male, female, and random bobcats.

RESULTS

We monitored 16 bobcats (10 F, 6 M) during the season that supplemental food was spread. Male and female home-range sizes did not differ ($F_{1,9}$ = 2.08, P = 0.1829) during the period that supplemental food was available, and our regression analysis indicated that supplemental feeding had no effect ($F_{1,9}$ = 0.26, P = 0.6216) on home-range size.

Although home-range sizes generally were smaller during winter (control animals: 2.52 ± 0.95 km^2 [$\bar{x}$ ± SE], treatment animals: 2.70 ± 0.63 km^2) when supplemental food was available than during summer (control animals: 3.04 ± 0.59 km^2, treatment animals: 3.14 ± 0.55 km^2) when food was not provided, the BACI design relies on the season × treatment interaction to discern actual treatment effects; testing for differences in main effects is inappropriate. When we investigated the interaction term to assess whether apparent seasonal differences in home-range size were related to supplemental feeding, we found no evidence (treatment × season interaction; $F_{1,12}$ = 0.02, P = 0.890) that supplemental food altered home-range size.

We found no interaction ($F_{2,290}$ = 0.04, P = 0.9574) between distance to field edge and type of locations (e.g., random, male, female). Males (222 ± 187 m) and females (363 ± 144 m) were found closer ($F_{2,290}$ = 53.08, P < 0.0001) to supplemental food than were random locations (2,350 ± 61 m; Fig. 2).

DISCUSSION

We observed bobcats to be approximately 10 times closer to supplemental food than expected under a null model. On our study area, bobcats most commonly consumed rodents (91% frequency of occurrence), and most (70%) rodent remains were identified as cotton rats (Godbois 2003). Doonan and Slade (1995) observed cotton rats to be approximately 2.5 times denser in supplementally fed areas than in control areas. Similarly, Boutin (1990), in his review of the effects of supplemental feeding on terrestrial vertebrates, concluded that supplemental feeding resulted in a 2- to 3-fold increase in population density of small-bodied herbivores. A preliminary analysis

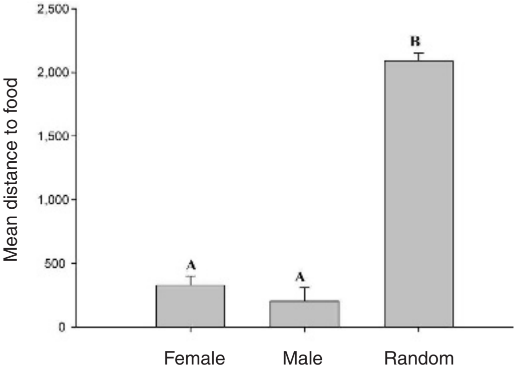

Fig. 2. Least-squared mean distance of male and female bobcat locations versus random locations to supplemental food placed for northern bobwhite on Ichauway, Georgia, USA, 2001–2002. Standard error bars with different letters are different ($P < 0.001$).

of data collected on our study site suggested that populations of house mouse (*Mus musculus*) were 3.5 times greater, cotton mouse (*Peromyscus gossypinus*) were 1.5 times greater, eastern harvest mouse (*Reithrodontomys humilis*) were 2 times greater, and cotton rat were 5.5 times greater on fed sites than non-fed sites (L. M. Conner, unpublished data). The preponderance of rodents in the diet of bobcats on our study area, the reported effects of supplemental food on rodent densities, and our preliminary analysis of the effects of supplemental food on rodent populations lead us to suggest that supplemental food concentrated bobcat prey and subsequently increased use of supplementally fed areas by bobcats.

Bobcat home-range size was not affected by the amount of supplemental food found within their home range. Because supplemental food was well dispersed throughout the study site, we suggest that bobcats had no need to concentrate their movements around a particular supplementally fed site. Rather, we speculate that bobcats moved among supplemental feeding sites, thereby increasing encounters with rodents and leading to increased use of fed relative to unfed areas. Further, because supplemental food was only temporarily available, territoriality may have resulted in home-range sizes that were independent of supplemental food.

MANAGEMENT AND RESEARCH IMPLICATIONS

Wildlife populations often become concentrated as a result of supplemental feeding (Boutin 1990, Doonan and Slade 1995). Increased animal densities may lead to increased competition (Schmitz 1990), increased incidence of disease (Schmitt et al. 1997), and/or increased predation (Stoddard 1931, Simpson 1976, Staller 2001). Also, nontarget species may consume supplemental food that was meant for other animals, increasing costs associated with a wildlife feeding program (Landers and Mueller 1997). However, for some species, supplemental feeding may be beneficial (Townsend et al. 1999). The net long-term effect of supplemental feeding programs will likely vary, necessitating the need for long-term, community-level studies of the effects of supplemental feeding.

Increased densities of nontarget species that consume supplemental food also may attract predators that subsequently prey on target species. For example, supplemental food intended for consumption by quail may result in locally dense rodent populations. If predators are attracted to these dense rodent populations, incidental predation on quail may increase. However, bobcats do not appear to be a major predator of quail (Miller and Speake 1978; <2% frequency of occurrence on our study area [Godbois 2003]), and bobcats may help keep other predator populations in check through competition for prey or direct predation (Godbois 2003). Clearly, further research is warranted to better elucidate indirect effects of supplementally feeding wildlife.

Future research should evaluate population dynamics of wildlife populations within fed and non-fed areas. Such experimentation should focus on understanding the underlying mechanisms responsible for any differences in population dynamics as a function of feeding. Competition for supplemental food between wildlife species and the effects of predators on reducing that competition also warrant further study.

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