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EFFECTS OF SUPPLEMENTAL FEEDING ON BREEDING SEASON HOME RANGES AND RESOURCE SELECTION OF NORTHERN BOBWHITES

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ABSTRACT

Providing supplemental food resources for northern bobwhite (*Colinus virginanus*) has been a common management practice for decades, but its impact on bobwhite home ranges sizes and space use has been debated. Between 2001 and 2007, we established a 397 ha fed study area on Tall Timbers Research Station, which received grain sorghum biweekly along a 19.5 km feed trail. An adjacent 465 ha area was treated as a control with no supplemental food resources. Radio-tagged wild bobwhites were located 3 – 5 times each week throughout the breeding season and we used these locations to calculate home ranges during early breeding season (15 April – 30 June) and late breeding season (1 July – 1 October). We also determined second and third order selection of a 10-m buffer area surrounding the supplemental feed trail using compositional analyses. In total, 552 and 286 bobwhite home ranges were calculated for early and late breeding seasons, respectively. We observed significantly smaller early breeding season home ranges on the fed area ($\bar{x} = 12.3$ ha, 95% CL $\pm$ 0.6) relative to the control ($\bar{x} = 17.4$ ha $\pm$ 1.9). Average length of feed trail within home ranges was 583 m and 710 m for early and late breeding season home ranges, respectively. The feed trail buffer area was 3 to 5% of all home ranges. Home range placement was not random with high selection preference for the feed trail buffer area. However, there was a low selection preference for the feed trail buffer area within home ranges. Average distances to the feed trail for bobwhite locations ($\bar{x} = 64.4$ m $\pm$ 16.1) was similar to random locations ($\bar{x} = 74.4$ m $\pm$ 16.9). The effect of supplemental feeding on bobwhite home ranges size and resource use was greatest during the early breeding season when food and useable habitat were likely lower in availability. On our study area, supplemental food resources distributed along a feed trail impacted bobwhites during a critical transition period from the spring prescribed burning season to the early breeding season.

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Key words: *Colinus virginanus*, Florida, home range, northern bobwhite, resource selection, supplemental feeding

INTRODUCTION

Providing supplemental food resources for northern bobwhites (*Colinus virginanus*) (hereafter: bobwhite or quail) has been a common management practice for many decades (Frye 1954, Guthery 1986, Sisson et al. 2000). Historically, stationary feeders have been used to provide a high energy grain such as sorghum (*Sorghum bicolor*, hereafter: milo), and/or corn (*Zea mays*) (Townsend et al. 1999, Doerr and Silvy 2002, DeMaso et al. 2002, Guthery et al. 2004). Concern exists that supplemental feeding may increase disease transmission, predation, and harvest, because bobwhites are attracted to a known point (Godbois et al 2004, The Wildlife Society 2006). More recently supplemental feeding with milo along a designated feed trail has become a widely-used management practice on quail hunting properties (Michener et al. 2000, Sisson et al. 2000, Haines et al. 2004, Buckley et al. 2015). Spreading grain along a continuous feed trail through suitable habitat may not concentrate bobwhites at a location, therefore alleviating these concerns; however research on the effects of a feed trail on home range size, placement, and resource selection is limited.

Initially, supplemental feeding was used during the nonbreeding season to provide high energy foods during winter months when declining food resources and severe weather reduced availability of native foods to bobwhites (Frye 1954, Robel and Slade 1965). As such, researchers have focused on effects of supplemental feeding on bobwhite nonbreeding season movements and home ranges (Sisson et al. 2000, Buckley et al. 2015, Miller et al. this volume). In southwest Georgia, Sisson et al. (2000) observed smaller nonbreeding season home ranges on a supplemental feed trail area compared to a nearby but separate control area and noted more localized move-

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ments and shorter foraging times on the fed area. Similar results were observed in south Texas with decreased home range size and localized movements around feed trails on a treatment area (Haines et al. 2004) when compared to control area. Conversely, Buckley et al. (2015) in the Rolling Plains of Texas and Miller et al. (this volume) in northern Florida observed no effect on home range size during the nonbreeding season from supplemental feeding.

Supplemental feeding during the breeding season may affect bobwhites differently than during the nonbreeding season. During the breeding season bobwhites have access to increased natural food availability, such as insects, fruits, and seeds. Further, habitat availability and the suitability of those habitats rapidly change during the breeding season, especially in pine savanna systems with frequent prescribed fire. After the application of prescribed burning during March – April, bobwhites use the previous year's habitat for cover and nesting until vegetation recovers in burned habitats, then increasingly use burned habitats for nesting and brooding during late summer (Stoddard 1931, Carver et al. 1998). The presence of a supplemental feed trail may affect bobwhites' home range size and spatial position, and how bobwhites allocate time in habitats within their home range, and these effects may be different in the early versus late breeding season.

Research on the impacts of supplemental feeding on bobwhite habitat and resource use during the breeding season is lacking. Therefore, the objectives of this research were to determine the impacts of a continuous supplemental feed trail during 2 time periods within the breeding season for the following variables: 1) home range size, 2) second and third order habitat and resource selection (Johnson 1980), and 3) location proximity to the feed trail. This research project was part of a larger experiment that investigated the impacts of supplemental feed on multiple bobwhite parameters, including survival and reproductive output during the breeding season; these data will be presented in a separate manuscript.

STUDY AREA

We conducted this study on Tall Timbers Research Station (TTRS) (1,568 ha), Leon County, Florida (30.66° N, 84.22° W). The landscape composition of TTRS was rolling hills consisting of primarily upland pine forests (66%) including loblolly pine (*Pinus taeda*), shortleaf pine (*Pinus echinata*), and longleaf pine (*Pinus palustris*) in the overstory, and equal proportions of grasses, forbs, and shrubs associated with "old-field" plant succession in the understory. Intermixed throughout the uplands were mesic hardwood-dominated drainages and wetlands (17%), annually disked fallow fields (13%) which were 0.4 to 1.2 ha in size, and open wet areas (4%). Prescribed fire was used throughout TTRS on a 2-year interval to control encroachment of hardwood trees and to maintain the mix of herbaceous and woody ground cover. Approximately, 50% of the uplands were burned each year between March and April in an alternating mosaic of patches ranging from 2 to 20 ha. Other management practices used were spot mowing and roller chopping of hardwood and pine saplings in recently burned upland areas to assist with hardwood control. In 2007, a selective timber harvest was completed on all upland portions of the study areas. Land management objectives were to optimize upland habitat suitability for bobwhites throughout the year.

Between January 2001 and December 2007, TTRS was divided into 2 approximately equal sides with 1 side receiving supplemental feed (hereafter: supplemental feed treatment area or fed area) that was 397 ha in size and the other side with no supplemental feed (hereafter: control area) was 465 ha. On the fed area, approximately 1,651 kg (2,290 liters) of milo seeds were scattered along a designated feed trail every 2 weeks, year around, throughout the upland pine forest and fallow field edges in areas useable by bobwhites (Figure 1). Supplemental feed was applied using a tractor with an attached broadcast spreader. The feed trail was established to maintain a consistent line density of 2.4 km of feed trail per 40.5 ha of useable habitat over the entire fed site, which summed to an overall feed trail length of 19.5 km. The overall rate of milo spread every two weeks was 84.6 kg of milo per each km of feed trail.

METHODS

Telemetry Data

For the years, 2001 – 2007, bobwhites were captured in January and March using standard walk-in funnel traps (Stoddard 1931). We determined sex, age class, and weight for each captured bobwhite and attached a uniquely numbered aluminum leg band (National Band and Tag Co., Newport, KY 41072). From each captured covey we selected 2-3 bobwhites to be fitted with a 6-g radio transmitter (American Wildlife Enterprises, Monticello, FL 32344). Radio transmitters were distributed at an approximate ratio of 1 radio-tagged male to 4 radio-tagged females. In January, trapping efforts and radio distributions were equally applied to all areas of TTRS, while March trapping was focused on areas with an inadequate radio tag sample. Trapping, handling, and marking procedures were consistent with Palmer and Wellendorf (2007) and followed the guidelines of the Tall Timbers Research, Inc. Institutional Animal Care and Use Committee Permit (#GB2001-01).

For all years, radio-tagged bobwhites were located 1 to 3 times weekly until 15 April and then 3-5 times weekly thereafter until 1 October. We determined locations of radio-tagged individuals using homing procedures (White and Garrott 1990) and then marked locations on detailed landcover maps developed in ArcGIS (ESRI, Redlands, CA). While the precision of calculated locations to the actual locations of radio-tagged bobwhites has not been formally determined, we thoroughly trained technicians on the homing technique to ensure they determined locations to within at least a 10 m^2 area. Additionally, they verified that the correct macrohabitat landcover type (e.g., burned upland, unburned

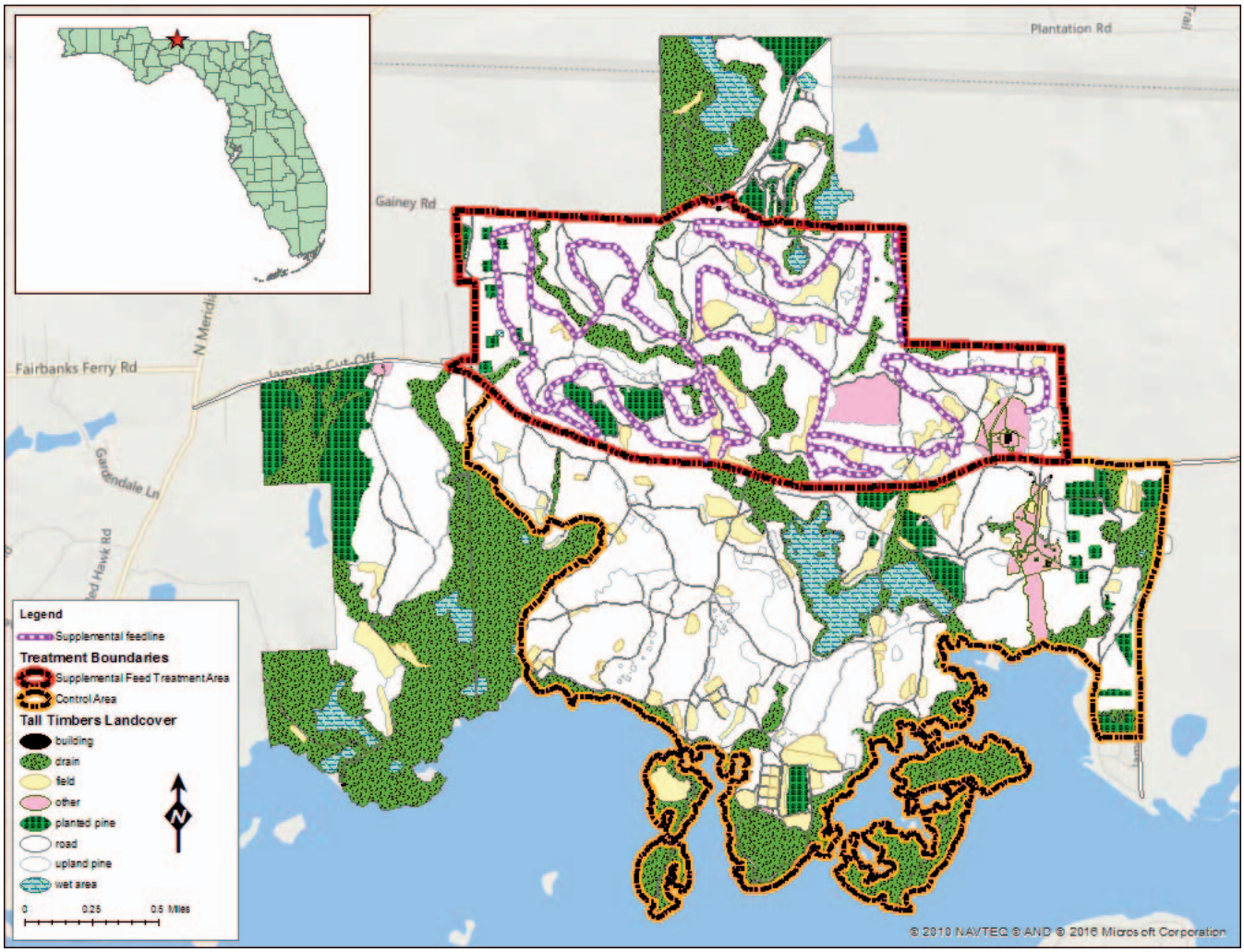

Fig. 1. A map of the supplemental feed treatment area with the feed trail and the control area on Tall Timbers Research Station and Land Conservancy, Leon County, FL, USA.

upland, field, hardwood drain) or feed trail was assigned to the location. Transmitters motionless for 12 hours changed pulse rate to notify observers of a potential mortality. Idle transmitters were located to determine if mortality or transmitter slip had occurred.

We determined that a bobwhite was nesting when its locations were unchanged for 2 consecutive days and the mortality sensor had not activated. Nesting sites were flagged and monitored daily until a depredation or hatch. Bobwhites with a hatch were treated as a brood until 14 days post hatch or until it was determined the bobwhite was no longer with a brood.

Data Analysis

Within the reproductive season, we calculated bobwhite home ranges and resource use at 2 specific time intervals (Taylor and Burger 2000). The early breeding season, 15 April – 30 June, was meant to capture the period of post covey dispersal, pre-incubation activity, first incubated nesting attempts, and early brood rearing activities. The late breeding season, 1 July – 1 October, corresponds to all reproductive activities and pre-covey development.

In order to minimize any potential bias of repeated observations at the nest site on home range size or resource selection, only 1 nest site location for each nesting attempt was used in the analysis. Since bobwhites were only located once per day, incubating birds were typically located on the nest. These repeated locations during the incubation period would have potentially resulted in a compacted home range and resource selection concentrated around the nest site, and therefore repeated locations were removed. We did include all brood locations in the analysis.

Home Range Calculations

For every breeding season, each bobwhite location was determined to be in one of the following areas: supplemental feed treatment area, control area, other TTRS areas, or off property. For each bobwhite, in each breeding season, we calculated the percentage of total locations for each of the areas. We assigned a treatment type to a bobwhite when more than 75% of their locations

were observed within an area. This is an arbitrary classification meant to assist with assigning a treatment type based on the majority of locations, but allow for some individual bobwhite locations to be outside of the treatment boundary. Prior to any home range or resource use analyses, we determined the average percentage of locations for bobwhite classified in the supplemental feed treatment and control areas. Over the 6 years, birds assigned the supplemental feed treatment had an average of 96% of bobwhite locations within the supplemental feed treatment area. For the control area, 95% of locations were in the control area for birds assigned to the control area.

Home ranges were only calculated for bobwhites that survived the entire period of interest, which was done to minimize any potential bias to home range size due to reduced sample size because of any possible survival differences between treatment areas. For each surviving bobwhite we computed a fixed-kernel home range using a bivarate normal (Gaussian) kernel density estimator (HRT: Home Range Tools for ArcGIS; version 1.1; Rogers et al. 2007) in ArcGIS 9.3. Prior to home range estimation, the bandwidth (h) was calculated for all individuals using a least-squares cross-validation procedure (LSCV) for each time period (adehabitat package, https://www.faunalia.it/animove/trac/; R Foundation for Statistical Computing, Vienna, Austria) (Calenge 2006). Home ranges that did not converge were removed from any further analysis. We estimated the median h_{lscv} value for all remaining home ranges for each time period and this value was used as the bandwidth value for all home range calculations (Kenward 2001). For the raster portion of the kernel home range procedure we used a grid cell size of 10 m, which we estimated to be an appropriate scale for bobwhites, considering location resolution. From the grid that was produced we calculated a 95% volume contour, which was used in the comparison between the control and supplemental feed treatment areas.

Resource Use

We describe habitat and resource use for the supplemental feed treatment area only at 2 spatial scales, corresponding to Johnson (1980), second and third order selection using compositional analysis (Aebischer et al. 1993, Martin et al. 2013). Our primary interest was in the selection preference of the feed trail buffer area relative to other habitats on the fed area.

At the beginning of the breeding season each year we mapped macro-habitat classifications for the supplemental feed treatment area. Annual evaluation was necessary due to changes from prescribed fire applications and minor adjustments to the feed trail made each year. Macro-habitat classifications used in the analysis included: feed trail buffer area, burned upland pine, unburned upland pine, annually-disked weed fields (field), and forested hardwood mesic drainages and wetlands (drain). In order to develop an area for the linear feed trail a 5 meter buffer was applied to each side (10 m total width) to represent the area where supplemental feed was applied. The proportional area of the supplemental feed trail buffer area ranged between 2.7 and 3.1% of the treatment area. For each home range, the proportional amount of each macro-habitat was determined. We determined amount of available habitat for the second order resource selection analysis by calculating a minimum convex polygon (MCP) around all points used for each year and time interval combination. Each year/season MCP was expanded by a 100 meter buffer to account for habitat influences beyond the MCP. Proportional habitat and feed trail buffer area amounts were compared to habitat proportions within the supplemental feed treatment area for each year and both time intervals to determine second order resource selection. For third order resource selection, we calculated the proportional use by determining the macro-habitat for each bobwhite location within each home range and compared those values to the proportional habitat amounts available within each bobwhite's home range. Similar to Taylor and Burger (2000) and Martin et al. (2013), we used a multivariate approach to test if resource use of bobwhite were at random for second and third order selection. We used the adehabitat package (Calenge 2006) for program R to conduct the analysis according to Aebischer et al. (1993). Prior to analysis, we replaced zero values for use with the value 0.001 which was one order of magnitude less than the smallest recorded nonzero proportion (Aebischer et al. 1993).

Proximity to Feed Trail

We wanted to determine if bobwhite locations were closer in proximity to the feed trail relative to random locations within the feed trail treatment area at both breeding season time intervals. Random points were calculated within each home range using Geospatial Modeling Environment software (version 7.4.0, www.spatialecology.com, 2009-2015), and random numbers were equal to bobwhite locations used to produce the home range. For each year, distance to the feed trail for all random and bobwhite locations were calculated using the near function in ArcGIS (version 10.3 ESRI, 2015).

RESULTS

Early Breeding Season Home Range

We calculated early-breeding season home ranges for 554 radio-tagged bobwhites for the years 2001 – 2007, of which 2 home ranges did not converge and those observations were removed from any additional analysis. The median h_{lscv} was 30.1 and this value was used as the smoothing parameter for all early-breeding season home ranges. There were 27,205 locations used in the analysis with an overall mean of 49.2 (SD = 22.1) locations per radio-tagged bobwhite. Early breeding season home ranges for the fed areas were similar among years (CV = 7.1%), and ranged from 11.6 ha to 14.1 ha with an overall average of 12.3 ha (95% CL = 0.64) (Table 1). For control areas, early season home ranges fluctuated between 14.8 ha and 21.5 ha, averaged 17.4 ha (95% CL = 1.89), and had higher variability among years (CV =

Table 1. Average home range size of northern bobwhites on supplemental feed treatment areas and control areas for Tall Timbers Research Station, Florida, USA.

		Early-Breeding Season Home Range			Late-Breeding Season Home Range		
Year	Treatment	*n*	$\bar{x}$	95%CI	*n*	$\bar{x}$	95%CI
2001	Fed	12	14.1	2.3	4	15.7	3.3
	Control	57	21.5	1.7	25	19.9	3.2
2002	Fed	39	11.7	1.1	30	14.8	1.5
	Control	117	15.8	0.9	68	15.7	1.3
2003	Fed	23	12.7	1.5	7	16.7	2.7
	Control	49	16.0	1.4	25	19.6	2.1
2004	Fed	31	11.6	1.3	11	13.5	2.2
	Control	25	18.8	2.2	9	20.6	5.4
2005	Fed	29	12.0	0.9	13	14.7	1.6
	Control	34	15.2	1.3	16	19.4	2.1
2006	Fed	44	11.8	1.1	24	14.3	1.4
	Control	42	14.8	1.0	25	18.6	2.4
2007	Fed	28	12.3	1.1	19	15.2	1.9
	Control	22	19.5	2.6	7	21.5	4.4

14.7%). Annual early breeding season home ranges were between 20.3% and 36.9% smaller on fed areas than control areas (Figure 2). For the fed area, every calculated home range had a portion of feed trail within its area. The feed trail lengths ranged between 36.4 and 1,631.0 m with an overall mean of 582.9 m (SE = 18.0, n = 171).

Late Breeding Season Home Range

We calculated late breeding season home ranges for 286 radio-tagged bobwhites for 2001 – 2007. There were 15,389 bobwhite locations used in the analysis with an overall mean of 53.8 (SD = 15.9) locations per radio-tagged bobwhite. The smoothing parameter was a median h_{lscv} of 32.9, and all late breeding season home ranges converged. Late season home ranges for the fed areas pooled for all years was a mean of 14.9 ha (95% CL = 0.76) with minimal annual variability (CV = 6.8%). On control areas, we observed larger late season home ranges that averaged 19.3 ha (95% CL = 1.37) among years and were also relatively consistent (CV = 9.5%). The late season home ranges on fed areas were between 5.7% and 34.5% smaller than control area home ranges (Table 1). Every late breeding season home range in the supplemental feed treatment area had at a portion of feed trail within the calculated area. Feed trail lengths ranged between 136.5 and 1,433 m with an overall mean of 710 m (SE = 26.5, n = 96).

Habitat and Resource Use of Fed Areas

Early Breeding Season Resource Use.—We calculated second and third order habitat and resource selection for 175 early breeding season home ranges for all years, except 2004, which was excluded due to missing landcover data. There was a nonrandom use of resources in the positioning of home ranges and within home ranges among all years ($0.1221 \leq \Lambda \leq 0.459$, $P < 0.05$). We observed that bobwhites oriented home ranges with a selection preference for the feed trail buffer area as compared to other habitats in the surrounding study area, and the feed trail buffer area had the highest or second highest rank for all years (Table 2). This selection preference for the feed trail buffer area was significant relative to all other habitats in 2002 and 2005. In 2006 and 2007, there was a significant selection preference for the

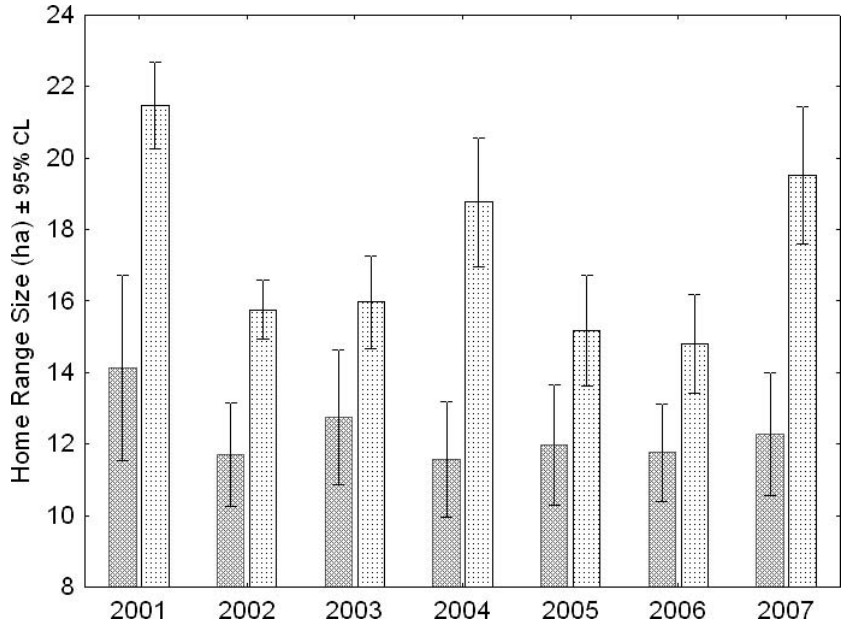

Fig. 2. Comparison of average early breeding season home ranges of northern bobwhites for supplemental feed treatment and control areas, Leon County, FL, USA, April – October, 2001 – 2007. Dark gray bars represent the supplemental feed treatment area and light gray represent the control area.

Table 2. A compositional analysis simplified ranking of second order habitat and resource selection for northern bobwhite on the supplemental feed treatment area during the early breeding season, Tall Timbers Research Station and Land Conservancy, 2001 – 2007.

YEAR	*n*	Habitat Rank 5[a]	[b]	Habitat Rank 4		Habitat Rank 3		Habitat Rank 2		Habitat Rank 1
2001	12	feed trail buffer area	>	unburned upland pine	>	burned upland pine	>	field	>>>	drain
2002	39	feed trail buffer area	>>>	burned upland pine	>	unburned upland pine	>>>	field	>	drain
2003	23	unburned upland pine	>	feed trail buffer area	>	burned upland pine	>	field	>>>	drain
2005	29	feed trail buffer area	>>>	unburned upland pine	>	burned upland pine	>>>	field	>	drain
2006	44	unburned upland pine	>	feed trail buffer area	>>>	burned upland pine	>>>	field	>	drain
2007	28	unburned upland pine	>	feed trail buffer area	>>>	drain	>	burned upland pine	>	field

[a] An increase in rank value signifies increased use relative to the study area.
[b] The >>> symbol represents significant resource selection preference over lower ranked habitats, and the > symbol represents resource selection preference over lower ranked habitats.

feed trail buffer area and unburned upland pine compared to other habitats.

Within home ranges, we observed a significantly higher selection preference for unburned and burned upland pine habitat, which had the highest or second highest ranking for all years, when compared to the other habitats and feed trail buffer area (Table 3). Also, selection preferences for both upland pine habitats were significantly higher than the feed trail buffer area for 5 of 6 years.

Late Breeding Season Resource Selection.—For late season breeding home ranges we determined second order habitat and resource use selection preferences for 96 home ranges relative to the surrounding study area for 2002 – 2007. Habitat and resource selection preferences were not calculated for 2001 due to small sample size and 2004 due to missing landcover data. There was a nonrandom use of resources in the positioning of home ranges and within home ranges for all years ($0.0566 \leq \Lambda \leq 0.469$ $P < 0.05$), except in 2003, when we observed third order selection with no significant selection preference. For 2002, 2005 and 2006, the feed trail buffer area had a significantly higher selection preference relative to other habitats and was the highest ranked resource type (Table 4). In 2007, selection preferences were similar among feed trail buffer area, unburned upland pine, and fields, but the feed trail buffer area was the second ranked resource type.

Selection of the feed trail buffer area within home ranges, third order selection, for late season breeding home ranges was not significant compared to selection of resource types. The feed trail buffer area was ranked lower than burned and unburned upland pine for every year (Table 5).

Distance to Feed Trail.—For the early breeding season, the mean distances to the feed trail for bobwhite locations were less for all years when compared to random locations, with an overall mean distance of 67.4 m (± 15.6) and 76.5 m (± 15.7) for bobwhite and random locations, respectively (Table 6). Among years, bobwhite locations were between 4 and 21% closer to the feed trail relative to random locations, but these differences were not significant. Similarly, we observed that late breeding season average bobwhite locations (61.5 m ± 16.5) were closer to the feed trail when compared to random points

Table 3. A compositional analysis simplified ranking of third order habitat and resource selection for northern bobwhite on the supplemental feed treatment area during the early breeding season, Tall Timbers Research Station and Land Conservancy, 2001 – 2007.

YEAR	n	Habitat Rank 5[a]	[b]	Habitat Rank 4		Habitat Rank 3		Habitat Rank 2		Habitat Rank 1
2001	12	unburned upland pine	>	burned upland pine	>	feed trail buffer area	>>>	field	>	drain
2002	39	burned upland pine	>	unburned upland pine	>>>	drain	>	feed trail buffer area	>	field
2003	23	unburned upland pine	>>>	burned upland pine	>>>	feed trail buffer area	>	drain	>>>	field
2005	29	unburned upland pine	>	burned upland pine	>>>	feed trail buffer area	>>>	field	>	drain
2006	44	unburned upland pine	>>>	burned upland pine	>>>	drain	>	drain	>	feed trail buffer area
2007	28	unburned upland pine	>>>	burned upland pine	>>>	drain	>	field	>	feed trail buffer area

[a] An increase in rank value signifies increased use relative to the home range.
[b] The >>> symbol represents significant resource selection preference over lower ranked habitats, and the > symbol represents resource selection preference over lower ranked habitats.

Table 4. A compositional analysis simplified ranking of second order habitat and resource selection for northern bobwhite on the supplemental feed treatment area during the late breeding season, Tall Timbers Research Station and Land Conservancy, 2001 – 2007.

YEAR	n	Habitat Rank 5[a]	[b]	Habitat Rank 4		Habitat Rank 3		Habitat Rank 2		Habitat Rank 1
2001	4	sample size not large enough								
2002	29	feed trail buffer area	>>>	burned upland pine	>	unburned upland pine	>	field	>>>	drain
2003	7	feed trail buffer area	>	unburned upland pine	>	burned upland pine	>	field	>	drain
2005	13	feed trail buffer area	>>>	burned upland pine	>	unburned upland pine	>	field	>	drain
2006	24	feed trail buffer area	>>>	unburned upland pine	>	burned upland pine	>	field	>	drain
2007	19	unburned upland pine	>	feed trail buffer area	>	field	>>>	burned upland pine	>	drain

[a] An increase in rank value signifies increased use relative to the study area.
[b] The >>> symbol represents significant resource selection preference over lower ranked habitats, and the > symbol represents resource selection preference over lower ranked habitats.

(72.3 m ± 18.1), but these differences were not significant (Table 6).

DISCUSSION

Our results demonstrated that on this study area supplemental feeding along a dedicated feed trail reduced the size of bobwhite home ranges during the breeding season. Supplemental feeding has been found to reduce home ranges during the nonbreeding season when feed is spread along roadways or trails (Sisson et al. 2000, Haines et al. 2004) or provided in stationary feeders or localized feeding areas (Frye 1954, Doerr and Silvy 2002, Guthery et al. 2004).

Home ranges sizes on the fed area were consistent from year to year even though a broad spectrum of environmental conditions was observed, including drought conditions in 2007 and above average rainfall in 2003 and 2004 (National Weather Service, Tallahassee Forecast Office). Conversely, home ranges on the control areas were much more variable, especially during 2004 and 2007. Bobwhites select breeding season home ranges that provide suitable protective cover, food resources, nesting, and brooding habitat (Carver 1998). Previous research has documented habitats for nesting and brood-rearing are not limited on Tall Timbers (DeVos and Mueller 1993, Hammond 2001, Palmer et al. 2012). Consistent habitat management between the treatment and control areas suggests larger and more variable home ranges sizes on the control area were likely a function of changing food resources from year to year. During the early breeding season, the burned portion of upland pine habitat had temporarily reduced useable space, which may result in bobwhites moving over larger distances in order to obtain adequate natural food resources, and therefore resulting larger home ranges. However, when a consistent food resource is available, home ranges can remain relatively small and consistent in size, such as what we observed on the supplemental feed treatment area.

For the entire breeding season, bobwhite home ranges on the treatment area included a significant portion of the feed trail. On average, bobwhites had approximately 0.5 km of feed trail available within home ranges. The potentially negative effects of supplemental feeding, such as concentration of predation or disease transference (The Wildlife Society 2006), are often associated with stationary feeding applications (Guthery et al. 2004), where bobwhite activity may be concentrated at a few locations. The potential deleterious effects of concentrated bobwhite locations are less likely when food resources are available along a continuous trail providing all bobwhites access to a relatively large area with available food resources. We believe a long and circuitous feed trail better mimics the scattered patchiness of natural food resources normally available during the breeding season.

Table 5. A compositional analysis simplified ranking of third order habitat and resource selection for northern bobwhite on the supplemental feed treatment area during the late breeding season, Tall Timbers Research Station and Land Conservancy, 2001 – 2007.

YEAR	n	Habitat Rank 5[a]	[b]	Habitat Rank 4		Habitat Rank 3		Habitat Rank 2		Habitat Rank 1
2001	4	sample size not large enough								
2002	29	burned upland pine	>>>	unburned upland pine	>	feed trail buffer area	>	field	>	drain
2003	7	burned upland pine	>	unburned upland pine	>	feed trail buffer area	>	field	>	field
2005	13	burned upland pine	>	unburned upland pine	>>>	feed trail buffer area	>	field	>	drain
2006	24	burned upland pine	>	unburned upland pine	>>>	feed trail buffer area	>	field	>	drain
2007	19	burned upland pine	>	unburned upland pine	>>>	field	>>>	feed trail buffer area	>	drain

[a] An increase in rank value signifies increased use relative to the home range.
[b] The >>> symbol represents significant resource selection preference over lower ranked habitats, and the > symbol represents resource selection preference over lower ranked habitats.

Table 6. Average distance to feed trail for northern bobwhite and random locations on the supplemental feed treatment areas during the early and late breeding season, Tall Timbers Research Station and Land Conservancy, 2001 – 2007.

		Bobwhite Locations		Random Locations	
	n	MEAN	95% CI	MEAN	95% CI
Early Breeding Season					
2002	39	57.3	7.8	66.5	7.6
2003	23	69.8	23.2	72.8	21.1
2005	29	57.6	6.6	73.0	8.2
2006	44	60.7	7.4	68.3	7.7
2007	28	103.6	40.0	110.7	40.1
Late Breeding Season					
2001	4	44.8	7.2	59.3	11.8
2002	30	59.2	12.0	75.7	14.9
2003	8	59.9	9.1	61.7	16.5
2005	13	58.6	10.7	69.5	9.5
2006	25	53.4	11.3	65.6	10.0
2007	19	93.0	48.9	101.8	45.7

Our research supports the conclusion of Buckley et al. (2015) that bobwhites shift home ranges to overlap a reliable food resource. For our study, the second order selection preference for the feed trail buffer area indicates home ranges were orientated to include a higher proportion of feed trail than what was available. Overall, this outcome was consistent for both breeding season time intervals and was observed for all years, regardless of annual and seasonal differences in environmental conditions.

Within home ranges, there was not a consistently high selection preference for the feed trail buffer area relative to the other upland habitats. Miller et al. (this volume) observed that nonbreeding season use of the feed trail buffer area was limited to 14% of the day. While it is possible we did not locate bobwhites frequently enough to document use of the feed trail buffer area, we believe lack of third order selection for the feed trail buffer area supports the idea that bobwhites spent a low percentage of the day using it, similar to Miller et al. (this volume).

Our proximity analysis also supported the conclusion that bobwhites were not significantly adjusting locations closer to the feed trail buffer area. Miller et al. (this volume) similarly found bobwhite coveys during the nonbreeding season were not closer to the feed trail than expected. Presumably, bobwhites were utilizing suitable habitats in the surrounding landscape for other breeding season needs, such as nesting, protective cover, and brood-rearing and only visiting the feed trail buffer area for brief periods as part of their daily habitat use.

A potential conclusion from this experiment is that supplemental food resources resulted in more efficient home ranges, especially during the early breeding season when there are dramatic changes in available habitats due to prescribed fire. Conversely, on the control area the temporary reduction in available habitats from prescribed fire in the early breeding, in addition to the lack of a dedicated food resource, resulted in bobwhites having to move farther distances to meet cover and resource needs and therefore larger and more variable home ranges.

Home ranges for the early breeding season had higher than expected use of unburned upland pine and feed trail buffer area, which were interchangeable as the top 2 ranked resource types. Preference for unburned pine habitat in the early breeding season was consistent with the results of Carver (1998) and supports need for unburned pine habitat in the early season for protective cover and nesting sites. However, preference for burned upland pine in the late breeding season increased when vegetative cover recovered after the spring fires, and also corresponded with increased brood rearing activities. Slight increases in home range sizes during the late breeding season could be attributed to the increased use of burned upland habitats. These outcomes highlight the importance of frequently burned upland pine with similar amounts of unburned upland pine to support bobwhite habitat needs throughout the breeding season for our study area.

MANAGEMENT IMPLICATIONS

Based on this 6 year study, we recommend for managers of properties of similar habitat conditions and management goals to utilize broadcast supplemental feeding along a continuous feed trail, during the breeding season. This is especially important during the early breeding season when habitat management and prescribed burning may reduce useable space and cause bobwhites to move larger distances to meet resource needs. For pine savanna habitats, we recommend prescribed burning to produce a mix of burned and unburned patches along with supplemental feeding to increase habitat suitability and reduce movements and home range size of bobwhites.

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