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FORAGING BEHAVIOR OF NORTHERN BOBWHITE IN RELATION TO RESOURCE AVAILABILITY

By

Ryan Spencer Miller

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Mississippi State, Mississippi

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FORAGING BEHAVIOR OF NORTHERN BOBWHITE IN RELATION TO RESOURCE AVAILABILITY

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The Northern Bobwhite (*Colinus virginianus*) is a popular game bird that inhabits pine grasslands throughout the Southeast. This study used experimental manipulation of food resources to investigate how resource availability influenced foraging behavior and space use of bobwhite in a southern pine-grassland forest system.

Radio marked bobwhite were monitored to determine daily space use, movements, and daily and seasonal ranges. I observed no difference in daily ($P = 0.06$) or seasonal home range size ($P = 0.55$) between feeding treatments. However, dispersion in daily locations of radio-marked bobwhite differed among feed levels ($P < 0.001$).

I assessed effects of food availability on diet and total body lipids of birds harvested from each treatment during February. Although bobwhite extensively utilized supplemental feed when available, energy value of pre-roosting crop contents did not differ among treatments ($P = 0.41$), but total body lipids differed between feed treatments and years ($P < 0.001$).

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R.S.M.

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CHAPTER I

INTRODUCTION

Temporal and spatial distribution of food resources influence how animals make foraging decisions, utilize space, and allocate time and energy, thus potentially affecting resource selection, energy balance, reproductive success, and survival. Therefore, management of food resources has been a central component of wildlife habitat management. Providing of supplemental food resources, through habitat manipulation (e.g., disking or burning), establishment of food plots, leaving unharvested grain crops, or direct distribution of feed stuffs has long been a common practice in wildlife management in general and bobwhite management specifically (Stoddard 1931, Leopold 1933, Rosene 1969). Supplemental food provisioning is predicated on the assumption that abundance, distribution, and/or availability of energy or other macronutrients limits individual absolute fitness (survival and/or reproduction) and hence population performance. In contrast, Guthery (1997, 1999) proposed that food rarely limits bobwhite populations because total food production in the environment exceeds total nutritional requirements of most bobwhite populations, therefore providing supplemental feed has little effect on individual fitness or population performance. However, this argument fails to consider temporal and spatially variation in resource availability and energetic and predation costs associated with foraging.

The practice of supplemental feeding wildlife populations is a controversial issue among wildlife professionals. Some professionals view it as a means of improving condition of individuals, hence individual fitness and population performance; whereas others view it as a means to increase harvest (baiting) (TWS 2007). Research on effects of supplemental feeding on demographics and vulnerability to harvest have produced contradictory results (Frye 1954, Robel et al. 1974, DeMaso et al. 1999, Townsend et al. 1999, Sisson et al. 2000, Doerr and Silvy 2002, Guthery et al. 2004, Doerr and Silvy 2006). Concerns about effects of supplemental feeding on bobwhite include increased predation, increased harvest, facilitating spread of diseases, diet quality, and introducing toxins to wildlife. Benefits have included increased survival rates under stressful climatic conditions (Lehmann 1984, Guthery 1986, Landers and Mueller 1986, Townsend et al. 1999), lower daily and seasonal movements (Sisson et al. 2000), increased over-winter survival if food is limiting (Doerr and Silvy 2002), higher winter body fat levels (Robel et al. 1974, Leif and Smith 1993, Doerr and Silvy 2006) and increased productivity (Palmer and Wellendorf, unpublished data).

Most prior studies on supplemental feeding examined feeding programs, either on private or public lands, and were not experimentally designed to evaluate behavioral responses of bobwhite relative to food availability. Contradictory results from food supplementation studies are partly due to differences in food supplementation rates, feeding methodology (e.g., spreading feed trails, feeders, food plots), seasonality of supplementation, natural resource abundance, and annually varying environmental conditions. Moreover, few studies have attempted to design feeding programs to affect specific aspects of individual behavior and population demographics. The mechanisms through which food availability influences demographic parameters are poorly understood. A more thorough understanding of the potential benefits of supplemental food provisioning requires knowledge of how the distribution of food resources influences individual behavior and fitness. For example, do fitness benefits occur through reduced energy expenditure, reduced predation risk, increased body condition, or some combination thereof?

Food limitation has traditionally been perceived as greatest during seasonal periods of low or declining food availability, increased thermoregulatory costs, and greatest predation risk. For bobwhite, these conditions occur during winter over most of the range. Over-winter survival varies geographically and temporally in relation to habitat conditions, winter weather, and local and regional predator context. Over-winter survival of bobwhite populations in Missouri has been as low as 15.9 % (Burger et al. 1995). Williams et al. (2004) estimated overwinter survival rates of 20.9 % in hunted parts in Kansas. Over-winter survival is a primary determinant of population trajectory and bobwhite populations are very sensitive to changes in annual and overwinter survival (Link et al. 2008, Sandercock et al. 2008). Long-term demographic studies support these results (Tall Timbers Unpublished data). Bobwhite populations are particularly sensitive to winter survival because it determines number of breeders the following spring which, given reasonably weak density-dependency, drives population growth. Previous research at Tall Timbers demonstrated that winter survival was significantly greater on fed sites relative to unfed sites in some years.

Supplemental feeding may alter survival through direct or indirect means. Direct effects of food availability on survival must occur through changes in foraging behavior and efficiency. Foragers must make choices about which patches to forage within, which food items to select, and how long to forage within a given patch. Optimal Foraging Theory (OFT) predicts that foragers make feeding decisions based on the energetic content of food packets, rate of food intake, and metabolic costs of foraging within the context of predation risk and opportunity costs (Brown 1988). Superabundant, high energy food should decrease foraging time as well as travel distance to and from food sources, thereby reducing energetic cost of foraging and predation risk. Consistent with these hypotheses, home ranges of radio-marked bobwhite in Florida were up to 50 % smaller on fed sites compared to unfed sites from 1998 to 2007 (Palmer and Wellendorf, unpublished data). Similarly, Sisson et al. (2000) observed smaller home ranges and more localized movements on fed sites and reduced likelihood of harvest.

Increased survival of bobwhite provided supplemental feed may be attributable to reduced predation risk because bobwhite are able to decrease foraging time and potentially avoid foraging during periods of high predation risk. Weather, in particular drought, has a strong influence on natural food abundance and security of foraging cover. Sisson et al. (2000) reported that during drought years avian predation could account for 72 % of over-winter mortality. Kohlmann and Risenhoover (1996) found that quail abandon patches with poor cover earlier when compared to good cover, implying that predation risk alters foraging behavior and giving up density (GUD). Supplemental feed, if placed in or near secure cover, may allow coveys to feed for longer periods of time without exposing coveys to avian predation. Inter-patch distance has also been shown to influence GUD and may affect predation risk. Strategic distribution of supplemental feed may not only increase within patch food density, but also reduce inter-patch distance, thereby altering predation risk and foraging behavior. A decrease in the distance that quail travel between food sources may decrease the detection rates by mammalian olfactory predators.

Supplemental feed may indirectly affect predation risk as supplemental feeding increases density of small mammal prey such as the southern cotton rat (*Sigmodon* *hirsutus*) and the cotton mouse (*Peromyscus gossypinus*) (Doonan and Slade 1995). This increase could provide predators an alternative prey source, buffering predation pressure on bobwhite. However, there may be an edge effect created by activities associated with spreading feed that allows mammalian predators access to a new travel corridor. This new travel corridor may increase detection rates as predators can now cover more ground. In a study evaluating corridors and habitat use of meso-predators, Frey and Conover (2006) found that carnivores incorporated areas with travel corridors into their home ranges. They determined that corridors such as roads or levees allowed predators to increase distance they traveled and amount of hunting ground searched.

In addition to potential changes in predation risk associated with bobwhite behavioral changes, supplemental feeding may influence nutrition or energy balance of bobwhite during winter and spring. Giuliano et al. (1996) found that macronutrient deficiencies may lead to reproductive failures in northern bobwhite. They also reported that low energy diets and low protein diets negatively affect bobwhite body and ovary mass, and egg production. Low energy diets can have a greater impact on bobwhite populations compared to low protein diets, but bobwhite are able to increase foraging to compensate for a low energy diet (Giuliano et al. 1996).

Available energy becomes increasingly important to bobwhite condition during drought and severe winter weather. Leif and Smith (1993) observed that bobwhite fed low-energy foods accumulated less body fat compared to high-energy foods. Supplemental feeding during winter provides quail and other buffer prey species with high-energy foods. Doerr and Silvy (2006) hypothesized that bobwhite fed supplemental feed (milo) would have greater body fat content and Robel et al. (1974) noted that bobwhite in Kansas with access to food plots during winter accumulated more body fat.

Southern bobwhite populations do not experience the extreme cold temperatures of the Mid-west for long periods resulting in lower energy demands for thermoregulation, which can account for 70 % of their energy budget. Supplemental feeding during winter along with warmer temperatures and high native food abundance suggests energy may not be as limiting for southern bobwhite survival, although it may influence reproduction. However, bobwhite at southern latitudes make extensive use of supplemental feed when available. For example, Whitelaw et al. (2009) observed a juvenile female with 385 sorghum seeds in her crop and suggested that when supplemental feed is available to southern bobwhite, one to 2 feeding events/day would allow quail to meet daily metabolizable energy requirements. First level subheading sample

OBJECTIVES

My objectives were to determine: (1) temporal variation in resource availability following food supplementation; (2) relationship between supplemental seed availability and daily movement and activity periods of bobwhite coveys during winter; (3) how supplemental seed density affects bobwhite winter home ranges; and (4) how supplemental seed density influences late winter diet and body condition. This study used experimental manipulation of food resources to investigate how resource availability influenced foraging behavior and space use of bobwhite in a managed southern pine-grassland forest system. In 2009 and 2010, three study sites were assigned one of three supplemental feeding regimes; control, 0.5 bu/ac/yr, and 2.0 bu/ac/yr. Radio-marked bobwhite on each site were monitored to determine daily space use, movements, and daily and seasonal ranges. During February 2009 and 2010, bobwhite were harvested from each site prior to evening roosting to determine crop contents and lipid reserves.

HYPOTHESES

I hypothesized that: (1) daily covey movements in the 2.0 bushel treatment will be less than the 0.5 bushel treatment because of increased feed density; (2) daily and seasonal home ranges in the 2.0 bushel treatment will be less than the 0.5 bushel treatment because of increased feed density; (3) coveys on fed treatments will maintain higher body fat levels compared to the control.

This thesis follows Journal of Wildlife Management guidelines and is organized in 5 chapters. Chapter I provides introductory material and justification. Chapter II addresses the first objective of this study, and describes how I estimated temporal variation in resource availability following food supplementation. Chapter III addresses research objectives 2 and 3 and presents relationships between supplemental seed availability and daily movements of bobwhite coveys during fall and winter and determining daily and seasonal covey ranges. Chapter IV addresses my final research objective to determine effects of an additional food source on bobwhite energy intake and late winter body condition as measured by total body lipids. Chapter V synthesizes the overall project outcomes and discusses management implications.

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CHAPTER II

SUPPLEMENTAL FEED LOSS IN AN UPLAND PINE ECOSYSTEM

INTRODUCTION

Variation in temporal and spatial distribution of energetic resources affects animal resource selection, energy balance, reproductive success, and survival. Thus management of food resources through habitat manipulation (e.g., disking or burning), establishment of food plots, leaving unharvested grain crops, or direct distribution of feed stuffs has long been a central component of wildlife management in general and bobwhite management specifically (Stoddard 1931, Leopold 1933, Rosene 1969). Supplemental food provisioning is predicated on the assumption that abundance, distribution, and/or availability of energy or other macronutrients limits individual absolute fitness (survival and/or reproduction) and hence population performance.

Research on supplemental feeding effects on demographics and vulnerability to harvest have produced contradictory results (Frye 1954, Robel et al. 1974, DeMaso et al. 1999, Townsend et al. 1999, Sisson et al. 2000, Doerr and Silvy 2002, Guthery et al. 2004, Doerr and Silvy 2006). Most studies on supplemental feeding examined feeding programs and were not experimentally designed to evaluate behavioral responses of bobwhite relative to food availability. Contradictory results from food supplementation studies are partly due to differences in food supplementation rates, feeding methodology (e.g., spreading feed trails, feeders, food plots) seasonality of supplementation, natural resource abundance, and annually varying environmental conditions. One of the key limitations of prior feed supplementation studies has been a failure to quantify temporal variation in supplemental feed availability. Prior studies have tended to compare population metrics between study sites under different feeding regimes (e.g., food plots vs. no food plots) without quantifying temporal and spatially explicit differences in energy availability or usable space. A more thorough understanding of the potential benefits of supplemental food provisioning requires knowledge of how supplementation affects distribution and availability of energy through time and space.

Considerable research has addressed effects of supplemental feeding in the form of food plots (Robel 1969, Robel et al. 1974, Madison and Robel 2001) as well as feeders (Townsend et al. 1999, Sisson et al. 2000, Guthery et al. 2004) on Northern Bobwhite (here after bobwhite) populations. Increasingly however, supplemental feed is being distributed directly into cover using spreaders along feed lines. The plantation community of south Georgia and north Florida (> 300,000 ha) has been spreading supplemental feed, usually corn or grain sorghum (milo), along designated feed lines throughout upland pine (*Pinus* spp.) forests in an attempt to evenly distribute feed within cover types already being used by bobwhite. These feed lines give bobwhite quick access to highly energetic food resources within robust cover, potentially minimizing winter mortality rates by decreasing foraging activities and preventing localization caused by stationary feeders.

Feed distributed in this manner is readily available to and utilized by bobwhite, but is also subject to rapid loss, degradation, and depredation by other wildlife species, affecting resource availability through time. Periodic (typically biweekly) feed distribution along feed lines creates temporally dynamic peaks and troughs in resource availability to which birds must adapt foraging strategies. This pattern in resource availability is fundamentally different from natural patterns in which seed resources are most abundant at the end of the growing season and decline throughout fall and winter seasons. However, this feeding regime does mimic habitats with replenishing or renewing resources for which optimal foraging theory has been developed (Beauchamp and Ruxton 2005, Ohashi and Thomson 2005). An understanding of bobwhite foraging ecology in relation to periodically replenished supplemental food resources requires information on rate and pattern of seed loss following distribution.

Rate of seed loss in pine ecosystems depends on several factors. Subtropical climate of the southeastern United States causes rapid deterioration of seeds (Stafford et al. 2006, Foster 2009). Additionally, depredation by other wildlife in particular, black birds (*Agevailus sp*., *Euphagus sp*.) and cotton rats (*Sigmonodon hispidus*) have been found to substantially reduce seed in sorghum fields (Atkeson and Givens 1952, Neely and Davison 1971, Doonan and Slade 1995). Amount of rainfall also can affect seed loss as seed can become buried. Insects also consume supplemental feed which exacerbates rate of seed loss throughout time.

Determining rate of seed loss over time is important to understand how much supplemental feed remains in the ecosystem at any given time. Amount of available seed will influence foraging behavior of northern bobwhite. More abundant food resources in the ecosystem can allow bobwhite to forage with shorter movements over a smaller area for a shorter time period.

Foraging behavior might influence predation risk and subsequent predation rates experienced by bobwhite throughout winter. This is extremely important to bobwhite populations as they often experience high mortality rates during fall and winter. Williams et al. (2004) observed winter mortality rates of 79.1 % in Kansas and Burger et al. (1995) observed winter mortality rates of 84.1 % in Missouri.

My objectives were to: 1) calibrate spreading equipment and develop spreading protocols to distribute known amounts of feed over known areas and 2) determine seasonal rates of seed loss and temporal availability of supplemental feed in a pine upland ecosystem. Availability rates were determined monthly over the annual cycle to determine seasonal differences in seed loss. Winter availability rates were used throughout this project to determine if movement behavior and diet in northern bobwhite depended on amount of available feed.

Study Area

Tall Timbers Research Station (TTRS 30.66º N, 84.22º W) is located in north Leon County, Florida in an area commonly referred to as “the red hills”. Tall Timbers is approximately 1,570 hectares in size. Most of the property (66 %) is upland pine forests which consist of longleaf pine (*P. palustris*), loblolly pine (*P. taeda*) and shortleaf pine (*P. echinata*). Pine uplands are intermixed with hardwood drains (21 %) and annually disked fallow fields (13 %). Prescribed burning, mowing, and roller chopping are techniques frequently used at TTRS to reduce hardwood encroachment while maintaining adequate ground cover for nesting bobwhite.

Climate is considered relatively moderate with the mean annual temperatures ranging from 30 - 94° F. Average humidity is 77.5 %. Average rainfall is 57.25 inches with a most rain falling between June and September. Average elevation at TTRS is 200 feet.

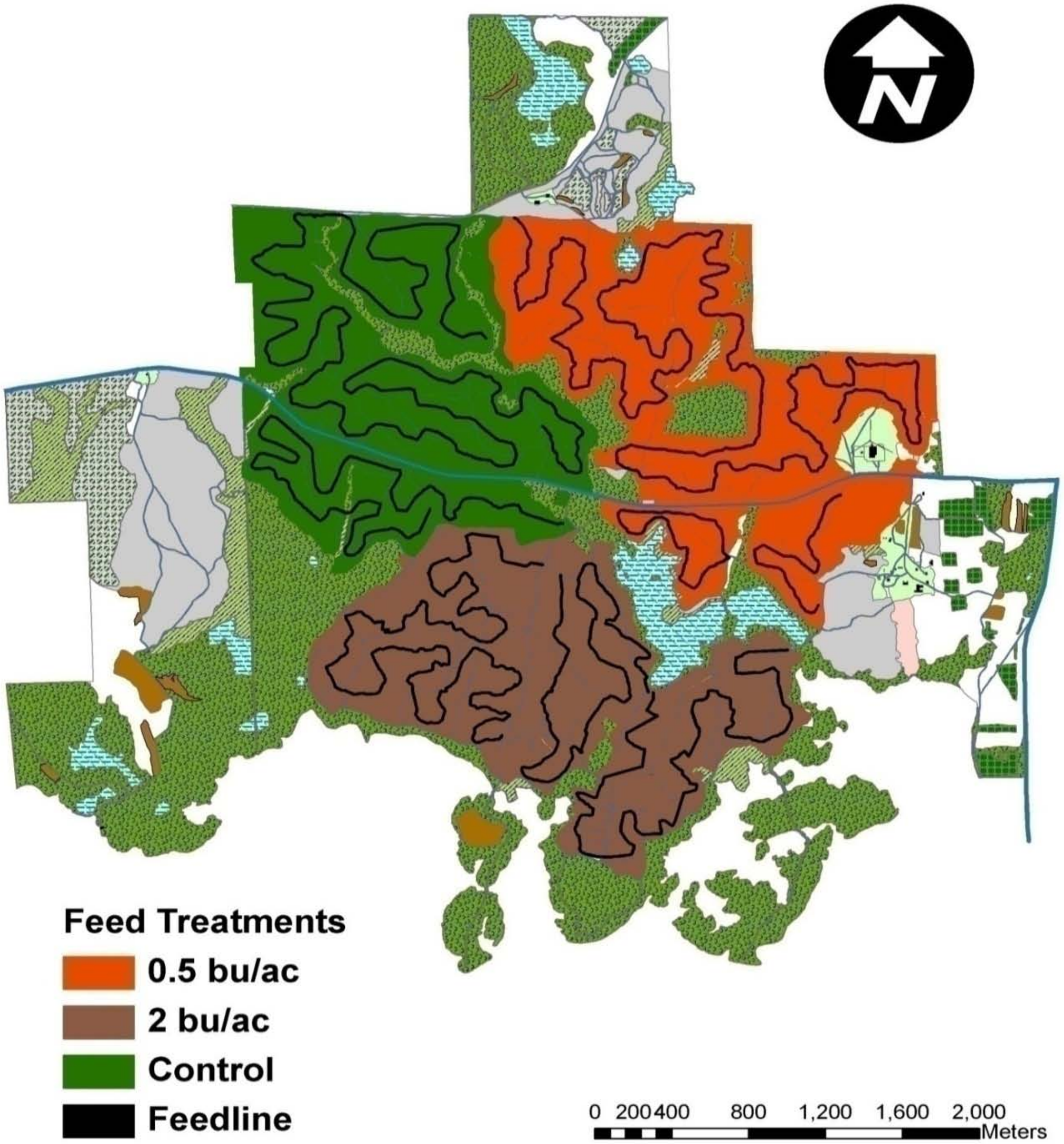

Figure 2.1 Tall Timbers Research Station treatments during winter of 2009. Treatments rotated clockwise during winter of 2010.

METHODS

TTRS was divided into three separate treatment areas, north, south and control. Treatment sizes were 244 hectares for north, 242 hectares for south and 242 hectares for control (Figure 2.1). Each year a feeding rate was assigned to an individual treatment area. Feeding rates consisted of 0.5 bushels/acre/year, 2.0 bushels/acre/year and no feed in control. In 2009 the north unit was assigned the 0.5 bushels/acre/year treatment and the south as the 2.0 bushels/acre/year treatment. Feed treatments rotated each field season to avoid confounding study site with treatment. In 2010, the previous year's control treatment became the 2.0 bushel/acre/year treatment, the 0.5 bushel treatment became the control treatment and the 2.0 bushel/acre/year treatment became the 0.5 bushel/acre/year bushel feed treatment.

At onset of each year, feed lines were established within each unit, evenly spaced throughout the entire treatment using Arc Map 9.3 (ESRI, Redlands, CA). Using a handheld GPS unit (Trimble Navigation Limited, Sunnyvale, CA) and an off road vehicle, terrain was assessed to avoid any potential pitfalls or damage to the tractor and a few minor adjustments were made to the initial feed lines. A John Deere 6400 tractor equipped with a handheld GPS unit followed the modified line, creating a final feed line. Feed line lengths were 9.95 miles for the N, 10.35 miles for the S and 8.5 miles for the control.

A John Deere 6400 tractor equipped with a 40 bushel 3-point spreader (Vicon Spreaders, Peach Bottom, PA, 17536) was used to distribute the supplemental feed uniformly along the feed line. *Sorghum* sp. hereafter (milo) was distributed on a bi-weekly schedule for the entire year. Feed rates were calculated using a constant ground speed of 6.4 km/hr and corresponding settings were assigned for each feed rate. Settings were determined by driving the tractor over a series of buckets laid out at 0.91 m intervals. Milo from each bucket was collected and using a mean from 10 samples a feed density per 0.5 m^2 was calculated. Seed release gate on the spreader was adjusted until calibrations were determined that produced feeding rates that approximated 0.5 bu/ac/year and 2.0 bu/ac/yr, representing the range of rates commonly used on intensively managed plantations.

Although the feed line traversed during supplemental feeding activities was a linear feature, spreader distributed feed over an area approximately 7 m perpendicular to the tractor path, either side of the centerline. I defined this 14 m-wide swath as the feed patch. Feed patch covered about 11 % of the total habitat within the 0.5 and 2.0 bu/ac/yr feed treatments.

To better understand how bobwhite move in relation to feed availability we must first understand amount of feed available to quail through time, under the standard two week spreading interval. I sampled both treatments bimonthly at 60 random sampling points along each feed line. Random sampling points along the feed line were generated using Hawth's tools in Arc GIS 9.3, and then located on the ground using handheld Trimble differentially corrected GPS units. Each point was flagged and assigned a number and pin flags were placed at each of the four corners of a 0.5 m^2 plot. I constructed a 0.5 m^2 sampling unit which consisted of a wooden frame encased with 35.6 cm tall metal roofing flashing.

During each sampling period, I sampled 20 plots within each feed treatment, for a total of 60 plots/bimonthly interval/treatment. Seed loss was estimated by removing all vegetation and seeds down to the soil humus layer. Then a known number of seeds, specific to each feeding treatment as predetermined from spreader calibration, were hand deposited within each plot. Finally, I redistributed vegetation back over the plot, mimicking the surrounding environment. A 5.5 hp wet dry vacuum (Shop-Vac, Williamsport, PA) powered by a portable generator was used to remove any milo or other debris from the sampling plot. I sampled residual seed availability within 20 of the 60 plots during 3 sampling periods on days 5, 10, 15 post-feeding.

During each sampling period, a 5.5 hp wet dry vacuum powered by a portable generator was used to collect all plot material, including milo and other debris. Samples were then transferred in the field from the vacuum to 30 gallon trash bags and a numbered flag was attached. In the lab, samples were transferred to a paper bag, labeled and placed in an industrial-sized drier set at 80º C for a period of no less than 12 hours. Desiccation removed any moisture from the sample, dried it to a constant weight, and inhibited seed germination. Dried samples were sifted through a USA Standard Test Sieve, size (2mm) (Newark Wire Cloth Company, Clifton, NJ) to remove any large debris. All milo in the sample was removed and counted by hand.

I estimated seed availability rates bimonthly for the entire annual cycle. Bimonthly sampling intervals were used to estimate seasonal differences in seed loss and availability. These data collected from January to March was considered winter, April to June was spring, July to September was summer and October to December was fall. Seasonal mean seed density (seeds/0.5m^2) and associated standard errors were calculated from the 6 sampling intervals within each season. Two feeding cycles in February and one feeding cycle in March coincided with my daily telemetry schedule and were used in tests of effects of resource abundance on foraging behavior (Table 2.1)

To estimate rate of seed loss and seed density during the 15 days post distribution, I assumed seed abundance declined monotonically and fit a curve to the seed abundance vs. time data using Curve Expert 1.3 (Hyams, D.G., Curve Expert Software). To determine type of function that best fit the data, I considered a set of models that included linear, exponential, power law, yield-density, and sigmoidal. I selected best fit model based on largest coefficient of determination (r^2).

RESULTS

I sampled 326 0.5 m^2 plots (164 2.0 bu/ac/yr, 162 0.5 bu/ac/yr) between 1 February 2009 and 15 March 2009 and 255 0.5 m^2 plots (125 2.0 bu/ac/yr, 130 0.5 bu/ac/yr) between 1 February 2010 and 15 March 2010. These plots were used to determine rate of loss of supplemental feed (Figures 2.2 – 2.5) during the period for which daily telemetry data were collected. Best fit curve for the winter season was a linear model for the 2.0 bushel treatment and a modified power for the 0.5 bushel treatment with r^2 values of 0.998 and 0.998, respectively.

I sampled 300 0.5 m^2 plots (150 2.0 bu/ac/yr, 150 0.5 bu/ac/yr) between 1 April and 30 June 2009 and 2010 to determine rate of supplemental feed loss during spring season. Curve function that best described the 2.0 bushel treatment was a logistic equation (Figure 2.6) whereas the 0.5 bushel treatment was best described with a modified power equation (Figure 2.7).

I sampled 302 0.5 m^2 plots (134 2.0 bu/ac/yr, 168 0.5 bu/ac/yr) between 1 July and 30 September 2009 and 2010 to determine rate of supplemental feed loss during summer. Curve function that best described the 2.0 bushel treatment (Figure 2.8) was a linear function and a modified power function best described the 0.5 bushel treatment (Figure 2.9).

I also sampled 288 0.5 m² plots (146 2.0 bu/ac/yr, 142 0.5 bu/ac/yr) between 1 October and 31 December 2009 and 2010 to determine rate of supplemental feed loss during the fall season. The function that best described seed loss in the 2.0 bushel treatment (Figure 2.10) was a linear function and a modified power function best described seed loss in the 0.5 bushel treatment (Figure 2.11).

I sampled 1,216 0.5 m² plots (594 2.0 bu/ac/yr, 622 0.5 bu/ac/yr) to compare seasonal rates of seed loss over time (Table 2.2).

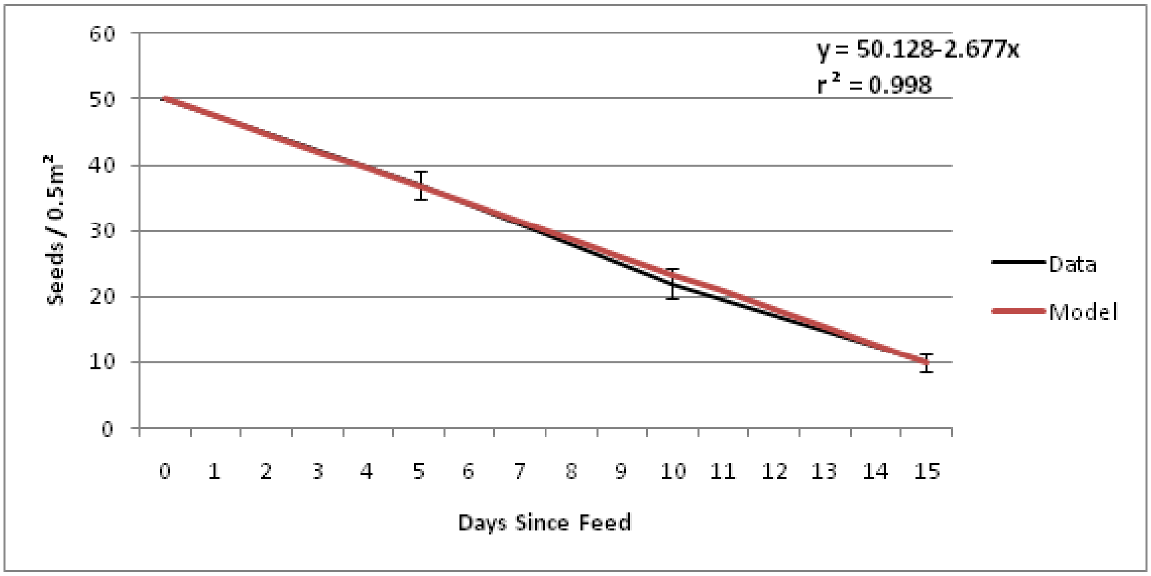

Figure 2.2	Seed loss for 2.0 bu/ac/yr feed treatment in Winter, February 2009, Tall Timbers Research Station, Leon Co, FL, USA.

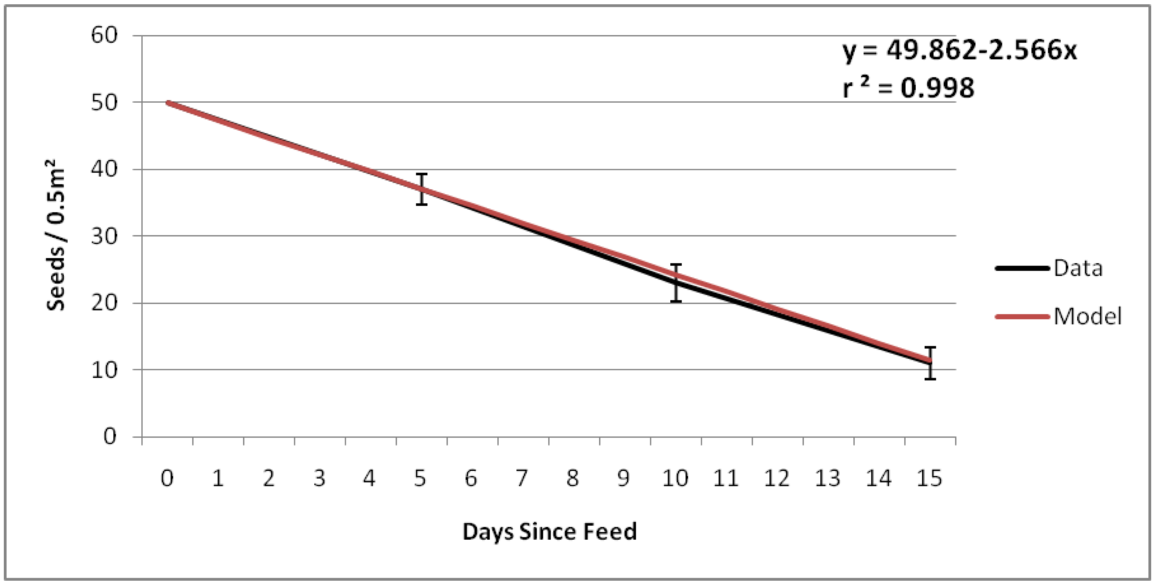

Figure 2.3	Seed loss for 2.0 bu/ac/yr feed treatment in Winter, February 2010, Tall Timbers Research Station, Leon Co, FL, US

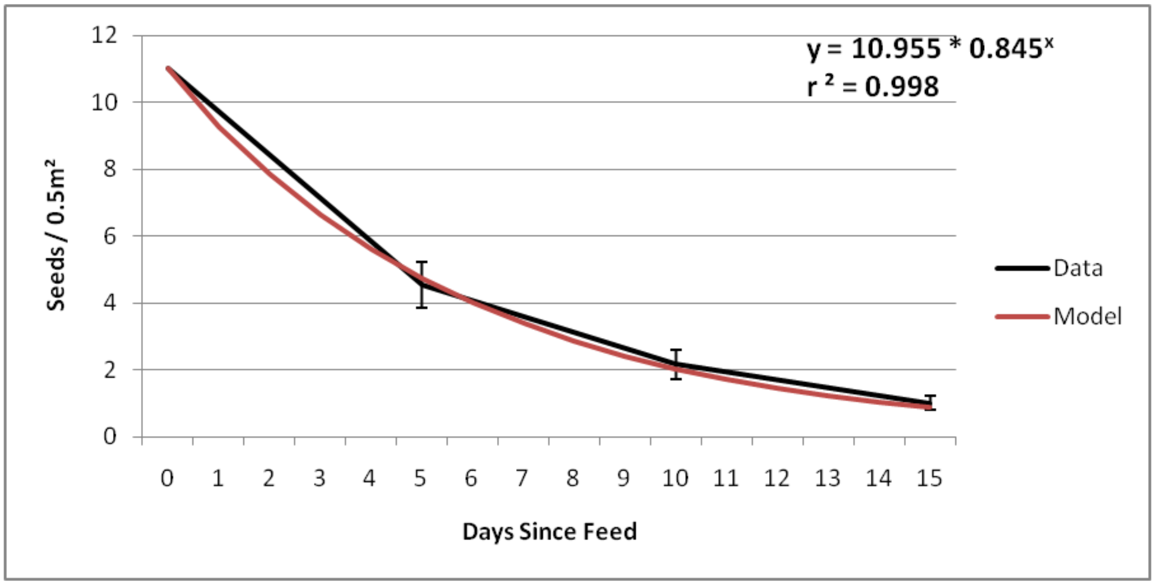

Figure 2.4 Seed loss for 0.5 bu/ac/yr feed treatment in Winter, February 2009, Tall Timbers Research Station, Leon Co, FL, USA.

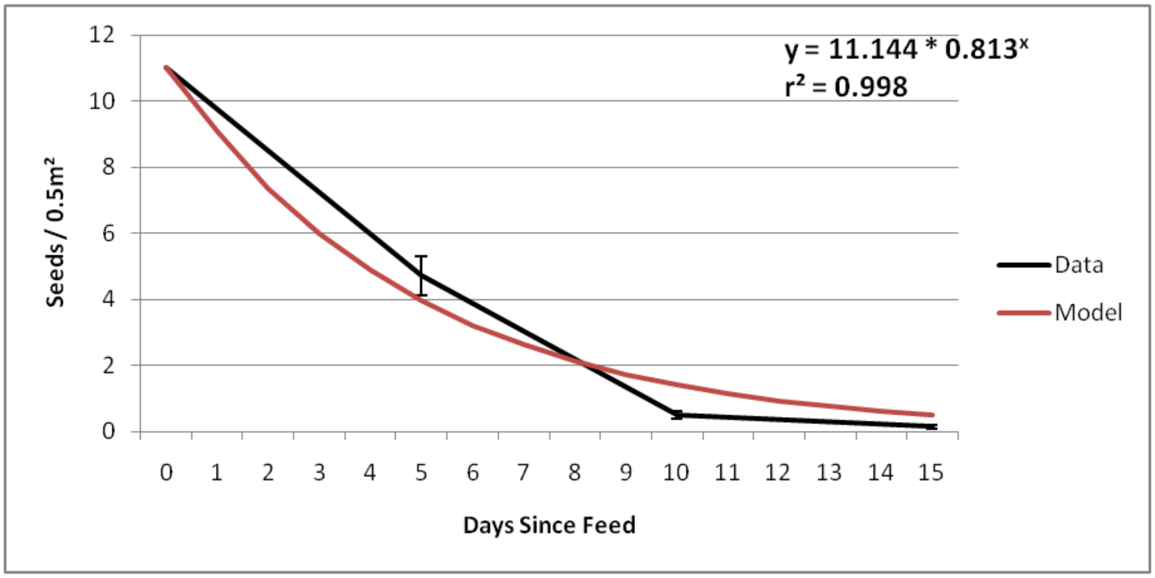

Figure 2.5 Seed loss for 0.5 bu/ac/yr feed treatment in Winter, February 2010, Tall Timbers Research Station, Leon Co, FL, USA.

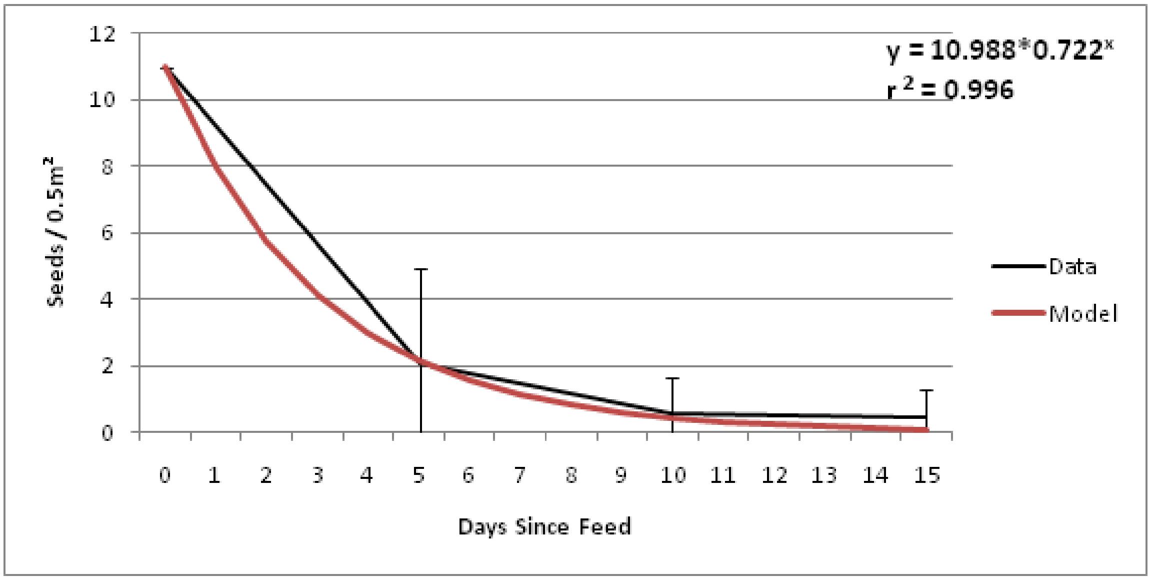

Figure 2.6 Seed loss for 0.5 bu/ac/yr feed treatment during Spring, April to June, 2009 and 2010, Tall Timbers Research Station, Leon Co, FL, USA.

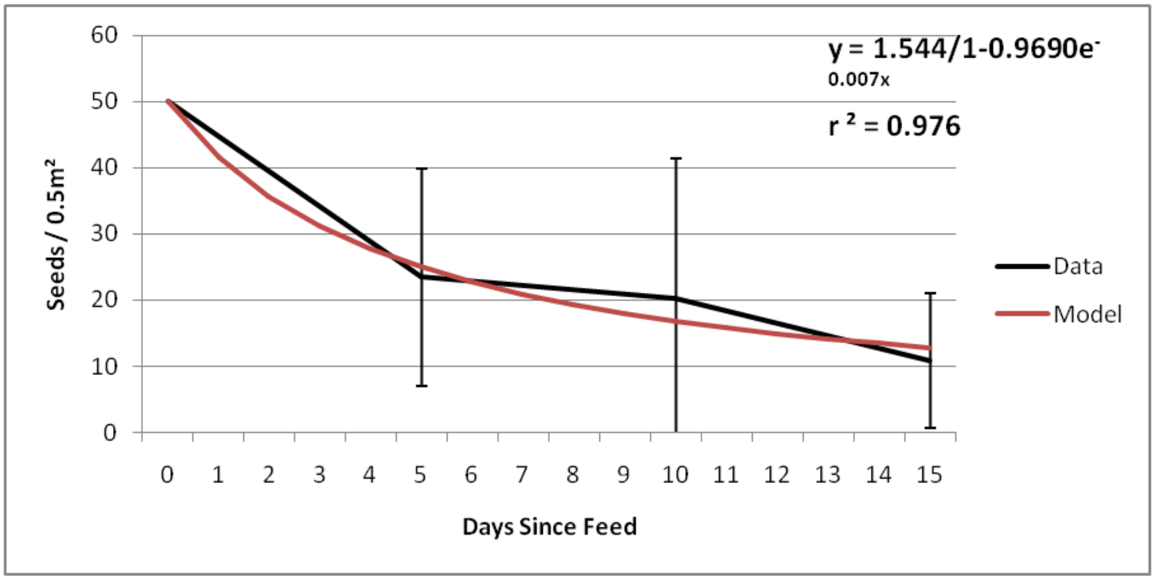

Figure 2.7 Seed loss for 2.0 bu/ac/yr feed treatment during spring, April to June, 2009 and 2010, Tall Timbers Research Station, Leon Co, FL, USA.

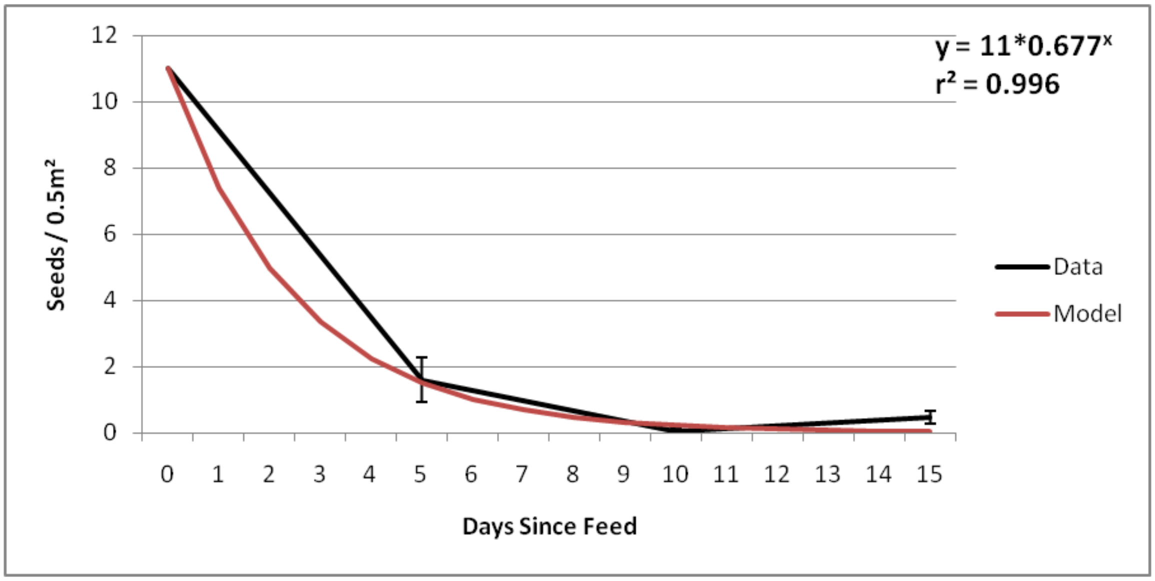

Figure 2.8 Seed loss for 0.5 bu/ac/yr feed treatment during summer, July to September in 2009 and 2010 at Tall Timbers Research Station, Leon Co, FL, USA.

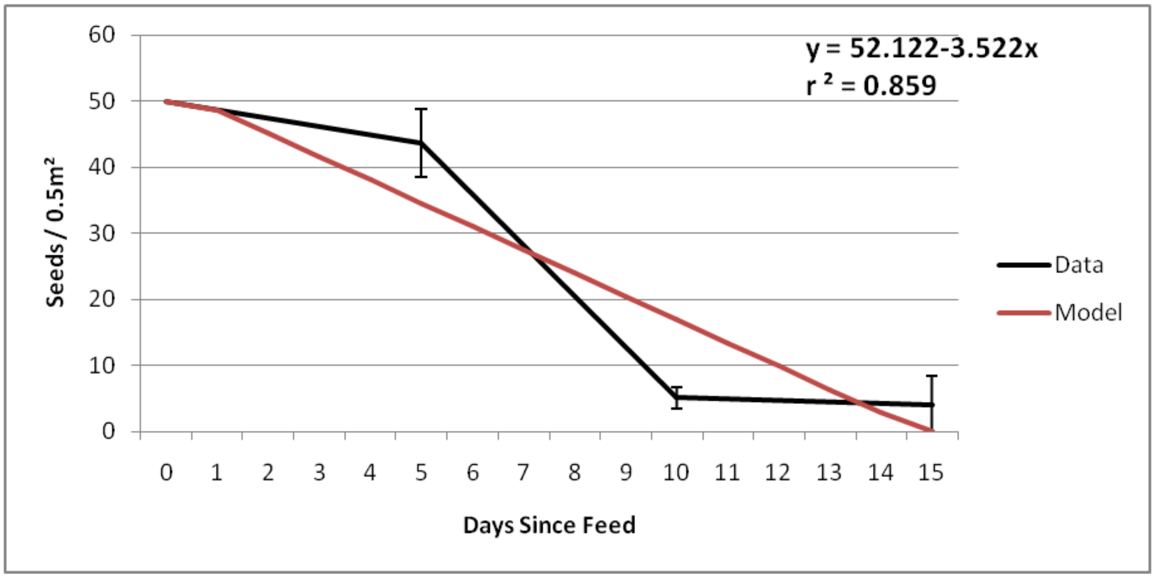

Figure 2.9 Seed loss for 2.0 bu/ac/yr feed treatment during summer, July to September in 2009 and 2010 at Tall Timbers Research Station, Leon Co, FL, USA.

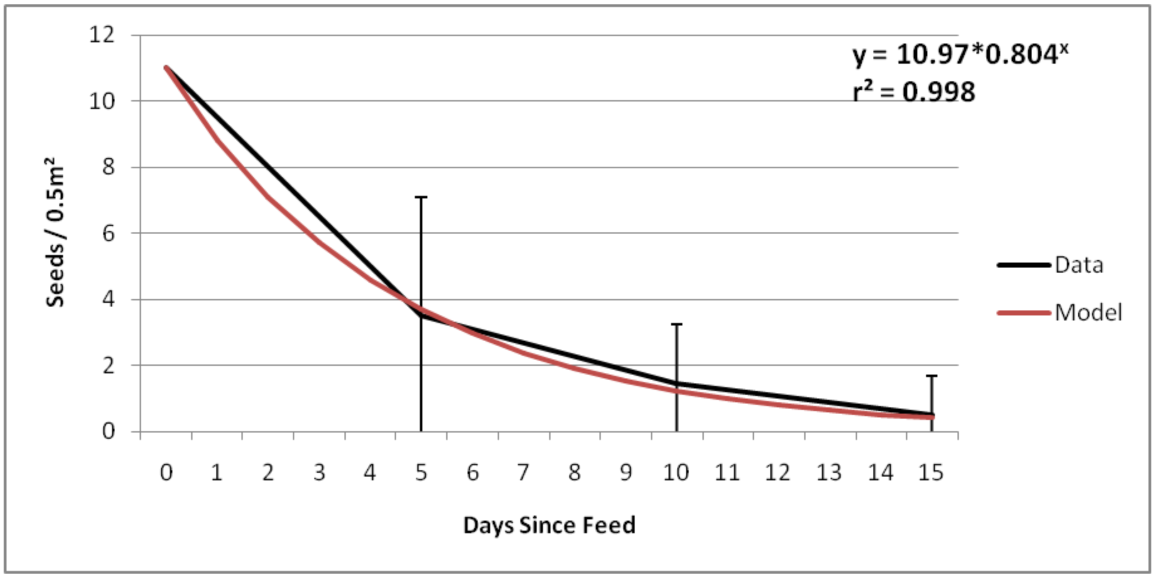

Figure 2.10 Seed loss for 0.5 bu/ac/yr feed treatment fall, October to December in 2009 and 2010 at Tall Timbers Research Station, Leon Co, FL, USA.

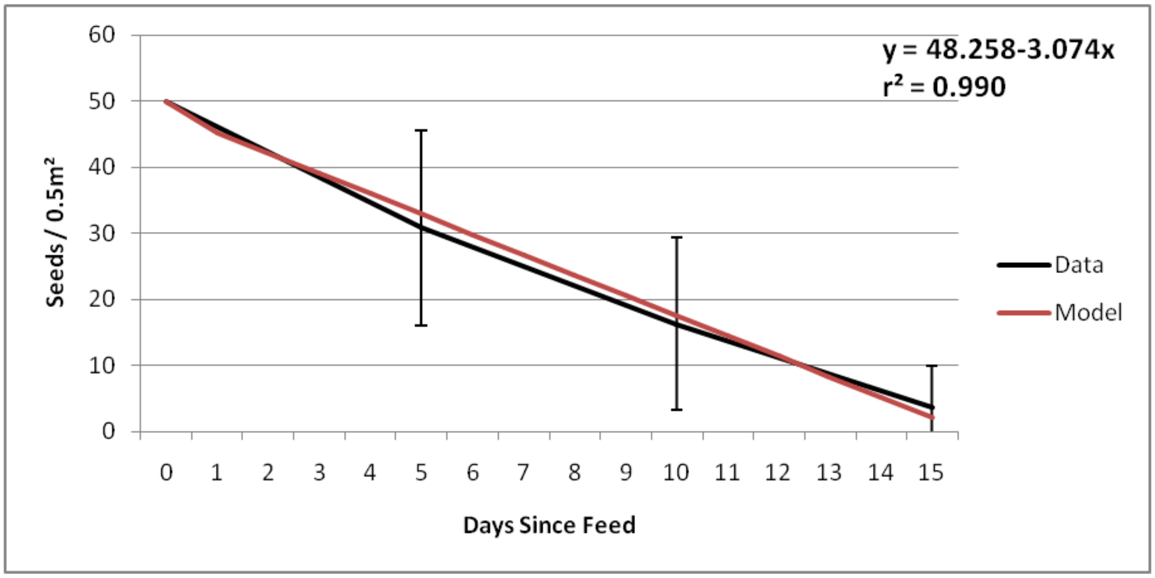

Figure 2.11 Seed loss for 2.0 bu/ac/yr feed treatment during fall, October to December in 2009 and 2010 at Tall Timbers Research Station, Leon Co, FL, USA.

Table 2.1 Seed density (seeds/0.5 m²) for feed treatments during February and March, 2009 and 2010 at Tall Timbers Research Station, Leon Co, FL, USA.

				Days	Since	Feed			
		0		5		10		15	
Treatment	Year*n*	Mean	SE	Mean	SE	Mean	SE	Mean	SE
2.0 bu/ac/yr	2009164	50	0	37.1	2.1	22.9	2.4	10	1.5
	2010125	50	0	37	2.3	23.9	2.9	11.6	2.4
0.5 bu/ac/yr	2009162	11	0	4.5	0.7	2.2	0.5	1.1	0.2
	2010130	11	0	4	0.6	0.5	0.1	0.1	0.06

Table 2.2 Seed density (seeds/0.5m²) for feed treatments collected during 2009 and 2010 at Tall Timbers Research Station, Leon Co, FL, USA.

		Days Since Feed							
		0		5		10		15	
Season	Treatment	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Winter	0.5 bu/ac/yr	11	0	5	0.6	1	0.1	0	0.01
Spring	0.5 bu/ac/yr	11	0	2	0.5	1	0.2	0	0.1
Summer	0.5 bu/ac/yr	11	0	4	0.7	2	0.5	1	0.2
Fall	0.5 bu/ac/yr	11	0	4	3.5	2	1.8	1	1.2
Winter	2.0 bu/ac/yr	50	0	37	2.3	24	2.9	12	2.4
Spring	2.0 bu/ac/yr	50	0	23	2.8	20	3.5	11	1.7
Summer	2.0 bu/ac/yr	50	0	35	3	6	1.2	4	1.2
Fall	2.0 bu/ac/yr	50	0	31	14.7	16	13	4	6.3

DISCUSSION

Supplemental food management programs are predicated on the assumption that food limits individual fitness and population performance during some or all of the annual cycle. Although supplemental feeding is a commonly used management practice (Stoddard 1931, Leopold 1933, Rosene 1969) few studies have quantified seed loss, persistence, or availability through time. Without information on resource availability, inferences regarding effects on foraging behavior are speculative. Amount of feed (supplemental or natural) that is available to bobwhite influences foraging decisions that they make throughout the day. High seed densities might allow bobwhite to decrease amount of time searching as well as actual handling time. This study quantified loss and availability of supplemental feed during a two week feeding cycle under different feeding rates throughout the annual cycle. My results showed similar rates of loss of milo over time with Foster et al. (2010). This study also evaluated rate of supplemental feed loss between seasons. Estimates of seed availability can then be used to make inferences about bobwhite population parameters such as daily home range, percent of milo in diet, average distance to feed line, average metabolizable energy and average percent of lipid reserves in relation to resource abundance.

The 2.0 bushel treatment showed a consistent rate of seed loss throughout the two week cycle. This rate of loss was similar for the winter, summer and fall seasons. Over the 2-week feeding cycle, seed availability declined from 50 seeds / 0.5 m^2 to approximately 10 seeds / 0.5 m^2. Range of supplemental feed availability suggests that 2.0 bushel treatment provides bobwhite with abundant of feed that is continuously available throughout the two week cycle. Feed availability at the end of the 2-week feeding cycle in the 2.0 bushel treatment was approximately equal to that at the beginning of the 0.5 bu/ac treatment. In contrast to linear loss during summer, fall, and winter, spring seed availability in the 2.0 bushel treatment was more variable, exhibited a sigmoidal pattern that was best modeled as a logistic function. Variation that was observed in the spring could be due to native seeds being at their lowest levels during that time of year.

In contrast to the 2.0 bushel/ac rate, the 0.5 bushel treatment showed a different pattern of seed loss. Rate of seed loss was greater than that of the 2.0 bushel treatment and exhibited a modified power function. Over the 2-week feeding cycle, seed availability in the 0.5 bu/ac treatment varied from 10 seeds / 0.5 m^2 to essentially 0 seeds / 0.5 m^2. Bobwhite in the 0.5 bushel treatment can utilize milo until about day five, after which, amount of supplemental feed that remained was very small. The 0.5 bushel treatment showed consistent patterns of seed loss throughout the year.

Combination of 2.0 bu/ac and 0.5 bu/ac treatments repeated on a 15-day feeding cycle created a continuum of resource availability that varied through time and space from superabundant (50 seeds / 0.5 m^2) to scarce (0 seeds / 0.5 m^2). Estimates of seed availability through time in relation to season and feeding rate provide a foundation for examining effects of food availability on bobwhite foraging behavior. Seed availability of the 2.0 bushel treatment allows bobwhite consistent access to supplemental feed throughout the feeding cycle. This may allow bobwhite to minimize amount of time as well as amount of area required to achieve their daily metabolic needs. Whereas rate of seed loss in the 0.5 bushel treatment may cause bobwhite to change their feeding habits throughout the two week cycle. Bobwhite in the 0.5 bushel treatment may forage on milo for the first five days but then must either switch feed resources or increase amount of foraging time to achieve their daily metabolic needs. Either switching or foraging for longer periods may impose costs.

Although these results were based on supplemental provisioning, temporal dynamic created by the feeding regime has natural analogs. Natural food resources are often patchily distributed in the environment. Exploitation of these resources by foraging animals and loss to decomposition deplete food resources over time, causing animals to shift patches or food types. Some types of food resources are periodically renewed following exploitation by foragers. Regrowth of leaves, asynchronous fruiting, and recolonization by prey are examples of renewing resources. Animals foraging on renewing resources make choices about which patches to forage, search patterns between patches, and revisitation schedules to previously exploited patches. Beauchamp and Ruston (2005) investigated foraging strategies of individuals and groups foraging on renewing resources and showed that renewal time influenced optimal strategies. Ohashi and Thompson (2005) investigated informed vs. uninformed and random vs. systematic searching of renewing patches under a range of renewal rates and competition, and showed that systematic or informed-systematic search patterns were optimal, depending on conditions.

I used periodic feed supplementation along feed lines to experimentally manipulate food resources in a patch-based, renewing resource context so that I might test hypotheses about foraging behavior of bobwhite. Periodic feed supplementation fundamentally alters temporal and spatial patterns of resource availability for bobwhite, shifting it from a seasonally monotonically declining resource to an artificially-created renewing resource distributed in discrete patches.

This experimental supplementation regime mimicked that commonly used as a management technique on properties managed intensively for bobwhite. Differences between feeding rates in temporal patterns of food availability will clearly influence what constitutes optimal foraging strategies for bobwhite in managed landscapes. Lower seed availability experienced after day 5 in the 0.5 bushel treatment will likely necessitate switching of prey items and patches over the 15 day renewal cycle. Switching food sources or increasing amount of foraging time might make bobwhite more susceptible to predation. In contrast, continuous feed availability under the 2.0 bushel feeding rate might produce less variability in feeding strategies. Consequently, feeding at a 2.0 bushel rate most likely has the greatest potential to decrease predation while simultaneously increasing reproductive potential.

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CHAPTER III

SPATIAL AND TEMPORAL VARIATION IN SPACE USE OF NORTHERN BOBWHITE COVEYS

INTRODUCTION

Northern bobwhite (*Colinus virginianus*) is a popular game bird that often experiences low winter survival rates ranging from 20.9 % (Williams et al. 2004) to 15.9 % (Burger et al. 1995). Predation is a major component of winter mortality. Seasonal vegetation senescence exacerbated by winter precipitation and freezing weather produce deteriorating cover conditions throughout fall and winter increasing vulnerability to visual predators. As density and height of surrounding plant community decreases the cone of vulnerability, or air space in which a raptor has a direct line of attack increases (Guthery 2002). Also, decreasing temperatures in northern latitudes cause an influx of migrating raptors into southern regions, altering local predator context and predation risk for southern bobwhite. Increased thermoregulatory costs associated with lower temperatures require that bobwhite spend more time foraging to maintain energy balance. Increased foraging time in habitat that has less available cover along with increased predator densities may drive lower winter survival rates.

Parameter-based management is predicated on the assumption that management activities should focus on key vital rates that disproportionately influence population performance. Over-winter survival has been shown to be a key vital rate to which bobwhite population trajectory is particularly sensitive (Link et al 2008, Sandercock et al

2008). Management activities that increase winter survival will increase number of females in the breeding population, which, subject to density-dependent constraints, will inevitably increase number of offspring added to the population. Assuming that winter food resources are limiting, supplemental feeding has often been implemented as a strategy to reduce foraging time, decrease foraging area, reduce predation risk, and increase winter survival.

Foraging animals must make decisions about how they feed and utilize the landscape on a daily basis. Foraging choices include which patches to forage in, patch-residence time, and selection of specific food resources. Charnov's (1976) marginal value theorem suggests that the longer an individual forager remains in a food patch the rate of food intake within that patch will decrease.

Animals must forage efficiently while also avoiding predation. For example, Lima (1985) observed Black-capped chickadees (*Poecile atricapilla*) carrying food items into the brush to decrease exposure to predation. Decision to fly back to the brush ultimately limits amount of resources that an individual can acquire in a given time period. Predation risk substantively influences foraging choices. To decrease their susceptibility to predation, bobwhite have to find a balance between minimizing amount of time spent foraging while maximizing amount of energy gained (Schoener 1971).

Supplemental feeding fundamentally alters resource availability through time and space, creating an opportunity to test hypotheses about food limitation, foraging behavior, resource selection, and fitness. For example, up to some satiation level, foraging time should decrease with addition of supplemental feed because of reduced searching and handling time between individual food items. Decreases in movement may reduce predation risk from visual and olfactory predators. Visual predators locate prey within a line of site (Conover and Borgo 2009). Olfactory predators locate their prey when their path crosses a bird's odor plume (Mech 1970, Mills 1990, Conover and Borgo 2009). Increasing food density through supplemental feed may allow bobwhite to forage over a small area for a briefer amount of time, decreasing their exposure to predation.

Supplemental feed may also alter space-use patterns causing animals to disproportionately use areas close to the supplemented food source. Previous studies have shown influences on winter ranges as well as site preferences where individuals selected locations close to food plots or wildlife feeders (Robel et al. 1974, Sisson et al. 2000). However, effects of food density on bobwhite space use, movements, and resource selection are poorly understood at best.

My objective was to determine how temporal and spatial variability in resource abundance influenced bobwhite resource selection, space use, utilization distributions, and movement rates. I hypothesized that supplemental feed would cause bobwhite to decrease their ranges at daily and seasonal time scales because foraging opportunities should be more frequent, resulting in bobwhite having to cover less ground to achieve energy demands. I also hypothesized that bobwhite that were fed a low amount of supplemental feed would potentially have to forage over greater areas between consecutive locations as they search for available food items. Finally, I hypothesized that bobwhite would select locations close to the supplemental feed in an attempt to decrease travel time to and from feeding sites and susceptibility to predation.

Study Area

Tall Timbers Research Station (TTRS 30.66º N, 84.22º W) is located in north Leon County, Florida in an area that is commonly referred to as "the Red Hills". Tall

Timbers Research Station is approximately 1,570 hectares in size. Most of the property (66 %) was upland pine forests which consist of longleaf pine (*P. palustris*), loblolly pine (*P. taeda*) and shortleaf pine (*P. echinata*). Pine uplands are intermixed with hardwood drains (21 %) and annually disked fallow fields (13 %). Prescribed burning, mowing, and roller chopping are techniques frequently used at TTRS to reduce hardwood encroachment while maintaining adequate ground cover for nesting bobwhite.

Climate is considered relatively moderate with mean annual temperatures ranging from 30 - 94° F. Average humidity is 77.5 %. Average rainfall is 57.25 inches with most rain falling between June and September. Average elevation at TTRS is 200 feet.

METHODS

TTRS was divided into three separate treatment areas: north, south and control. Size of treatment units were 244 hectares for the north, 242 hectares for the south and 232 hectares for the control. Each year a feeding rate was assigned to an individual treatment area. *Sorghum* sp. hereafter (milo) was used as the supplemental feed being applied. Feed rates consisted of a 0.5 bushels/acre/year treatment, 2.0 bushels/acre/year treatment and no feed in the control. Feeding treatments were named in relation to annualized rates of feed distribution, over the treatment unit. During the 2009 field season the north unit was assigned the 0.5 bushels/acre/year treatment and south unit the 2.0 bushels/acre/year treatment. Control unit received no supplemental feed. All three treatments were rotated each field season to avoid confounding study site with treatment (Figure 2.1). Mechanics of seed distribution and seed availability over a two week feeding cycle were predetermined (see chapter II).

Supplemental feed was distributed on a biweekly feeding schedule throughout the year. The entire feeding process took two days. Supplemental feed was applied to half of both feed treatments on the first day and then the second halves were spread the second day. This was done so that some birds within both feed treatments had access to feed on the first day of feeding.

Bobwhite were captured using baited walk-in funnel traps (Stoddard 1931). Traps were baited with Milo and then covered with recently cut pine boughs in an attempt to minimize stress of captured birds and to keep traps hidden from predators. Gender, age class, and weight for each captured bobwhite were recorded (Rosene 1969). Additionally, a uniquely numbered aluminum leg band was attached (National Band and Tag Co., Newport, KY). Bobwhite were then fitted with 6.4 – 6.9 g necklace radio transmitters (American Wildlife Enterprises, Monticello, FL). Trapping, handling, and marking procedures were consistent with the guidelines of the Tall Timbers Research, Inc. Institutional Animal Care and Use Committee Permit (IACUC no. GB2001-01).

Daily Telemetry

During period of 1 February through 15 March 2009 and 2010, locations and movements of radio-marked coveys were intensively monitored in units receiving the 2 supplemental feeding regimes. Coveys were intensively monitored on average four times a week in a manner that coincided with the seed availability schedule. This resulted in an even distribution of samples throughout the two week feeding cycle. Each day one covey was chosen at random using a random number generator in Microsoft® Excel within each of the two feed treatments.

Coveys were located every 30 minutes diurnally. Observers tried to maintain a buffer of at least 40 meters from the monitored coveys and were as quiet as possible in order to limit any potential influence on covey movements. Using an orienteering compass, observers took bearings and estimated distances to covey locations, producing an average of 21 (17-24) locations/covey/day. I provided observers with GPS units that had the feed line omitted from their background to eliminate any potential bias for locations on or near the feed line.

Observer locations were then georeferenced (+/- 1 m) using a differentially corrected Trimble Geoexplorer GPS unit and Pathfinder Software (Trimble Navigation Limited, Sunnyvale, CA). Covey locations were triangulated using a minimum of three positions within LOAS 4.0 software (Ecological Software Solutions LLC.) using a maximum likelihood estimator. I then censored locations with an error eclipse greater than 0.01 ha. Observers also recorded time, bird id, radio frequency, covey status, and comments. Covey status could include roosting, covey moving, no covey movement or covey flushed. Data was entered immediately into a handheld Trimble GPS unit while in the field.

Seasonal Telemetry

Individual birds in the 2 bu/ac/yr, 0.5 bu/ac/yr, and control treatments were located three or more times per week from 1 November to 15 March during both 2008-09 and 2009-10 winter seasons. Observers used homing techniques to determine bird locations to within 50 meters (Fuller et al. 2005). Locations were plotted on detailed aerial photos at a scale of 1:1000 in the field which were created in Arc Map and included land cover types as well as terrain features. Then later positions were transferred into a Geographical Information System ArcGIS 9.3 (ESRI 2009) to determine spatial coordinates.

Telemetry locations were used to estimate daily and seasonal utilization distributions of radio-marked bobwhite in relation to supplemental feed availability. I used daily telemetry locations for all radio-collared birds in the 3 treatments to estimate seasonal utilization distributions. I used intensive telemetry locations from bobwhite coveys to estimate daily utilization distributions to investigate bobwhite space use in relation to temporally dynamic resource availability. To compare my range estimates with previous studies I generated 50 and 95 % utilization distribution. Utilization distributions as well as the smoothing parameter (h) were created using the ADEHABITAT package in R (Calenge 2006) using scripts provided by Dr. Theron Therhune, (personal comm.). A smoothing parameter was created for ranges in each year of the study as the mean, least-squares cross-validation-derived h over all individuals where the algorithm converged (bivariate normal kernel; Kenward 2001, Terhune et al. 2010).

Area within 50 and 95 % utility distributions were then calculated using X tools Pro extension in ArcGIS 9.3. Utility distributions were used to measure daily and winter ranges. An analysis of variance (ANOVA) within a general linear model (GLM) in SAS® software, Version 9.2 (SAS Institute Inc., 2002) was used to test for treatment, year and year by treatment effects on winter and daily ranges. Range estimate was (dependant) variable whereas treatment and year were (independent) variables. Estimates were reported as least squared means and associated standard errors.

Proximity to Feed Line

To determine if bobwhite preferentially selected locations closer to supplemental feed patch, I compared mean distance to feed patches between covey locations and an equal number of randomly generated locations. I used Hawth's tools in ArcGIS to generate an equal number of random locations that were time and treatment specific. These random locations were generated within the treatment units that the covey locations were in during that specific season.

Once the random locations were generated I used the NEAR function in ArcGIS to calculate distances from random locations to feed patch. This method was also used for the intensive telemetry locations. Then an overall mean was determined for each radio-marked covey and paired random locations using PROC MEANS in SAS® software, Version 9.2 (SAS Institute Inc., 2002) (Table 3.1). Individual coveys were used as sampling unit (random effect) for an analysis of variance (ANOVA) within a Mixed model in SAS. Estimates of distance to feed line were compared using least squared means.

Although feed line traversed during the supplemental feeding activities was a linear feature, the spreader distributed feed over an area approximately 7 m perpendicular to the tractor path, either side of the centerline. I defined this 14 m-wide swath as the feed patch. Feed patch covered about 11 % of the total habitat within both the 0.5 and 2.0 bu/ac/yr feed treatments. I classified locations of coveys from intensive daily monitoring as in or out of feed patch in a binary fashion. I treated covey-days as independent sampling units and estimated the proportion of 30-minute relocations in feed patch for each covey-day. To determine if proportional use of feed patches was influenced by supplemental feed, I modeled probability of being in a patch using an events/trials (locations in feed patch/total number of locations in covey day) response in a logistic regression within PROC LOGISTIC in SAS® software, Version 9.2 (SAS Institute Inc., 2002).

I constructed a candidate model set that included models that predicted percentage use of the patch as a function of : 1) seed availability 2) seed availability + year, 3) seed availability + year + seed availability*year 4) seed availability + seed availability^2 + year 5) seed availability + seed availability^2. I selected best approximating model using least AIC scores, and Hosmer-Lemshaw goodness of fit (Burnham and Anderson 2002) (Figure 3.4).

It is possible for locational distributions to differ without influencing either mean daily movements, distance to feed lines, or range size. I used multiresponse permutation procedures (MRPP) to test for distributional differences between locations of bobwhite in 2 bu/ac/yr and 0.5 bu/ac/yr feeding treatments. MRPP can be used to simultaneously test for distributional differences in central tendency and dispersion for univariate and multivariate analyses in a completely randomized one-way design (Cade and Richards, 2005). I used MRPP to test for differences between feed treatments in dispersion of daily locations within BLOSSOM version W2008.04.02 (USGS, Fort Collins, CO). I centered the daily locational data relative to the mean x and y coordinate for each individual covey, scaling all locations to a common origin. Having removed differences in central tendency through centering, subsequent MRPP test on the centered data then became a test of bivariate dispersion.

RESULTS

During 2009 and 2010 winter seasons, I estimated daily utilization distributions and ranges for 107 covey days across two supplemental feeding treatments. Daily range size did not differ between supplemental feed levels ($F_{1,103} = 3.47$ $P = 0.06$) or years ($F_{1,103} = 0.07$ $P = 0.79$). In 2009, mean daily ranges were 0.72 ha (SE = 0.06) in 2 bu/ac/yr and 0.85 ha (SE = 0.06) for 0.5 bu/ac/yr treatment (Table 3.1). Ranges were similar during the 2010 winter season with mean daily ranges of 0.71 ha (SE = 0.06) and 0.83 ha (SE = 0.08) for 2.0 and 0.5 bu/ac/yr treatments, respectively.

Mean daily range sizes, grouped by seed availability classes, had overlapping confidence intervals and as such did not differ substantively. There was an increase in range size as seed availability fell to 40 seeds / 0.5 m^2. Range size decreased as seed availability decreased from 40-31 seeds / 0.5 m^2 followed by an apparent pattern of increasing range size as seed availability fell from 30 to zero seeds / m^2 (Figure 3.1).

I used telemetry locations collected from 1 November to 15 March at TTRS to determine seasonal range sizes based on 37 birds for the 2009 winter and 52 birds for the 2010 winter. Seasonal range sizes did not differ significantly among supplemental feed levels ($F_{2,83} = 0.60$ $P = 0.55$) or between years ($F_{1,83} = 1.29$ $P = 0.25$). During 2009, mean winter range sizes were 18.03 ha (SE = 1.24) in 2.0 bu/ac/yr treatment, 18.6 ha (SE = 1.77) in 0.5 bu/ac/yr treatment and 18.7 ha (SE = 1.75) for control treatment (Table 3.2). In 2010, mean winter range sizes were 18.3 ha (SE = 1.18), 20.4 ha (SE = 1.19) and 21.2 ha (SE = 2.53) for 2.0 bu/ac/yr, 0.5 bu/ac/yr, and control treatments, respectively.

Bobwhite traveled a mean 25.16 m (SE = 0.65) between consecutive (30 Minute) locations during daily intensive focal periods. Mean step length between consecutive locations did not differ between feeding treatments ($F_{1,2178}$, $= 0.99$, $P = 0.32$) or years (F

$_{1,2178} = 0.81$, $P = 0.36$). During 2009, mean step lengths were 27.25 m (SE = 1.53) and 24.49 m (SE = 1.19) for 0.5 bushel and 2.0 bushel treatment, respectively. In 2010, the mean step lengths were 24.61 m (SE = 1.2) and 24.75 m (SE = 1.29) for the 0.5 bushel and 2.0 bushel treatments, respectively.

Similarly, total distance that bobwhite coveys traveled throughout the day did not differ between treatments ($F_{1,103} = 0.17$, $P = 0.68$) or years ($F_{1,103} = 0.00$, $P = 0.95$). In 2009 total distance traveled over the entire day was 528.3 m (SE = 33.01) for 0.5 bushel treatment, and 495.8 m (SE = 33.04) for 2.0 bushel treatment. In 2010, birds in 0.5 bushel treatment had a mean total travel distance of 513.5 m (SE = 40.99) compared to 514.9 m (SE = 39.2) for 2.0 bushel treatment.

Although daily range size, seasonal range size, step length, and total daily movements did not differ between feeding treatments, centered bivariate locational distributions did differ ($P < 0.001$). Mean Euclidian distance between all pairwise combinations of centered locations in 0.5 bu/ac treatment (D = 1.75 m) was 23 % greater than that in 2.0 bu/ac treatment (D = 1.43 m), indicating greater dispersion.

I also found similar results using data from coveys tracked throughout 1 November to 15 March 2009 and 2010. Coveys in 0.5 bushel treatment showed greatest distances traveled between consecutive locations throughout winter ($F_{1,63} = 4.13$, $P = 0.04$). The 0.5 bushel treatment average covey movement was 167.5 m (SE = 7.10) and 2.0 bushel treatment was 139.7 m (SE = 5.77).

Telemetry locations from 38 intensively monitored bobwhite quail coveys between 1 February 2009 and 15 March 2010 provided information on proximity of daily locations to feed line. Number of coveys tracked varied by year from 16 to 22 (Table 3.3). Mean distance to feed line did not differ significantly from random, indicating that coveys locations were not disproportionately close to or far from the feed line ($F_{1,71}$ = 0.04, P = 0.83). Moreover, mean distance to feed line did not differ significantly between treatments ($F_{1,71}$ = 0.43, P = 0.52), or years ($F_{1,71}$ = 0.27, P = 0.60). I also modeled interactions between random and treatment effects ($F_{1,71}$ = 0.0 P = 0.97) (Table 3.4). The mean distance to feed line was 42.0 m (SE = 1.0) and 41.3 m (SE = 3.15) for random and actual covey locations, respectively. Although I did not observe strong evidence for disproportionate selection of locations close to feed line, there were consistent patterns in proximity to feed line across the range of temporally varying seed availability. Coveys tended to choose locations closer to feed line as seed availability decreased from 40 to 11 seeds / 0.5 m^2, reaching a minimum distance of 26.6 m (SE = 6.07) at about 11 seeds. This decreasing trend was followed by an increase in the mean distance to feed line to 40.4 m (SE = 3.17) when seed availability decreased below 10 seeds (Figure 3.2), suggesting that birds may have abandoned the feed patch at very low seed density.

Locations from 102 covey days with greater than 15 locations were used to estimate proportion of time within feed patch. Mean number of locations per covey day was 20.8 (SD = 2.2). Proportion of daily locations within feed patch (9 – 22 %) varied in relation to seed availability (Figure 3.3). The model that best explained proportional use of feed patches included seed availability and seed availability squared (Figure 3.4). At 0 – 10 seeds / 0.5 m^2, approximately 17 % (SE = 2.5) of locations were within the feed patch, increasing to 22 % (SE = 7.5) at 10 – 20 seeds / 0.5 m^2, then declining monotonically to 9.2 % (SE = 3.5) at 40 – 50 seeds / 0.5 m^2 (Figure 3.3).

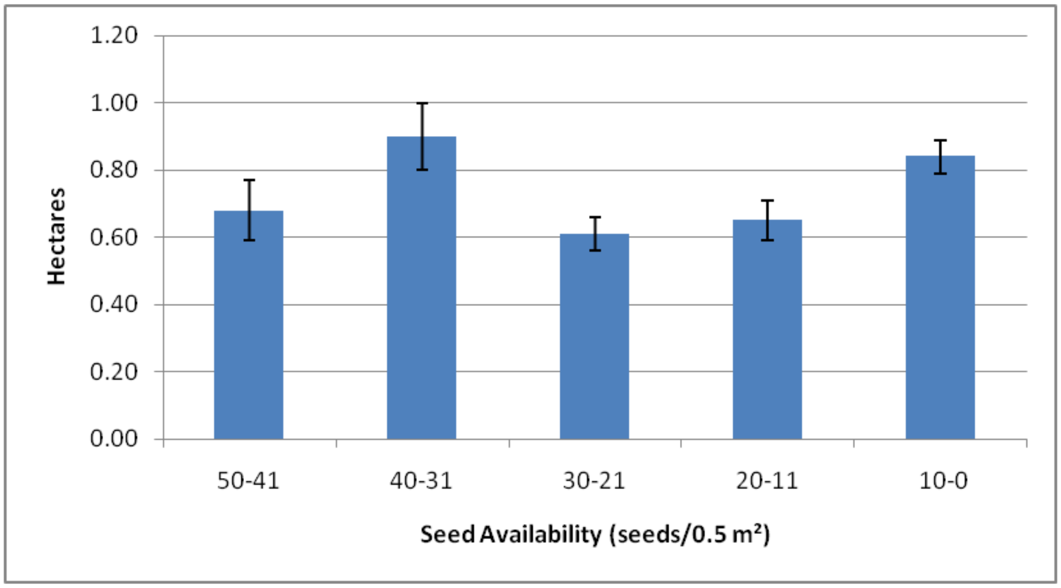

Figure 3.1 Daily range sizes (ha) for radio-marked Northern Bobwhite coveys, in relation to daily seed availability, February and March, 2009 and 2010, at Tall Timbers Research Station, Leon Co., FL, USA. Error bars indicate 1 standard error.

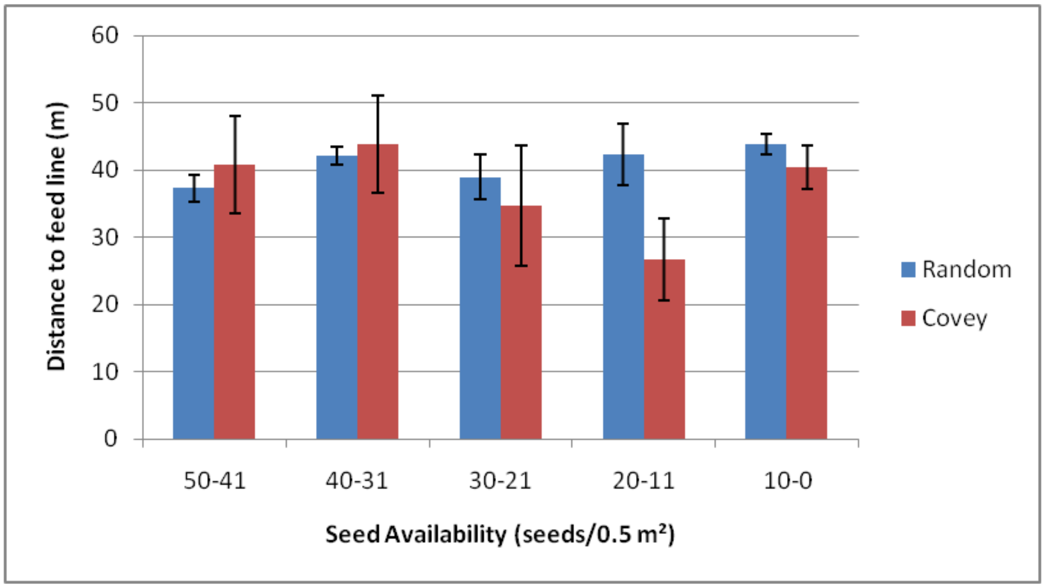

Figure 3.2 Mean distance to feed line for radio-marked Northern Bobwhite coveys and randomly-generated locations, February 2009 and 2010, at Tall Timbers Research Station, Leon Co., FL, USA. Error bars indicate 1 standard error.

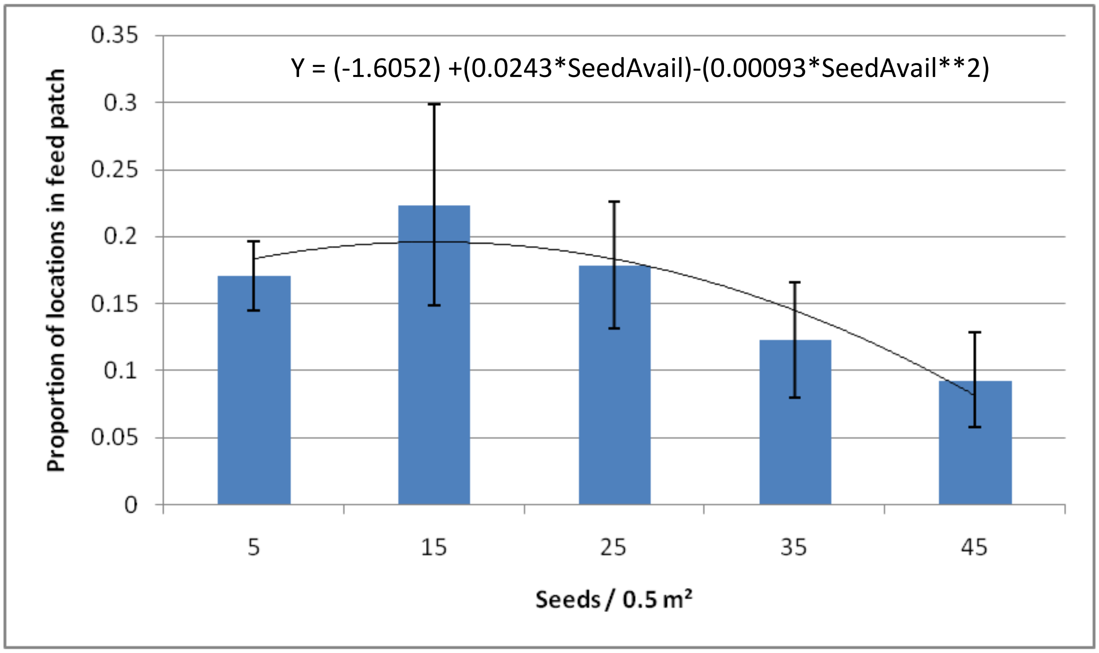

Figure 3.3 Mean proportion of covey locations within feed patch, February 2009 and 2010, at Tall Timbers Research Station, Leon Co., FL, USA. Error bars indicate 1 standard error.

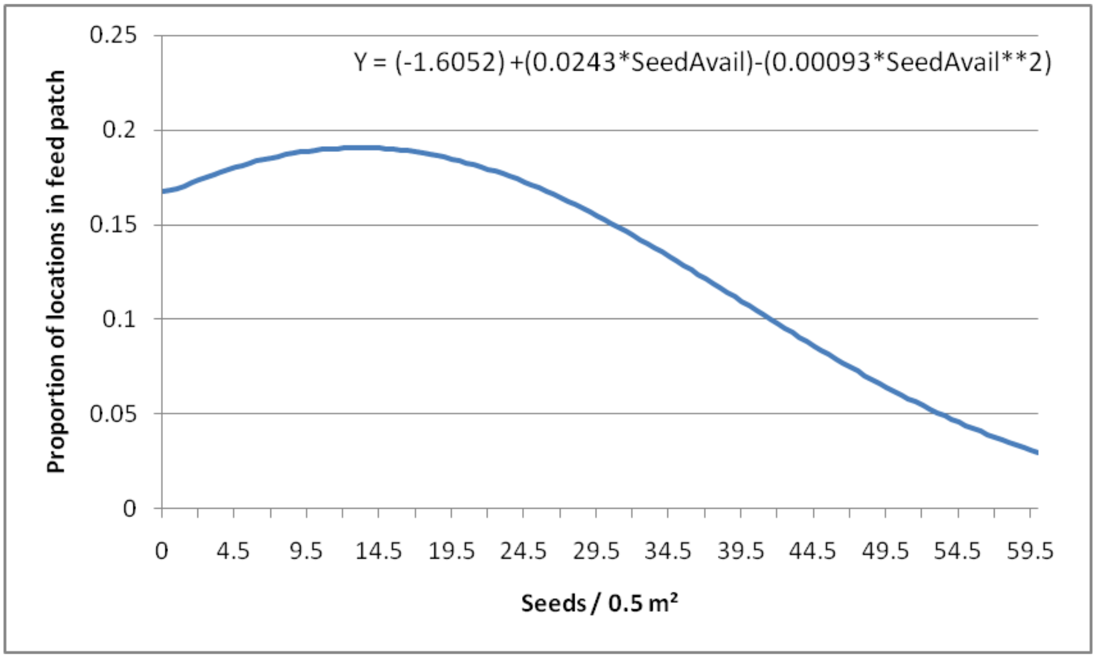

Figure 3.4 Best approximating model to determine proportional use of feed patches, at Tall Timbers Research Station, Leon Co., FL, USA.

Table 3.1 Mean daily range estimates (ha) for 50 % and 95 % utilization distributions for 2009 and 2010 winter seasons at Tall Timbers Research Station, Leon Co., FL.USA.

Treatment	Year	*N*	50%	SE	95%	SE
0.5 bu/ac	2009	23	0.19	0.02	0.85	0.06
2.0 bu/ac	2009	24	0.16	0.01	0.72	0.06
0.5 bu/ac	2010	30	0.17	0.02	0.83	0.08
2.0 bu/ac	2010	30	0.14	0.01	0.71	0.06

Table 3.2 Mean seasonal range estimates (ha) for 50 % and 95 % utilization distributions for 2009 and 2010 winter season at Tall Timbers Research Station, Leon Co., FL,USA.

Treatment	Year	*N*	50%	SE	95%	SE
0.0 bu/ac	2009	15	4.91	0.46	18.71	1.75
0.5 bu/ac	2009	11	4.67	0.48	18.6	1.77
2.0 bu/ac	2009	11	4.39	0.42	18.03	1.24
0.0 bu/ac	2010	11	5.24	0.44	21.18	2.53
0.5 bu/ac	2010	22	5.22	0.36	20.41	1.19
2.0 bu/ac	2010	19	4.31	0.31	18.34	1.18

Table 3.3 Mean distance to feed line for random and actual covey locations collected during February and March 2009 and 2010 at Tall Timbers Research Station, Leon Co, FL, USA.

Treatment	Year	*n*	Mean	SE
Random	2009	16	43.1	1.94
Actual	2009	16	41.8	456
Random	2010	22	41.2	1.01
Actual	2010	22	40.9	4.39

Table 3.4 Model, degree of freedom, critical F value and significance level for paired and actual covey locations at Tall Timbers Research Station, 2009-2010, Leon Co, FL. USA.

Model	DF	DF	F Value	P > F
Random /actual	1	71	0.04	0.83
Treatment	1	71	0.43	0.52
Year	1	71	0.27	0.6
Random/actual*Treatment	1	71	0	0.97

DISCUSSION

I *apriori* hypothesized that ranges would decrease in size as amount of supplemental feed increased. Supplemental feed could allow bobwhite to maintain smaller ranges because they would not have to use as much habitat to achieve daily energetic requirements. Although not statistically significant daily ranges for the 2.0 bushel treatment were nearly 15 % smaller than that of the 0.5 bushel treatment. Daily and seasonal range sizes were similar between feeding treatments. This suggests that although amount of supplemental food was not the primary factor influencing range size it was in fact influencing daily ranges to some extent. Sisson et al. (2000) observed similar results as winter ranges were smaller on fed versus unfed sites. However, abundance and distribution of resources may influence the manner in which bobwhite use space, without affecting range size.

Movement rates and dispersion of locations did differ between treatments. Bobwhite in 0.5 bu/ac/yr feed treatment had greater locational dispersion within ranges when compared to bobwhite in 2.0 bu/ac/yr treatment. Taken together with similarity in range size, differences in dispersion indicates that although bobwhite in 0.5 bu/ac/yr treatment do not necessarily utilize more space during the day or season, they use space differently, with greater spatial dispersion in 0.5 bu/ac/yr and more concentrated space use in 2.0 bu/ac/yr treatment. This could be because bobwhite have to forage over a greater area to find adequate food resources to meet metabolic requirements. More concentrated locations of bobwhite in 2.0 bu/ac/yr feed treatment may be a result of abundant food resources.

Along with smaller ranges I hypothesized that bobwhite would select locations close to supplemental feed line decrease travel time to and from feeding areas. However, mean distance to feed line did not differ between used and random locations, or between treatments, suggesting that bobwhite were not selecting locations disproportionately close to feed line. This could mean either that supplemental feeding did not concentrate bobwhite or that our study site was saturated with feed line to a point where random locations were within the same proximity as that of actual bobwhite locations. These results contradict that of research collected in Texas where managers baited roads with the intention of making bobwhite more susceptible to harvest (Lehman 1984, Boyer 1989). Baiting roads is somewhat different then this study because roadsides often lack sufficient cover, potentially concentrating bobwhite and therefore making them more susceptible to predation (Haines et al. 2004). This study used a feed line that was spread throughout the pine uplands where sufficient cover was evenly dispersed and therefore not a limiting factor. Further research that compares different feed line densities may better address the question of how supplemental feed influences bobwhite locations more accurately.

Although mean range size and mean distance to feed line did not differ between supplemental feed treatments, both metrics exhibited similar patterns in variation across a range of seed availabilities, declining as seed availability declined from 40 – 11 seeds / 0.5 m^2, then increasing markedly with greatest daily range size and distance to feed line observed at seed densities less than 10 seeds / 0.5 m^2. This consistent pattern suggests that as amount of supplemental feed decreases bobwhite are changing their foraging behavior. One could propose that as amount of available food decreases bobwhite are selecting sites closer to feed line to maximize amount of milo consumed. Additionally, decreases in range size could be due to bobwhite trying to concentrate daily movements around this known food source, but at very low seed densities they essentially abandon the feed line and forage at random on native seeds.

Similarly, proportion of their daily time spent within feed patch varied in relation to seed availability. Proportion of time within feed patch varied quadratically with seed density peaking at about 14 seeds / 0.5 $m^{2.}$ Proportion of time actually within feed patch declined monotonically as seed density varied from 14 – 50 seeds / 0.5 $m^{2.}$ As seed density increased bobwhite may have been able to completely fill their crop during relatively short foraging periods then leave the patch to loaf nearby. This behavior is consistent with a foraging technique referred to as area-restricted searching. Area-restricted searching suggests that individuals improve their foraging success by staying in or around a food patch with high densities (Gill 1995). Below seed densities of 14 seeds / 0.5 m^2 birds also decreased their time in the patch, but likely for different reasons. As seed density declined below some threshold level, birds likely spent less time in the patch because food availability did not differ markedly from that outside the patch. This suggests a potential GUD at which the energy gained within that feed patch is equal to or falls below that of the surrounding habitat. It is at this point where we see bobwhite beginning to select for locations outside of feed patch.

Increase in range size and distance to feed line that is observed as feed availability decreases below 11 seeds might also indicate a potential giving up density for bobwhite.

At lesser seed densities, bobwhite may begin searching for an alternate food source resulting in locations being farther away from feed line and increasing range sizes. If seed densities in the range of 10-14 seeds / 0.5 m^2 actually indicate a GUD threshold, mean energetic availability in the habitats at this time of year could be inferred as the energy content of 10-14 sorghum seeds, or approximately 1.5 kcals / $0.5m^2$.

It is interesting that even though the 2.0 bushel bobwhite had more localized movements throughout the day they still had nearly similar daily home range sizes to that of the 0.5 bushel bobwhite. This suggests that bobwhite in the 2.0 bushel treatment had abundant feed that allowed them to forage over a smaller area but some other factor must be causing them to make large movements between foraging events. If bobwhite in 2.0 bushel feed treatment are using the same amount of habitat in a day some other factor is causing this response.

Amount of available cover and way that cover is distributed across the landscape could influence bobwhite ranges throughout the day or season. For example areas on south facing hill sides receive more sunlight and become warmer causing thermals to raise making bobwhite less susceptible to mammalian predation. Bobwhite are susceptible to avian and mammalian predators which use different means of detecting their prey. Avian predators use vision to detect prey items whereas mammalian predators use olfactory senses. Less available cover makes bobwhite more susceptible to avian and mammalian predators. Because of less cover bobwhite may have to utilize more habitat throughout the day to avoid predation.

Although supplemental feed itself does not seem to affect over winter survival in bobwhite directly, it may influence survival indirectly through another mechanism, such as predation risk (Sisson et al. 2000). Other wildlife species such as cotton rats

(*Sigmodon hispidus*) and cotton mice (*Peromyscus gossypinus*) forage on supplemental feed. Doonah and Slade (1995) determined that cotton rat densities increased due to increased reproduction and immigration in relation to supplemental feed. Increases in these other species may buffer some of the winter mortality that bobwhite often experience.

In summary, although supplemental feed availability only slightly affected bobwhite daily and seasonal range size, it did influence dispersion of daily locations within daily and seasonal ranges. Moreover, proportional amount of time foraging within feed patch was greatest as food availability varied from 10 – 15 seeds / 0.5 m^2, then declined monotonically as seed density increased to from 20 - 60 seeds / 0.5 m^2. Apparently, at greater seed densities bobwhite could quickly acquire adequate food resources, and then left the patch to loaf in more secure cover. If time in feed patch is a measure of foraging time, then foraging time increased while efficiency decreased with decreasing seed density. A threshold of approximately 14 seeds / 0.5m^2 may represent a GUD, providing a crude approximation to time-specific energy availability in a larger managed pine-grassland system.

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CHAPTER IV

ENERGY AND LIPIDS OF NORTHERN BOBWHITE

INTRODUCTION

Acquisition of food resources during winter is important to all wildlife species. Foragers are often forced to make trade-offs between food acquisition and predator avoidance (Stephens and Krebs 1986). These decisions are extremely important during winter when temperatures are lower and amount of available resources is slowly decreasing. As a result, small birds are often forced to increase their lipid stores in an attempt to increase their survival. Optimal amount of lipid reserve is a compromise between costs and benefits of energy storage. If amount of lipid reserve is the only factor that influenced survival then fat reserves would be at their maximum level but this is rarely the case. Increased fat reserves impose a cost in the form of greater mass and less power in flight. Fatter, heavier birds may be more likely to be killed if a predator attacks (Houston et al. 1997). There are trade-offs between food acquisition and survival that influence amount of food acquired and therefore lipid reserve levels that bobwhite need to maintain during colder months.

Amount of energy a bobwhite can intake in a day is crucial as temperatures decrease during winter. Demand for thermoregulation increases linearly as ambient temperature decreases, below a lower critical temperature (Swanson and Weinacht 1997). Thermoregulation can account for 70 % of a bobwhite’s daily energy requirements (Blem 2000). A foraging bobwhite must ingest a large quantity of gross energy, which is the product of mass of food items ingested times heat of combustion of these food items, because only a portion of that energy will actually result in metabolizable energy (Blem 2000). Amount of metabolizable energy ingested has to be equal to or greater than amount of energy required for thermoregulation as well as any type of locomotion (i.e., walking, flight), growth, and maintenance. Flight is the most energetically demanding form of locomotion and flight at high velocities requires greater amounts of energy (Blem 2000). However, because most flights are short the energy expenditure of flights is negligible in bobwhite relative to total daily energy budget (Guthery 2002).

My objectives were to determine if: 1) if addition of supplemental feed would cause bobwhite to select for the supplemental feed (*Sorghum* Sp) compared to native seed types such as butterfly pea (*Centrosema* Sp.), partridge pea (*Chamaecrista* Spp.), lespedeza (*Lespedeza* Spp.), desmodium (*Desmodium* Spp.), downy milkpea (*Galactia volubilis*) and acorn mast (*Quercus* Spp.); 2) supplemental feed would result in bobwhite having a larger amount of food and subsequently, energy in their crops at a given time; 3) bobwhite shifted away from supplemental feed relative to amount of available feed; and 4) late winter lipid reserves are affected by supplemental feed availability.

I hypothesized that: 1) bobwhite in 2.0 bushel treatment would have greater crop weights and ultimately a greater amount of energy; 2) selectivity for supplemental feed would change over time as supplemental feed availability decreased; and 3) bobwhite in 2.0 bushel treatment would have a greater amount of lipid reserves due to the increased amount of available food.

Study Area

Tall Timbers Research Station (TTRS 30.66º N, 84.22º W) is located in north Leon County, Florida in an area that is commonly referred to as “the red hills”. Tall Timbers is approximately 1,570 hectares in size. Most of the property (66 %) was upland pine forests which consist of longleaf pine (*P. palustris*), loblolly pine (*P. taeda*) and shortleaf pine (*P. echinata*). Pine uplands are intermixed with hardwood drains (21 %) and annually disked fallow fields (13 %). Prescribed burning, mowing, and roller chopping are techniques frequently used at TTRS to reduce hardwood encroachment while maintaining adequate ground cover for nesting bobwhite.

Climate is considered relatively moderate with mean annual temperatures ranging from 30 - 94º F. Average humidity is 77.5 %. Average rainfall is 57.25 inches with most rain falling between June and September. Average elevation at TTRS is 200 feet.

METHODS

TTRS was divided into three separate treatment areas, north, south and control. Treatment sizes were 244 hectares for north, 242 hectares for south and 242 hectares for control. Each year a feeding rate was assigned to an individual treatment area. *Sorghum* sp. hereafter (milo) was used as the supplemental feed being applied. Feeding rates consisted of 0.5 bushels/acre/year treatment, 2.0 bushels/acre/year treatment and no feed in control. The 2009 field season had north as 0.5 bushels/acre/year treatment and south as 2.0 bushels/acre/year treatment. Feed treatments rotated each field season to avoid confounding study site with treatment. In 2010 the previous year’s control treatment became 2.0 bushel/acre/year treatment, 0.5 bushel treatment became control treatment and 2.0 bushel/acre/year treatment became 0.5 bushel/acre/year bushel feed treatment.

Daily seed availability was estimated using methods mentioned previously (see chapter II).

Although the feed line traversed during the supplemental feeding activities was a linear feature, spreader distributed feed over an area approximately 7 m perpendicular to tractor path, either side of the centerline. I defined this 14 m-wide swath as the feed patch. Feed patch covered about 11 % of total habitat within both the 0.5 and 2.0 bu/ac/yr feed treatments.

Northern bobwhite were captured using baited walk-in funnel traps (Stoddard 1931). Gender, age class, and weight for each captured bobwhite were recorded and a uniquely numbered aluminum leg band was attached (National Band and Tag Co., Newport, KY). Quail were aged as juvenile or adult based on differences in their primary coverts (Rosene 1969). Bobwhite were then fitted with 6.4 – 6.9 g necklace radio transmitters (American Wildlife Enterprises, Monticello, FL). Trapping, handling, and marking procedures were consistent with the guidelines of the Tall Timbers Research, Inc. Institutional Animal Care and Use Committee Permit (#GB2001-01).

Diet Assessment

Analysis of crop contents of harvested birds on each study site provided an instantaneous assessment of food intake in relation to feeding treatments and temporally varying food availability. By assessing the birds' diet I was able to determine degree to which bobwhite were feeding on supplemental sorghum relative to native seeds and confirm that birds close to feed line were indeed foraging and not just using feed line as a travel corridor. To assess food habits bobwhite were harvested during the last 2 hours before roosting in February as part of Tall Timbers annual bobwhite band recapture.

Following harvest, crops were collected and time of harvest, date, feed treatment, and gender were recorded for each kill. Diets were assessed for birds harvested in February 2009 and February 2010.

Crop contents were removed and food items were dried to a constant mass in an industrial sized dryer set at 80˚ F for 72 hours (Masters et al. 2007). Seed items were identified to lowest taxon possible using Tall Timbers Research Station reference seed collection, along with reference manuals by Martin and Barkley (1961) and Landers and Johnson (1976). Crop contents were classified as seeds, green vegetation and invertebrates. Items were weighed to 0.001 g and total number of seeds for each species was recorded. Energy values were calculated for each individual crop using metabolizable energy values of food items taken from Robel et al. (1979) and Madison and Robel (2001).

Harvested birds were frozen and shipped to the Nutrition Lab at Mississippi State University for a whole body proximate analysis. Proximate analysis followed Association of Analytical Communities (AOAC) methodology. Entire carcass was oven dried at 90º F for a week and weighed and then homogenized. Fat was extracted from two subsamples with anhydrous ether. After extraction, subsamples were dried and reweighed; difference between the two weights was concluded to be amount of lipid mass. Two additional subsamples were analyzed if lipid values differed by >1 % between the original subsamples. Final measurement of body lipid, % of body mass, was the mean from the two or four subsamples (Frawley et al. 1999).

To determine if bobwhite were adjusting their diets in relation to available food I used analyses of variance (ANOVA) within general linear models (GLM) to test for difference between feed treatments, year and treatment*year interactions. Total crop weight was my dependent variable, whereas year and treatment were independent variables. Estimates of total crop weight were compared using least squared means using SAS® software, Version 9.2 (SAS Institute Inc., 2002).

Food items that composed ≥ 95 % of bobwhite crops were included in analyses. The other 5 % was unidentifiable. Seeds in diet analysis included milo, butterfly pea, partridge pea, lespedeza, desmodium, downy milkpea and acorn mast.

I used an ANOVA within a GLM to determine if energetic values of total crop contents differed between treatments, year and treatment*year interactions. Energetic value was my dependent variable whereas year and treatment were independent variables. Least squared means and standard errors were calculated using SAS® software, Version 9.2 (SAS Institute Inc., 2002). Similar energetic values between bobwhite as diet selection changed would have been attributed to increases in consumption rates of each particular variety of seed.

I used an ANOVA within a GLM test for effects of treatment, year, and treatment*year on lipid reserves of bobwhite harvested in February, 2009 and 2010. Lipid content was my dependent variable whereas year and treatment were my independent variables for analysis. This analysis and calculation of least squared means and their standard errors were done using SAS® software, Version 9.2 (SAS Institute Inc., 2002). All means were reported ± SE.

RESULTS

I harvested 285 Northern Bobwhite during February 2009 and 2010. Number of birds harvested varied among treatments with 61 in control, 102 in 0.5 bu/ac/yr and 122 in 2.0 bu/ac/yr treatment (Table 4.1). Mean crop weight did not differ significantly between years ($F_{1,279} = 2.34$, $P = 0.13$) or among feed treatments ($F_{2,279} = 1.90$, $P = 0.15$). Mean weight of crop contents were 2.6 g and 2.8 g for 0.5 bu/ac/yr treatment in 2009 and 2010, 2.2 g and 2.4 g for 2.0 bu/ac/yr treatment in 2009 and 2010, and 2.3 g and 2.9 g for control in 2009 and 2010 (Table 4.2).

Total metabolizable energy of crop contents for bobwhite harvested did not differ significantly between feed treatments ($F_{1,278} = 0.92$, $P = 0.408$). Mean metabolizable energy within a crop was 7.9 kcals (SE = 0.63) for control, 8.9 kcals (SE = 0.63) for 0.5 bu/ac/yr treatment and 8.3 kcals (SE = 0.64) for 2.0 bu/ac/yr feed treatment (Table 4.1). Mean metabolizable energy in crops peaked at 11.7 kcals (SE = 1.27) when seed availability was between 40 and 50 seeds / 0.5 m^2 and as seed availability declined varied between 5.9 kcals (SE = 0.84) at 31-40 seeds / 0.5 m^2, and 9.1 kcals (SE = 0.65) of metabolizable energy at ten seeds / 0.5 m^2 (Figure 4.1).

Varieties of seed within the crops of birds harvested in February 2009 and 2010 varied by feed treatments and by year. Without supplemental feed, birds in control treatment foraged heavily on native seeds and mast. Crop contents of birds harvested in the control treatment in 2009 were primarily comprised of acorn mast (25 %) and partridge pea (49 %) (Figure 4.2). In 2010, crop contents from control feed treatment were predominantly partridge pea (65 %) (Figure 4.4). However, when available as supplemental feed, milo was a common component of bobwhite diets. Crop contents collected from birds harvested in 0.5 bu/ac/yr feed treatment in 2009 were comprised of partridge pea (30 %), acorn mast (19 %), and milo (27 %) (Figure 4.6). In 2010 crop contents from 0.5 bu/ac/yr treatment consisted of partridge pea (40 %), milo (29 %), and acorn mast (17 %) (Figure 4.8). At higher feeding rates, milo comprised a greater proportion of total crop contents. Crops of bobwhite harvested in 2.0 bu/ac/yr treatment consisted of 74 % milo during the 2009 season (Figure 4.10) and 95 % milo during the 2010 season (Figure 4.12). Mean percentage milo within crops varied in relation to seed availability during the 15-day feeding cycle. At seed availabilities of 50-20 seeds / 0.5 m², milo comprised 67.97 % (SE = 6.96) to 79.36 % (SE = 8.01) of crop contents, respectively (Figure 4.14). This was followed by a precipitous decline to 57.63 % (SE = 8.01) when seed availability was between 11 and 20 seeds / 0.5 m² and 23.91 % (SE = 3.8) when seed availability was below 10 seeds / 0.5 m².

I estimated mean body mass and total body lipids from a sample of 282 bobwhite harvested in 2009 and 2010 (Table 4.3). Mean live body mass of bobwhite were 165.7 g (SE = 0.7) ranging from 120.5 g to 216.8 g. Mean live mass did not differ among supplemental feed treatments ($F_{2,276} = 1.51$, P = 0.22). On average, 65.1 % (SE = 0.10) of fat-free body mass was water.

Mean percentage dry mass lipids for control treatment was 19.79 % (SE = 1.15) in 2009 and 16.60 % (SE = 0.41) in 2010. Mean percentage dry mass lipids for 0.5 bu/ac/yr treatment was 17.91 % (SE = 0.32) in 2009 and 17.46 % (SE = 0.43) in 2010. Mean percentage lipids of dry mass for 2.0 bu/ac/yr treatment was 20.39 % (SE = 0.64) in 2009 and 19.89 % (SE = 0.43) in 2010.

Mean lipid mass for bobwhite in control treatment was 10.63 g (SE = 0.69 in 2009 and 9.66 g (SE = 0.32) in 2010. Mean lipid mass for bobwhite in 0.5bu/ac/yr treatment was 9.75 g (SE = 0.22) in 2009 and 10.30 g (SE = 0.30) in 2010. Mean lipid mass for bobwhite in 2.0 bu/ac/yr treatment was 11.58 g (SE = 0.45) in 2009 and 11.91 g (SE = 0.31) in 2010.

Mean live mass percentage lipids of bobwhite harvested during February 2009 and 2010, differed significantly among treatments ($F_{2,276} = 12.86$, $P \leq 0.001$). Birds harvested in control treatment carried a mean lipid reserve of 6.6 % (SE = 0.41) in 2009 and 5.8 % (SE = 0.17) in 2010 (Table 4.3). Mean lipid content of bird harvested in 0.5 bu/ac/yr treatment was 5.9 % (SE = 0.12) in 2009 and 6.1 % (SE = 0.17) in 2010. Mean lipid content of bobwhite harvested in 2.0 bu/ac/yr treatment were 6.9 % (SE = 0.23) in 2009 and 7.2 % (SE = 0.17) in 2010.

Mean lipid reserves of bobwhite harvested during February varied in relation to seed availability at the time of harvest. Mean lipid percentage for bobwhite was 6.7 % (SE = 0.25) when seed availability was between 50 to 40 seeds / 0.5 m^2. This was followed by an increase to 7.2 % at 40-20 seeds / 0.5 m^2, which was then followed by a decline in lipid percent as to 6.1 % (SE = 0.10).

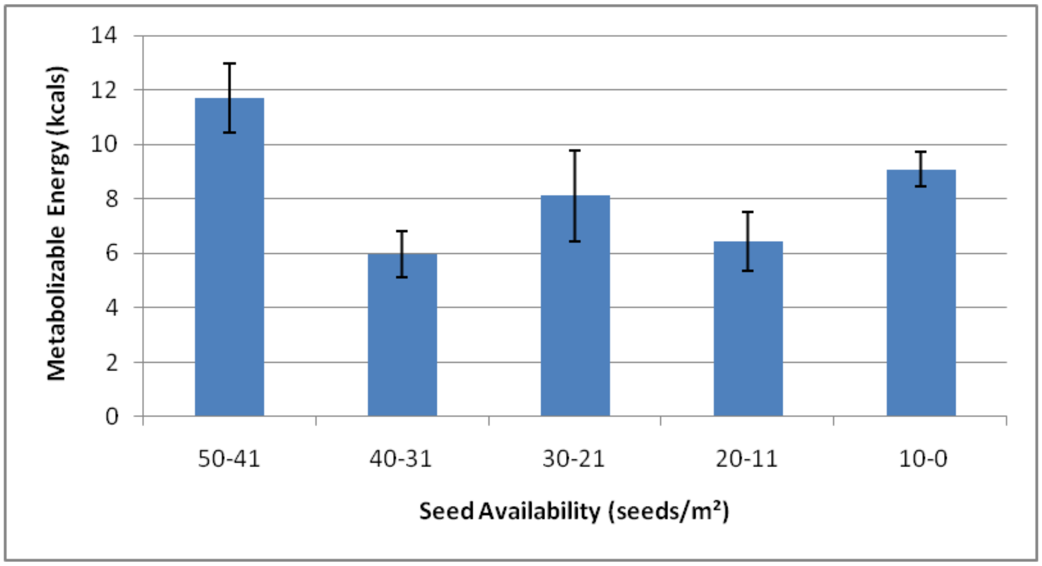

Figure 4.1 Mean metabolizable energy content of Northern Bobwhite crops collected in February 2009 and 2010, at Tall Timbers Research Station, Leon Co, FL, USA. Error bars indicate 1 standard error.

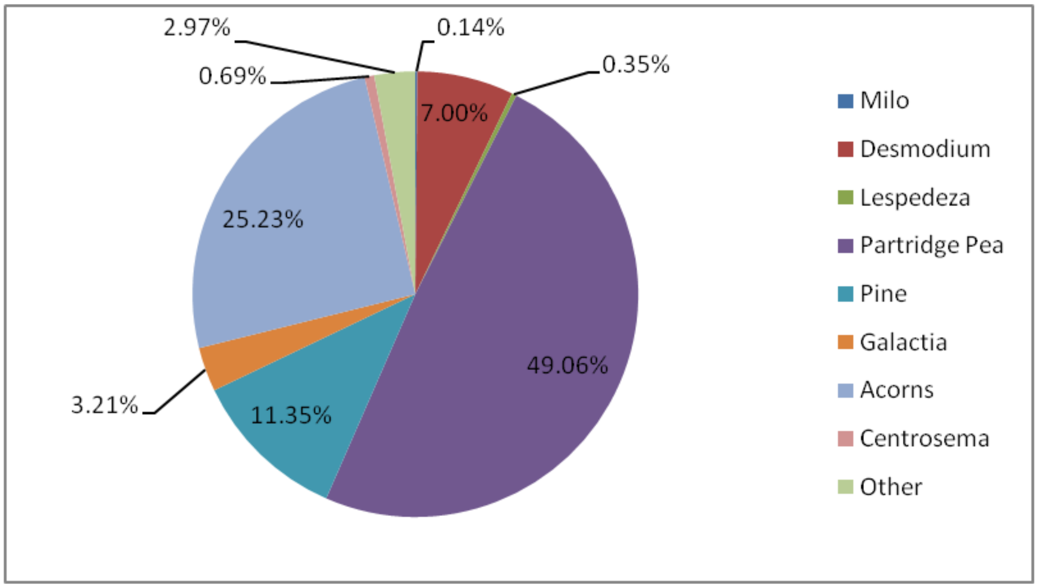

Figure 4.2 Percentage composition by weight of contents removed from crops, averaged for all Northern Bobwhite in control feed treatment at Tall Timbers Research Station, Leon Co, Fl, USA, in February 2009.

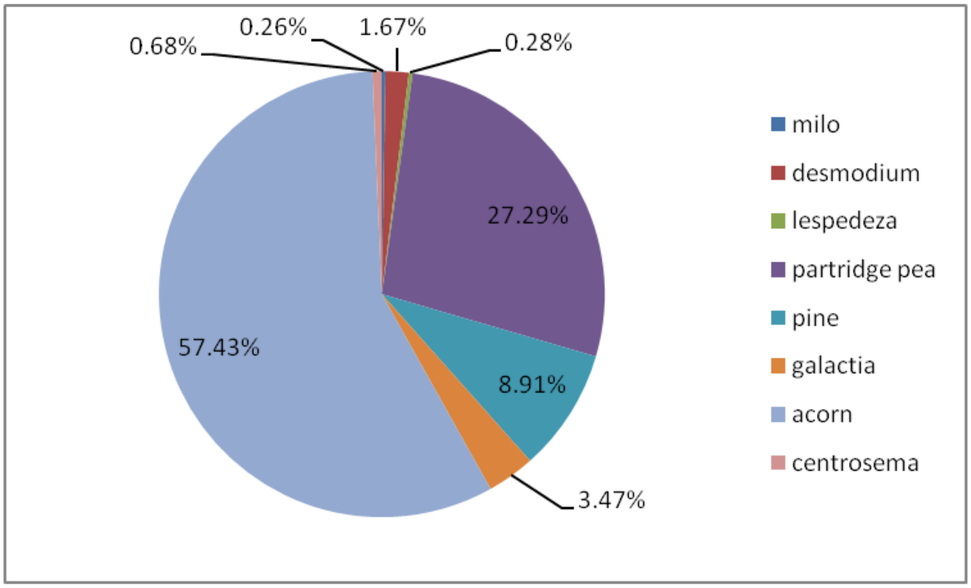

Figure 4.3 Percentages of metabolizable energy contents (kcal/g) of seeds removed from crops, averaged for all Northern Bobwhite in control feed treatment at Tall Timbers Research Station, Leon Co, FL, USA, in February 2009.

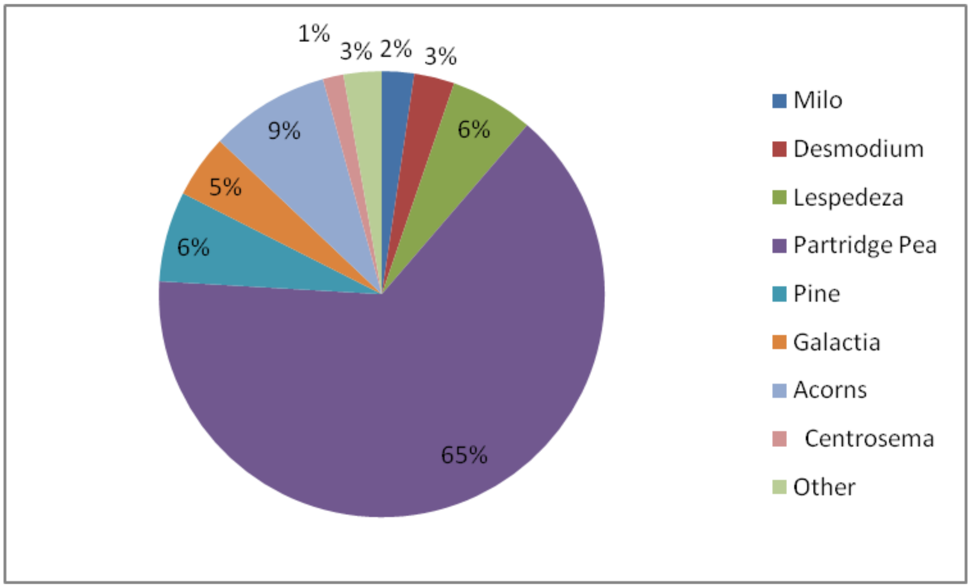

Figure 4.4 Percentage composition by weight of contents removed from crops, averaged for all Northern Bobwhite in control feed treatment at Tall Timbers Research Station, Leon Co, Fl, USA, in February 2010.

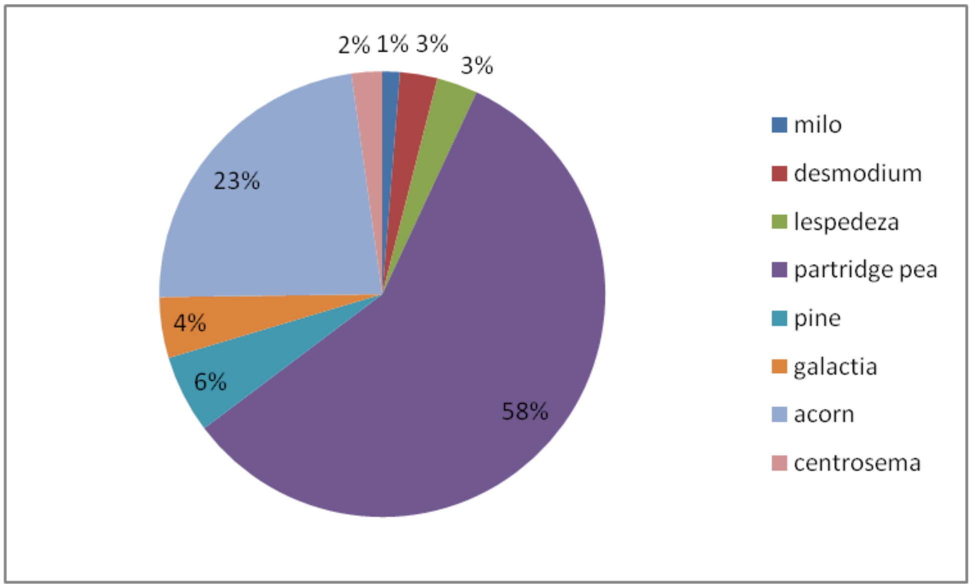

Figure 4.5 Percentages of metabolizable energy contents (kcal/g) of seeds removed from crops, averaged for all Northern Bobwhite in control feed treatment at Tall Timbers Research Station, Leon Co, FL, USA, in February 2010.

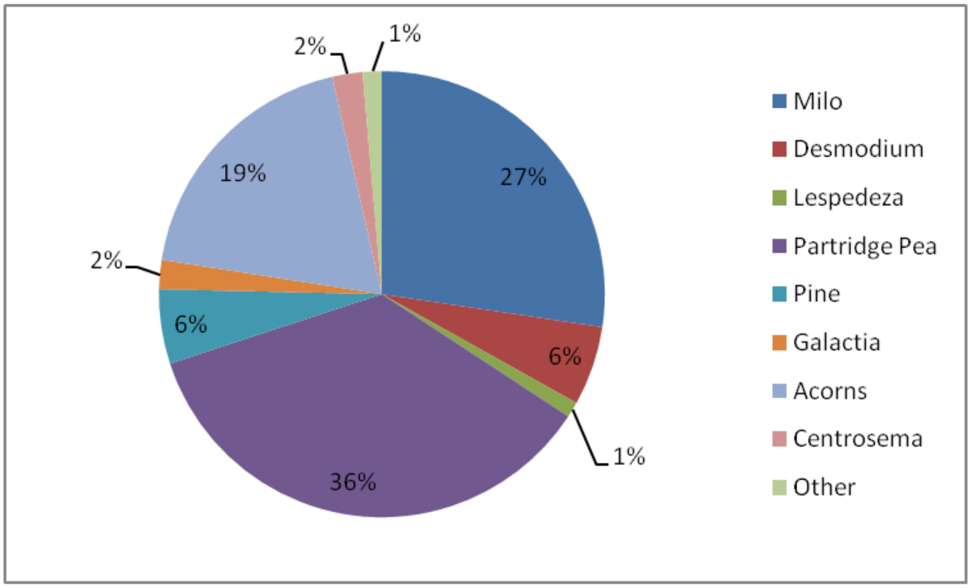

Figure 4.6 Percentage composition by weight of contents removed from crops, averaged for all Northern Bobwhite in 0.5 bu/ac/yr feed treatment at Tall Timbers Research Station, Leon Co, Fl, USA, in February 2009.

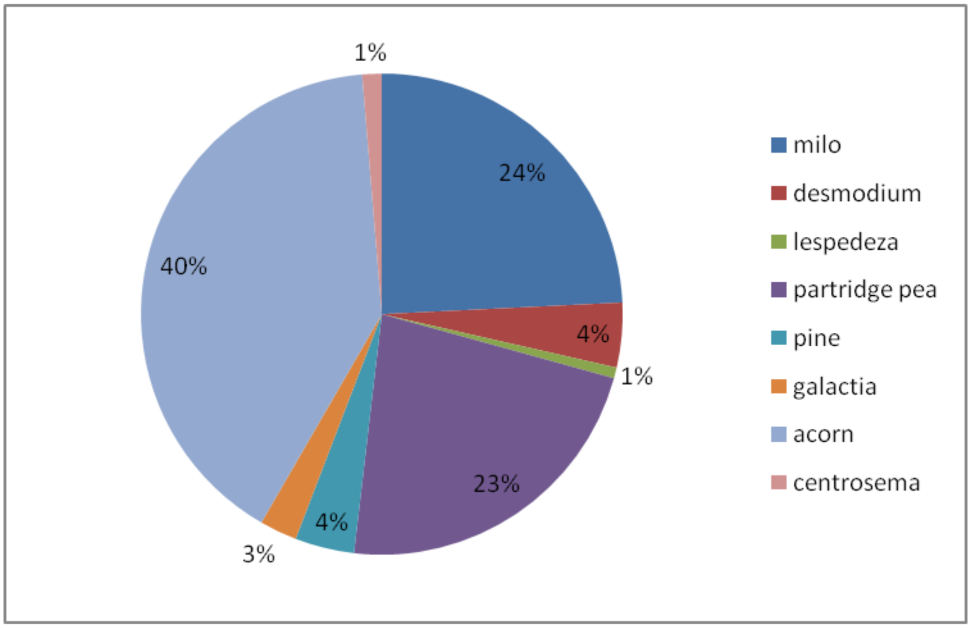

Figure 4.7 Percentages of metabolizable energy contents (kcal/g) of seeds removed from crops, averaged for all Northern Bobwhite in 0.5 bu/ac/yr feed treatment at Tall Timbers Research Station, Leon Co, FL, USA, in February 2009.

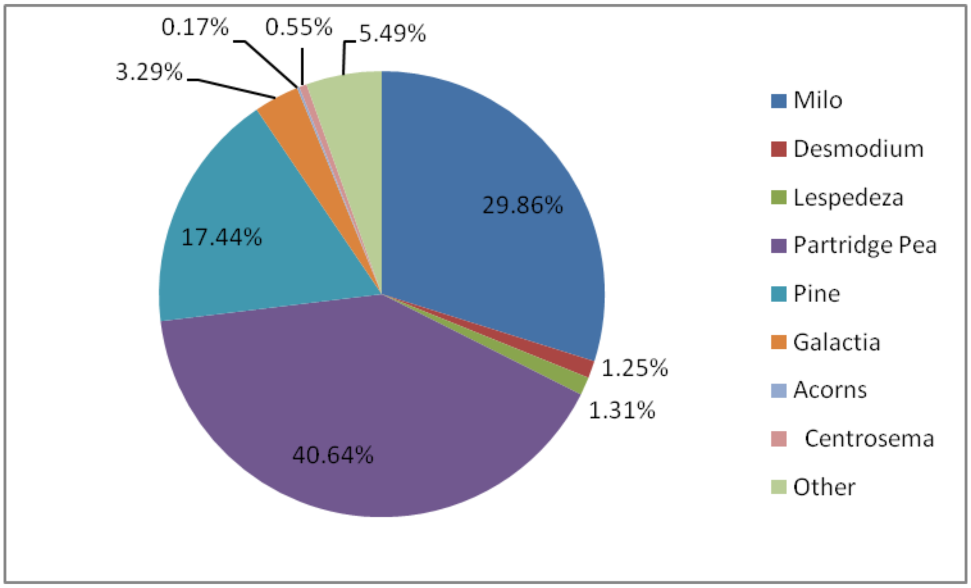

Figure 4.8 Percentage composition by weight of contents removed from crops, averaged for all Northern Bobwhite in 0.5 bu/ac/yr feed treatment at Tall Timbers Research Station, Leon Co, Fl, USA, in February 2010.

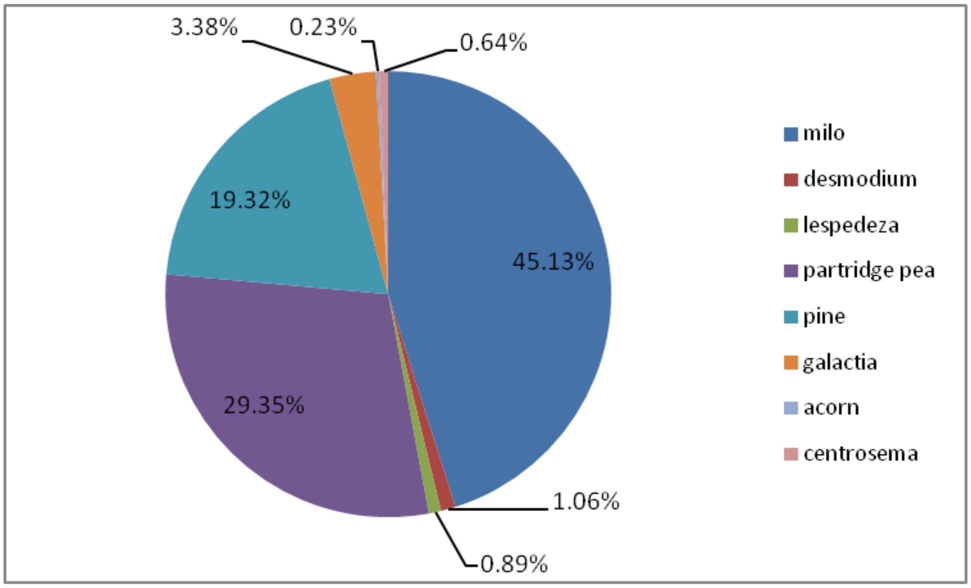

Figure 4.9 Percentages of metabolizable energy contents (kcal/g) of seeds removed from crops, averaged for all Northern Bobwhite in 0.5 bu/ac/yr feed treatment at Tall Timbers Research Station, Leon Co, FL, USA, in February 2010.

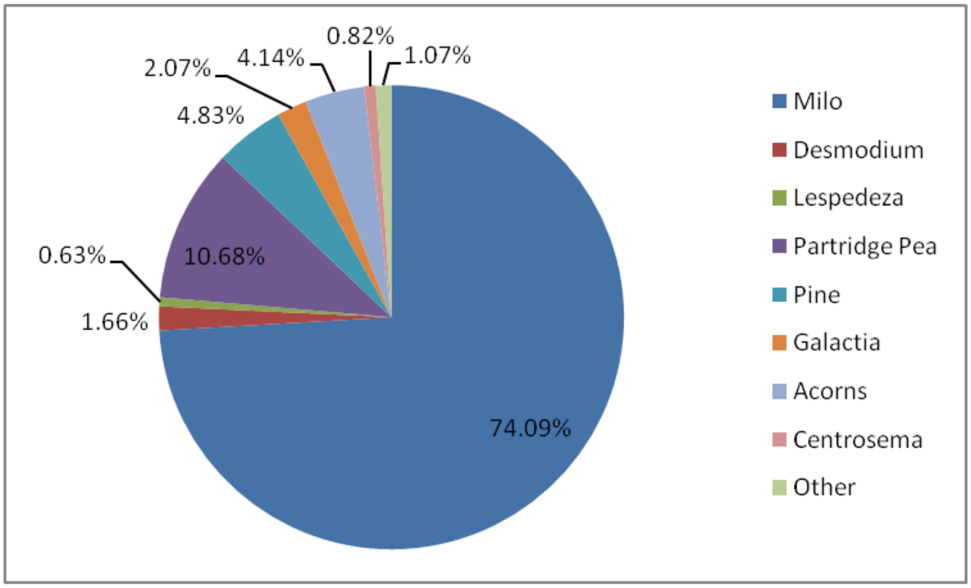

Figure 4.10 Percentage composition by weight of contents removed from crops, averaged for all Northern Bobwhite in 2.0 bu/ac/yr feed treatment at Tall Timbers Research Station, Leon Co, Fl, USA, in February 2009.

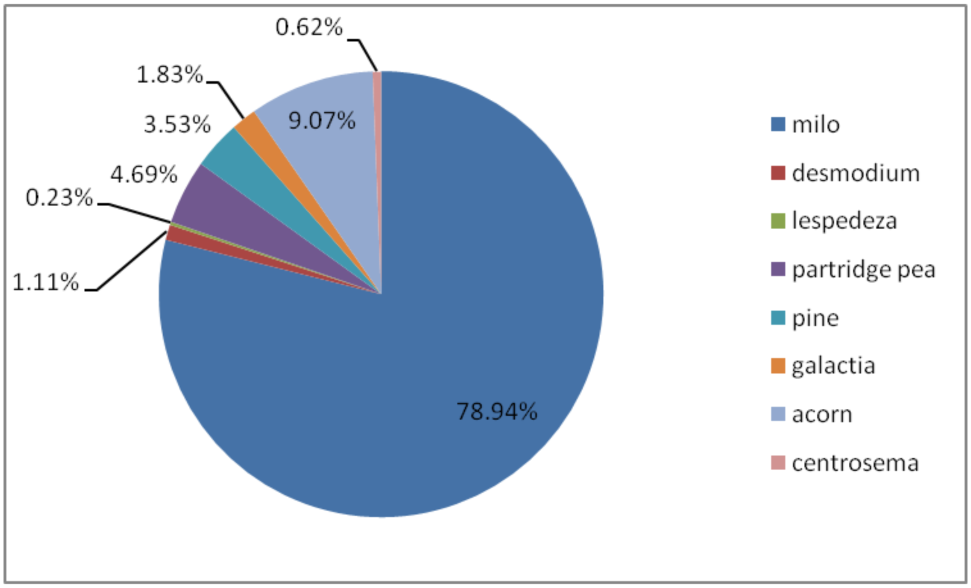

Figure 4.11 Percentages of metabolizable energy contents (kcal/g) of seeds removed from crops, averaged for all Northern Bobwhite in 2.0 bu/ac/yr feed treatment at Tall Timbers Research Station, Leon Co, FL, USA, in February 2009.

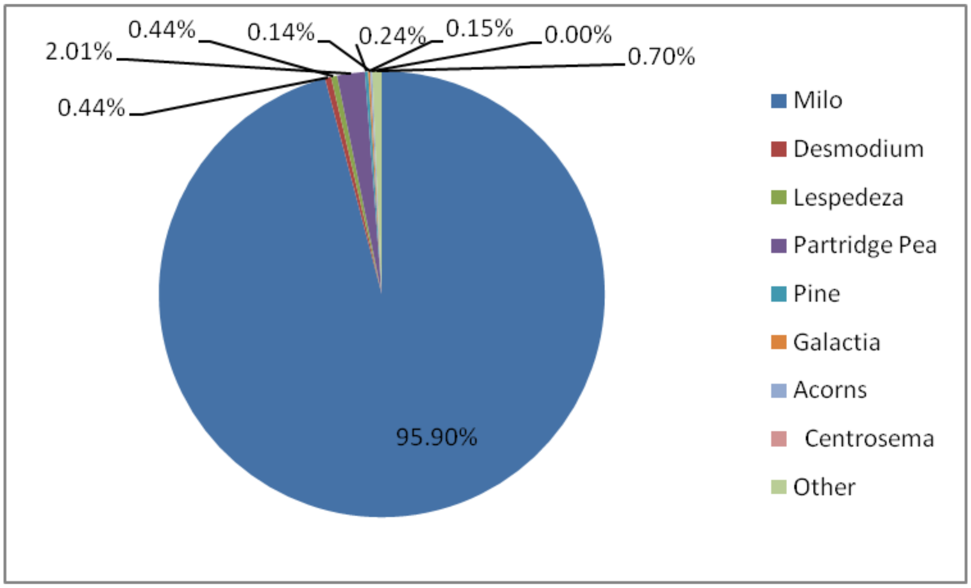

Figure 4.12 Percentage composition by weight of contents removed from crops, averaged for all Northern Bobwhite in 2.0 bu/ac/yr feed treatment at Tall Timbers Research Station, Leon Co, Fl, USA, in February 2010.

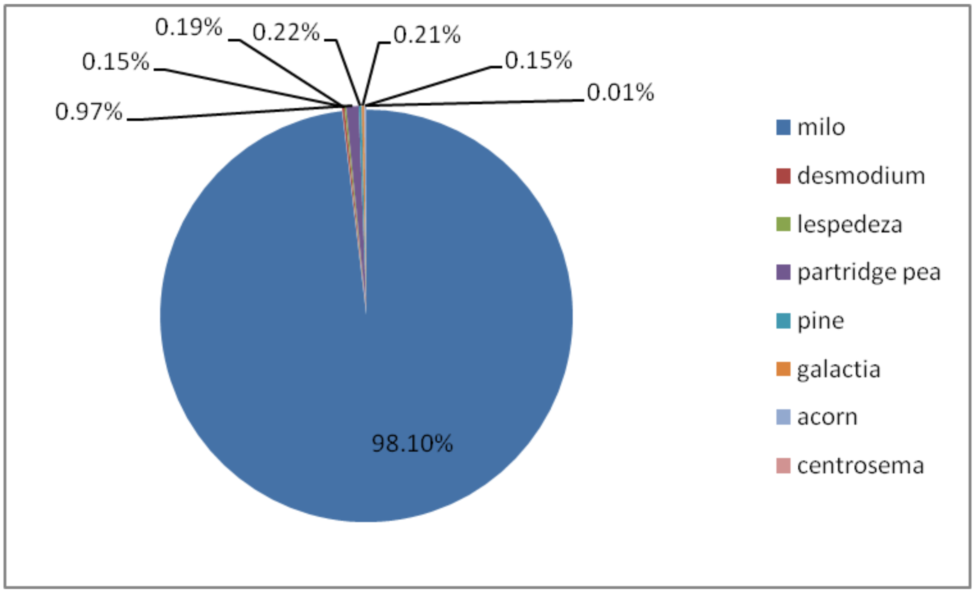

Figure 4.13 Percentages of metabolizable energy contents (kcal/g) of seeds removed from crops, averaged for all Northern Bobwhite in 2.0 bu/ac/yr feed treatment at Tall Timbers Research Station, Leon Co, FL, USA, in February 2010.

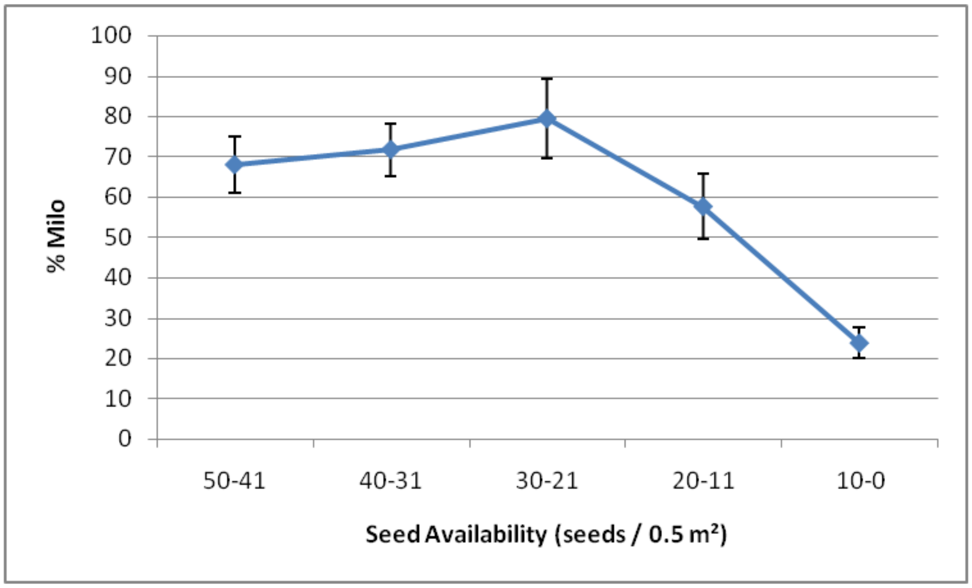

Figure 4.14 Mean percentage of milo in Northern Bobwhite crops collected in February 2009 and 2010, at Tall Timbers Research Station, Leon Co, FL, USA. Error bars indicate 1 standard error.

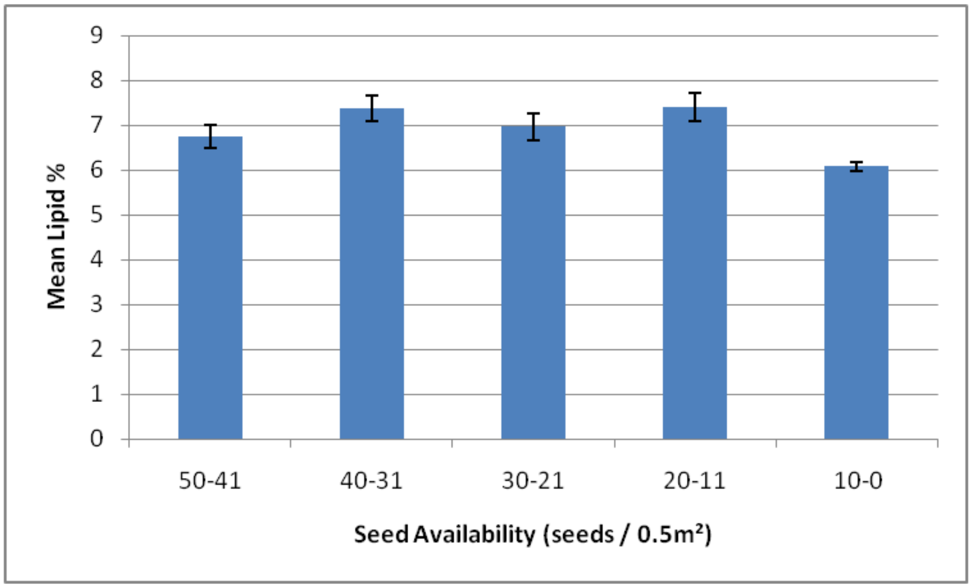

Figure 4.15 Mean percentage lipid reserve for Northern Bobwhite harvested in February, 2009 and 2010, at Tall Timbers Research Station, Leon Co, FL, USA. Error bars indicate 1 standard error.

Table 4.1 Metabolizable energy values (kcal) of crop contents for Northern Bobwhite harvested in February 2009, and 2010 at Tall Timbers Research Station, Leon Co, FL, USA.

Treatment	**Year**	***n***	**Mean**	**SE**
0.0 bu/ac/yr	2009	18	7.7	1.27
	2010	43	8.1	0.72
	combined	61	7.8	0.63
0.5 bu/ac/yr	2009	54	8.5	0.75
	2010	47	9.4	1.05
	combined	101	8.9	0.63
2.0 bu/ac/yr	2009	76	7.9	0.75
	2010	46	8.8	1.19
	combined	122	8.3	0.64

Table 4.2 Mean crop weight (g) of Northern Bobwhite harvested in February 2009, 2010 at Tall Timbers Research Station, Leon Co, FL, USA.

Treatment	**Year**	***n***	**Mean**	**SE**
0.0 bu/ac/yr	2009	18	2.3	0.23
	2010	43	2.9	0.23
0.5 bu/ac/yr	2009	55	2.6	0.2
	2010	47	2.8	0.25
2.0 bu/ac/yr	2009	76	2.2	0.2
	2010	46	2.4	0.32

Table 4.3 Mean lipid (%), total body mass and total body lipids (g) of Northern Bobwhite harvested in February 2009, 2010 at Tall Timbers Research Station, Leon Co, FL, USA.

Treatment	**Year**	**N**	**Lipid%**	**SE**	**Total body mass**	**SE**	**Total body lipids(g)**	**SE**
0.0 bu/ac/yr	2009	16	6.6	0.4	160.9	2.3	10.6	0.7
	2010	50	5.8	0.2	165.1	1.8	9.7	0.3
0.5 bu/ac/yr	2009	30	5.9	0.1	164.1	1.5	9.8	0.2
	2010	71	6.1	0.2	167.7	1.3	10.3	0.3
2.0 bu/ac/yr	2009	30	6.9	0.2	167.1	1.9	11.6	0.5
	2010	85	7.2	0.2	165.4	1.2	11.9	0.3

DISCUSSION

Amount of energy that a bobwhite acquires each day during winter is extremely important to its overall survival. Colder winter temperatures cause bobwhite to increase their metabolic rates. As ambient temperatures decrease, bobwhite use huddling or roosting in coveys to conserve energy (Case 1973). Along with roosting in coveys, actual roost location may allow bobwhite to conserve energy by using roost sites with overhead cover especially during clear winter nights when temperatures are often at their coldest levels. Thompson and Fritzell (1988) showed ruffed grouse (*Bonasa umbellus*) select roost sites which diminish night time thermoregulatory costs.

Daily energy expenditure in bobwhite depends on several factors, such as time of year, type and amount of activity and body mass. Using empirical equations developed by Case and Robel (1974) the temperature-adjusted daily energy requirements for bobwhite at TTRS during this study would be 117.1 kJ / day. This equates to about 27.97 kcals of metabolizable energy per day. Mean energetic value of crop contents from bobwhite harvested on TTRS during February ranged from 7.97 – 8.95 kcal. These energy values suggest that bobwhite would have to acquire an equivalent amount of food resources at least 3 times / day to meet estimated daily energetic requirements.

Bobwhite have different options as how to achieve this energy requirement. They can forage for this amount of energy or rely totally on lipid reserves in times when foraging is not possible. If they forage, they have to select for high quality seeds because on average bobwhite can only ingest and process 17 grams of dry mass per day during winter (Robel et al. 1974). During this study, birds harvested during 2 hours prior to roosting had a mean crop weight of 2.5 g / crop, suggesting that bobwhite were harvested before they had a chance to finish foraging, or they foraged multiple times throughout the day. Whitelaw et al. (2009) reported similar results of crop weights while using similar methods.

Fat produces about 9.38 kcals / g of metabolizable energy (Calder and king 1974). Therefore a fasting bobwhite would need to metabolize about 2.98 grams of fat a day. Mean total body lipids of bobwhite harvested on Tall Timbers during February were approximately 10.77 g, suggesting they could fast for less than 3.5 days. Mean total body lipid observed during this study was slightly less when compared to other research investigating bobwhite lipid levels in Illinois, Indiana, and Missouri which reported lipid weights of 20.5 g, 17.0 g and 12.1 g, respectively (Frawley et al. 1999). A decrease in body lipids for bobwhite in my study area would be expected when compared to more northern conspecifics due to less severe winters observed in the south. Blem (1990) suggests there are proximate and ultimate factors that influence lipid reserves. Proximate factors include photoperiod and weather conditions and ultimate factors might occur through sexual selection of individuals with reserves that are sufficient to withstand maximum stress.

I observed that bobwhite were consuming about the same caloric value regardless of feed treatment, (7.97 kcals of metabolizable energy). If I use the energy value from above, which represents the coldest temperatures recorded at TTRS during winters of 2009 and 2010 bobwhite would have to forage at least this amount about 3.5 times per day to achieve the amount of energy required for thermoregulation. Considering that on average bobwhite crops in this study weighed 2.56 grams, they could easily consume and process these amounts to achieve increased energy demands. On average bobwhite during this study went to the feed line about 2-3 times throughout the entire day. This suggests that they were able to achieve their energy needs.

Although amount of energy within a crop did not vary significantly between feed treatments, types of seeds ingested did. In winter of 2009 there was a large proportion of acorn mast in the crops of all birds harvested at TTRS. This pattern was not seen in the crops in 2010 and as a result birds in the control switched their primary food source to partridge pea. Similarly, acorn mast was a more important component of diets in the 0.5 bu/ac/yr treatment during 2009, than 2010. Birds ingested less acorn mast in 2010 and correspondingly increased amount of milo ingested. Two major types of oaks found at TTRS are water oak (*Quercus nigra*) and live oak (*Q. virginiana*). Water oaks typically take 2 years to produce an acorn crop whereas live oaks produce acorns yearly. As a result, there would be less opportunity for bobwhite to feed on acorns every other year. In those particular years bobwhite might be more likely to switch their diets to milo. Birds in 2.0 bu/ac/yr treatment which primarily consumed milo in 2009 just increased the proportion of milo in their crops in 2010. In habitats where milo is not available, bobwhite meet energetic requirements primarily from acorn mast and partridge pea. When supplemental feed is abundantly available bobwhite are selecting for milo. Pattern of percentage milo observed within bobwhite crops was similar to the patterns in range and proximity to feed line (see chapter III). This pattern in percentage milo lends support to the prediction that there is a potential giving up density at which bobwhite begin to choose alternate prey items over milo.

One might hypothesize that increasing foraging time causes bobwhite to be more susceptible to predation. Schoener (1971) suggests there are two ways to acquire more food while foraging less, time minimizing or energy maximizing. A time minimizer minimizes amount of time to gain a fixed ration of energy. An energy maximizer maximizes amount of energy gained in a fixed time. Bobwhite of this study are expressing time minimizer type behavior because all birds, regardless of feed treatment, acquired about the same amount of energy, (8.39 kcals). Similarly, data I collected on movements and range size supports this observation as I observed similar range sizes as well as similar distances of movements (See Chapter III).

Amount of time spent acquiring this energy is what is important because increases in foraging time have been shown to decrease survival probabilities (Guthery 2002). Milo has a greater amount of metabolizable energy then other native seeds such as, desmodium, lespedeza, partridge pea, pine, and acorn mast. In times of high supplemental feed densities bobwhite can forage on supplemental feed for a smaller amount of time and cover a smaller area. Additionally, lesser foraging times might allow additional foraging sessions throughout the day. These additional foraging sessions may be allowing bobwhite to acquire additional lipid reserves.

Data from this study suggests that in years where acorn mast is limited addition of milo into the system may substantively affect lipid reserves of bobwhite. Control birds had significantly lower lipid levels in 2010 than the 2009 season when acorn mast was abundant. I also noticed a shift in diet of the birds in 0.5 bu/ac/yr feed treatment in 2009 to a more native diet. In habitats where milo is abundant, for example 2.0 bu/ac/yr feed treatment availability of acorn mast is not as significant. If milo is available at high levels bobwhite will utilize this food source. Whitelaw et al. (2009) found similar results as bobwhite without supplemental feed showed significantly less body weights at two different sites. Variations in lipid mass at daily time scale is a function of body mass, maintenance of normal body temperatures as well as stability of food sources (Blem 1990).

Lipid data from this study was collected only during February. Roseberry and Klimstra (1971) determined that bobwhite showed a continuous decline in lipid levels throughout winter, which they assumed was a reflection of the declining of available food items. Koerth and Guthery (1987) observed similar decreasing trends in body fat throughout winter in south Texas. Further research investigating differences in bobwhite lipid levels where individuals are harvested throughout winter should be considered to better understand the dynamics of supplemental feeding and bobwhite lipids leading into the breeding season.

Northern bobwhite will be able to forage for enough energy to meet energy requirements whether supplemental feed is present or absent. This conclusion supports that of Guthery's (1999) hypothesis that energy-based carrying capacity often exceeds needs of populations. During this study bobwhite selected for supplemental feed however native food sources were not limiting as bobwhite were able to switch back to native resources as seed availability declined, additionally the bobwhite in the control consumed similar energy levels while consuming only native seeds. Addition of supplemental feed may allow bobwhite to forage for smaller amounts of time and cover smaller amounts of area. Smaller feeding times may allow additional feeding periods ultimately leading to increased lipid reserves.

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CHAPTER V

SYNTHESIS

INTRODUCTION

There has not been any research on rate of seed loss of supplemental feed spread in an upland pine ecosystem. Recent research in Tennessee characterized loss of agricultural seeds in fields after harvest using an exponential decay function yielded similar results to this study (Foster et al. 2010). When feeding at a light rate such as 0.5 bu/ac/yr after about a week the supplemental feed is basically gone and therefore not longer available to bobwhite. However feeding at a high rate of 2.0 bu/ac/yr showed that after two weeks since time of last feeding there was roughly an additional 0.5 bu/ac/yr remaining in the system.

Feeding at a low rate would give bobwhite access to supplemental feed for a short period of time before having to switch to a native seed diet consisting primarily of butterfly pea (*Centrosema* sp.), partridge pea (*Chamaecrista* spp.), lespedeza (*Lespedeza* spp.), desmodium (*Desmodium* spp.) and acorn mast (*Quercus* spp.). Shifting of food resources may cause increased predation risk as bobwhite are increasing the time spent foraging as well as the area searched. Feeding at the greater rate allows bobwhite to utilize supplemental feed as their primary food source for the two week duration between spreading feed. This could potentially reduce winter mortality if individuals do not have to travel very far or forage for a long period of time to acquire all the energy requirements necessary for survival.

Movement Rates and Ranges

Understanding the relationship of how supplemental feeding affects movement rates and range sizes is important, as they are dominant factors in over-winter survival. One could assume that as amount of foraging area increases, likelihood of coming into contact with either avian or mammalian predators also increases. If bobwhite can decrease amount of area that they are required to forage in a day and ultimately for the entire winter, they may increase their survival rates. Results from my study showed that level of supplemental feed did not affect either daily or seasonal range size. Average daily range was similar throughout the entire feeding cycle. Average daily range was 0.80 hectares. This suggests that other factors are influencing amount of space that a bobwhite use in a given day.

This study also suggests that bobwhite are not disproportionately selecting for areas that are close to supplemental feed compared to random locations within the environment. However, my results did suggest that when fed a low amount of supplemental feed bobwhite tended to have a greater amount of dispersion of locations throughout the day as well as throughout winter. This could potentially indicate that bobwhite have to travel farther between feeding patches. Covey locations show consistent site selection for feed line until about 0.5 bushels, followed by a selection of locations farther away. This could suggest that 0.5 bushels is the point at which bobwhite begin to select for other food sources as amount of supplemental feed available is not worth searching, for so they move to other alternative food resources. It is also at this point that we see amount of milo within crops finally drop to about 20 %.

Considering that daily ranges were relatively unaffected by amount of supplemental feed and dispersal rates were greater in lower fed bobwhite some other factor or factors must be influencing how much space bobwhite use within a day. Amount of available cover and how cover is distributed may be influencing how bobwhite move throughout the day to avoid predation.

Energy and Lipid Levels

Amount of energy that an individual ingests is important during winter as demands of thermal regulation increase. Lipid reserves can become important during times of inclement weather when foraging periods are limited or potentially unallowable. Often when bobwhite feed on low-energy foods they accumulate less body fat compared to bobwhite that are provided a high-energy food. This is why supplemental feeding programs are used throughout the year. In addition, amount of lipid reserves that a female bobwhite has at end of winter may influence on her contribution in upcoming breeding season, as caloric deficiencies have been resulted in delays in egg laying, reduced egg production and ovarian degeneration.

Amount of metabolizable energy stayed consistent throughout the feeding period. Average crop contained about 7 grams of metabolizable energy. Along with energy amount of stored lipids stayed consistent at about 18 % throughout the entire feeding period. Bobwhite are maintaining energy and lipid reserves constantly through feeding period although amount of milo in their diet is decreasing. This suggests that bobwhite are shifting to alternate food resources throughout the period to maintain constant energy demands and lipid reserves.

Addition of supplemental feed not only benefits bobwhite directly through consumption but also indirectly as other wildlife species utilize this food source. As small birds such as black birds and sparrows along with mammals like the cotton rats and cotton mice feed on the supplemental feed their populations increase. These populations provide alternate prey sources to predators within the system relieving some of the mortality burden of bobwhite populations throughout winter.

However, supplemental feeding continues to be a controversial issue. The Wildlife Society lists several potential concerns about supplemental feeding such as; concentrating individuals, increasing direct contact between individuals, increasing disease transmission and redirecting efforts away from habitat management. The method to which supplemental feed is applied is the primary factor influencing these concerns. This study applied supplemental feed along a 10 mile long feed line throughout the pine uplands. Results of this study suggest that applying supplemental feed by this method does not concentrate individuals, as individual coveys were not disproportionally selecting locations close to the feed line. Ten miles of feed line allows individuals to forage without increasing the likelihood of directly contacting other individuals. This will also likely decrease chance of disease transmission compared to other methods of applying supplemental feed such as stationary wildlife feeders. Finally, TTRS uses supplemental feeding as an additional management strategy rather than redirecting effort away from habitat management.

Management Recommendations

This study investigated influences of supplemental feeding in relation to bobwhite feeding behavior in the forms of daily movement rates, daily and winter range sizes and energy and lipid reserves during winter so any management recommendations about supplemental feeding rates will only be relevant to these factors. This research study was conducted at one study site; therefore any recommendations given may only be applicable for that particular study site. Other factors such as mortality rates and fecundity rates were not part of this study so any management recommendations given may not be pertinent to those factors.

Considering the data from this study in terms of movement rates and range size at the daily and winter time scales supplemental feeding is not justifiable, as there was no significant difference in range size in any of the treatments or any type of selection preference in covey locations when compared to random locations.

In terms of energy and lipid reserves the benefits from supplemental feeding varied between years. In a year with a high acorn abundance such as 2009 bobwhite acquired similar energy levels within their crops and actually had greater amounts of fat reserves compared to birds harvested in the 2.0 bu/ac/yr treatment. In years with a small acorn abundance as seen in winter, 2010 when fed a high rate of supplemental feed bobwhite had significantly greater levels of lipid reserves.

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APPENDIX A

SUMMARY OF COVEY AND RANDOM LOCATIONS

Table A.1 Mean distance (m) between bobwhite covey telemetry locations and supplemental food relative to mean distance from random locations to supplemental food at Tall Timbers Research Station, Leon Co, FL, USA, during 2009-2010.

Covey id	N[a]	Covey[b]	Random[c]	Covey id	N[a]	Covey[b]	Random[c]
60486	24	76.8	46.7	90741	48	46.8	57.9
80050	45	18.7	44.0	91092	33	26.1	40.9
80259	24	18.3	29.6	91125	44	54.6	41.9
82452	62	55.1	39.7	91215	24	44.5	36.5
90002	24	57.1	39.7	91395	24	29.3	39.9
90051	46	73.5	35.8	91412	44	105.3	39.4
90082	64	22.1	45.5	91417	66	54.9	39.0
90122	25	32.9	54.3	91471	24	27.0	43.1
90129	62	37.9	37.0	92124	25	28.0	43.6
90202	43	35.0	42.1	92171	60	47.4	35.8
90238	24	37.4	31.4	92173	24	15.9	39.4
90249	47	50.7	38.5	100033	68	31.2	36.1
90256	65	45.1	41.6	100204	40	68.3	35.1
90291	38	28.3	48.7	100218	46	24.3	43.3
90349	24	54.5	37.5	100233	44	17.9	48.4
90415	52	45.9	51.7	100334	43	42.7	42.6
90483	68	28.6	45.3	100621	43	39.8	46.3
90490	49	35.2	49.6	100694	25	16.2	46.5
90706	63	39.6	36.7	100710	85	44.7	38.2
				[d]	43.7	41.0	41.8
				SE		18.9	6.0

[a] No. of covey locations = no. of random locations

[b] Mean distance from locations to supplemental food.

[c] Mean distance from random locations to supplemental food.

[d] Overall ± SE