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Andrew N. Tri
Texas A&M University

Fidel Hernandez
Texas A&M University

David G. Hewitt
Texas A&M University

William P. Kuvlesky Jr.
Texas A&M University

Leonard A. Brennan
Texas A&M

EFFECTS OF CARBOHYDRATE-BASED AND PROTEIN-CARBOHYDRATE RATIONS ON WILD BOBWHITE NESTING AND HARVEST DEMOGRAPHICS

Andrew N. Tri[1]
Caesar Kleberg Wildlife Research Institute, Texas A & M University–Kingsville, TX 78363, USA

Fidel Hernández
Caesar Kleberg Wildlife Research Institute, Texas A & M University–Kingsville, TX 78363, USA

David G. Hewitt
Caesar Kleberg Wildlife Research Institute, Texas A & M University–Kingsville, TX 78363, USA

William P. Kuvlesky Jr.
Caesar Kleberg Wildlife Research Institute, Texas A & M University–Kingsville, TX 78363, USA

Leonard A. Brennan
Caesar Kleberg Wildlife Research Institute, Texas A & M University–Kingsville, TX 78363, USA

ABSTRACT

Northern bobwhite (*Colinus virginianus*) reproduction is a nutrient-intensive process. Arthropods are essential for breeding bobwhite hens and their offspring. Traditional supplemental feeding programs use corn and milo and typically neglect the protein needs of bobwhites. Commercial bobwhite rations are widely available but are seldom used in feeding programs due to high cost and lack of an appropriate supplement for field use. We compared the effect of a protein-carbohydrate ration (PC) to the effects of a carbohydrate only ration (CO) on: (1) bobwhite hen nesting demographics (clutch size, ordinal clutch initiation date, Mayfield nest survival), and (2) fall relative abundance (coveys moved/hr hunting). Nesting parameters for bobwhites based on a sample of 60 hens during the 2008 breeding season in South Texas were statistically similar based on overlap of 95% confidence intervals for both the PC and CO supplements. Mayfield nest success was high for both the PC ration (75.2%) and the CO ration (73.1%). Coveys moved during hunting (4.17 ± 14 coveys/hr in pastures with CO feed and 4.2 ± 12.5 coveys/hr in pastures with PC feed) did not differ during the 2008–2009 hunting season. The 2009 nesting season was a failure because all study animals died due to drought. Weekly Kaplan-Meier survival estimates of bobwhite hens were 6 times higher in 2008 than in 2009. The PC ration in our study provided no benefit to bobwhite populations or enhancement of wild bobwhite reproductive parameters over the CO ration. The additional cost of using PC over CO is not justified based on our results.

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Key words: *Colinus virginianus*, hens, nest success, northern bobwhite, protein, supplemental feed

INTRODUCTION

Northern bobwhite reproduction is a nutrient-intensive process. A diet consisting of > 24% protein and > 2.8 kcals of metabolizable energy (ME) is required for optimal reproduction in captive hens (Nestler et al. 1944b, Nestler 1949, Giuliano et al. 1996). Breeding female bobwhites tend to have higher daily energetic requirements and protein requirements than both non-breeding females and males (Guthery 1999, 2002). Hens meet their nutritional needs during the breeding season by consuming arthropods, gastropods, forbs, and seeds (Wood et al. 1986, Brennan and Hurst 1995). In South Texas, 54% ($n =$ 11 crops) of a bobwhite diet was arthropods with the remainder consisting of gastropods, seeds, and fruits (Campbell-Kissock et al. 1985). The diet shifted to high-protein, green vegetation (72%; $n = 91$ crops) during late winter.

Arthropods are essential for reproduction in many Galliformes (Potts 1986), especially bobwhites. Arthropods contain > 55% crude protein and >4.0 kcal ME/g (Bell 1990), and are the primary food source for bobwhite chicks during their first 30–60 days of life (Handley 1931, Hurst 1972). Arthropod abundance is positively related to increasing vegetation diversity, biomass, and rainfall

[1] *E-mail: antri@mix.wvu.edu*
[2] *Present address: West Virginia University, Davis College of Agriculture, Natural Resources, and Design, Division of Forestry and Natural Resources, 322 Percival Hall, P.O. Box 6125, Morgantown, WV 26506.*

(Varley et al. 1973). Bobwhite hens meet their protein needs through arthropod consumption, and low arthropod abundance can potentially reduce survival and reproduction.

Bobwhites with nutritional deficiencies in captivity produce fewer offspring than those without nutritional deficiencies. Hen bobwhites provided with 23% protein in captivity produced twice as many eggs as hens provided with 13% protein (Nestler et al. 1944b). Bobwhite hens with deficiencies in either fat or crude protein have decreased egg production (Giuliano et al. 1996). Nutritionally complete rations have been developed and used with success on game bird farms for more than 65 years (Nestler et al. 1944a, Fay 1963, McEwen et al. 1969). Studies of captive bobwhites have documented high reproduction by quail fed a complete ration (Giuliano et al. 1996, Radomski 1999), but the effect of this ration on wild bobwhite populations has not been reported.

Traditional supplemental feeding programs typically neglect the protein needs of bobwhites. Corn and milo are commonly distributed by bobwhite hunting operations in South Texas to facilitate harvest (Haines et al. 2004). Some managers believe providing these grains allows bobwhite hens to be in better body condition for reproduction (W. E. Palmer, unpublished data, Tall Timbers Research Station, http://www.talltimbers.org/gb-suppfeed.html). However, neither grain has sufficient protein for bobwhite body maintenance, much less optimal reproductive effort (Nestler et al. 1944b). Commercial bobwhite rations are widely available but are seldom used in feeding programs due to high cost.

Our objectives were to compare the effects of the PC ration to the effects of the CO ration on (1) hen nesting demographics (clutch size, ordinal clutch initiation date, percent hens nesting, nest attempts per hen, nesting season length, and Mayfield nest success), and (2) fall relative abundance (coveys moved/hr hunting). We hypothesized that: (1) bobwhite hens with access to PC would have greater clutch size, earlier ordinal clutch initiation dates, nest more readily (higher proportion of hens nesting), higher nest attempts per hen, longer nesting season, and higher Mayfield nest success than hens with access to the CO ration, and (2) pastures supplied with the PC ration would produce greater coveys moved per hour during fall hunts than pastures supplied with the CO ration.

STUDY AREA

We conducted our study during 2008 and 2009 on a private ranch, 10 km west of Falfurrias, Texas. The study area consisted of 800 ha of chaparral brush vegetation typical of the South Texas Plains ecoregion (Gould 1975). The study area was divided into 4, 200-ha pastures. Each pasture was buffered by a 200-m strip between each pasture. Each set of pastures (CO and PC) was 7 km from the other. Each pasture was randomly assigned an experimental feed type resulting in 2 pastures broadcast with CO and 2 pastures broadcast with PC. The primary vegetation community was mixed brush containing mesquite (*Prosopis glandulosa*), huisache (*Acacia farnesiana*), granjeno (*Celtis pallida*), and prickly pear (*Opuntia* spp.). The dominant grass species was seacoast bluestem (*Schizachyrium scoparium var. littorale)*. Soils on the site range from deep sand to sandy loam. The site received 42.2 cm of precipitation in April–August 2008 and 10.6 cm in April–August 2009 (U.S. Department of Commerce 2010). This site was a former livestock production ranch but has been operated as a private bobwhite hunting enterprise business since 1997.

METHODS

Ranch employees used a truck-mounted broadcast spreader to distribute feed (provided by the ranch) along feed roads spaced 450 m apart. Supplemental feed was broadcast year-round at 1-week intervals and distributed at a rate of 10 kg/ha on all pastures. Ranch employees distributed corn and milo on all surrounding pastures. We used the CO ration as a control to reduce emigration of bobwhite from the study pastures. Feed distributed on the CO sites for both years was a mix of 50% corn and 50% milo. We used a 16% protein formulated feed ration (Quail Breeder 16; Lyssy and Eckles Feed Co., Poth, TX, USA) on the PC pastures during 2008, and a 24% protein pellet (Appendix) during 2009. We used a crossover study design in which CO pastures during year 1 became the PC pastures during year 2 to mitigate potential site-specific variation. Continuous predator trapping (snares and box traps) conducted by ranch employees occurred throughout the ranch during both years of the study and was a normal ranch procedure since 1997. Ordinal clutch initiation date (number of days in a year from 1 Jan), clutch size, and nest fate were recorded for each nest. We also recorded the number of clutch laying attempts per hen, number of hens nesting per season, and nesting season length. We calculated Mayfield (1975) nest success for CO and PC pastures. Hunting guides collected data on coveys moved per hunt and the age class (juvenile or adult) of each harvested bird for the 2008–2009 and 2009–2010 hunting seasons.

Trapping and Telemetry

We trapped bobwhite hens from March to July using standard funnel traps (Stoddard 1931) baited with milo. We fit hens that had a mass > 150 g (Hernández et al. 2004) with a 5–6 g necklace-style radio package (American Wildlife Enterprises, Monticello, FL, USA) and an aluminum leg band. We monitored bobwhite hens using a 3-element Yagi antenna and a hand-held receiver (Communications Specialists, Orange, CA, USA). We located each radio-marked hen and marked the location with a hand-held Global Positioning System (GPS) unit a minimum of 2 times per week. We maintained a sample size of 15 hens per pasture ($n = 60$ hens) throughout the breeding season (Apr–Aug) and trapped as needed to replace deceased birds. Once a hen was located in the same place for > 2 consecutive tracking periods, we located her nest and recorded the UTM coordinates with a GPS. We removed transmitters from all surviving

Table 1. Bobwhite nesting parameters (Mean, 95% CI) on pastures supplied with a protein-carbohydrate (PC) ration and pastures supplied with a carbohydrate-only (CO) ration in Brooks County, Texas, USA, March–August 2008.

	Carbohydrate-only			Protein-carbohydrate		
	n	mean	95% CI	*n*	mean	95% CI
Clutch size (# eggs)	39[a]	11.7	10.7–12.7	35[a]	11.9	11.4–12.4
Clutch initiation (ordinal day)	39[a]	195	188–202	35[a]	193	185–200
Mayfield nest survival (%)	39[a]	73.1	73.1–73.2	35[a]	75.3	75.2–75.3
Nest attempts per hen (# nests)	30[b]	1.46	1.27–1.66	30[b]	1.43	1.23–1.62
Proportion of hens that nested (%)	30[b]	100		30[b]	100	

[a] Number of nests per feed type.
[b] Number of hens per feed type.

bobwhite hens in October and trapped new bobwhites in 2009.

Statistical and Survival Analyses

We pooled like feed type data for ordinal clutch initiation date (number of days from 1 Jan), clutch size, Mayfield nest survival, proportion of hens nesting, number of nests per hen, and coveys moved/hr due to relatively low sample size ($n = 30$ hens per feed type). We calculated means and 95% confidence intervals for each variable (excluding Mayfield nest survival) in R 2.10.0 (R Core Development Team 2012) and compared between feed types. Mayfield nest survival estimates and 95% confidence intervals (Johnson 1979) were calculated by hand and compared between feed types. There were no recaptured bobwhite hens in 2009 from 2008. We pooled all hens by year to compare weekly hen survival for 2008 and 2009. We calculated Kaplan-Meier survival estimates for 1 April 2008–30 June 2008 and 1 April 2009–30 June 2009 using the known fate platform in Program MARK (White and Burnham 1999). We pooled like feed type data for hunting parameters for 2008. Pastures were not hunted in 2009 due to a perceived decline in bobwhite abundance by the ranch employees.

RESULTS

Nesting Parameters

Nesting parameters (clutch size, clutch initiation date, nest attempts per hen, and number of hens nesting) were similar based on 95% confidence intervals for both the PC and CO pastures during 2008 (Table 1). All radio-marked hens ($n = 60$, 100%) had > 1 nesting attempt, 45% ($n = 14$ on CO pastures, $n = 13$ on PC pastures) had ≥ 2 nesting attempts, and 3% ($n = 2$ on CO pastures, $n = 0$ on PC pastures) had ≥ 3 nesting attempts during 2008. Mayfield nest success was $> 71\%$ for both feed types and was 2% higher in pastures with PC. Mayfield nest success did statistically differ between pastures, but this difference is not biologically meaningful. Hens in PC pastures had a nesting season length of 131 days and hens in CO pastures had a nesting season length of 123 days during 2008. No radiomarked hens ($n = 60$) attempted to nest, regardless of feed type, during 2009. Proportion of nests depredated was the same between feed types (26% in CO pastures, 26% in PC pastures).

Harvest and Survival Parameters

The number of coveys moved/hour hunting did not differ between feed types, during the 2008–2009 hunting season. The mean number of coveys moved/hr ($\pm$ 95% CI) was slightly higher (4.17 $\pm$ 14 coveys/hr in pastures with CO feed and 4.20 $\pm$ 12.5 coveys/hr) in pastures with PC feed. The mean ($\pm$ SE) number of hours hunted per pasture was 6.50 $\pm$ 0.35. Kaplan-Meier survival estimates were statistically different between 2008 and 2009 (Fig. 1). Hen survival from 1 April to 30 June during 2008 was 6 times greater than survival from 1 April to 30 June during 2009. All radio-marked bobwhites in our study during 2009 died by 7 July. We could not identify sources of mortality for all hens but the majority (63% of the mortality) was from avian (2/3 of the total predation) and mammalian (1/3 of the total predation) predators.

DISCUSSION

Nesting Parameters and Survival

Supplemental feed has not been documented to consistently increase wild bobwhite reproductive param-

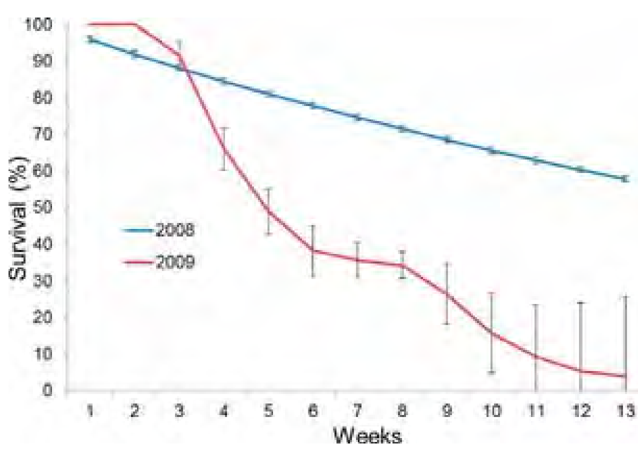

Fig. 1. Kaplan-Meier weekly survival estimates ($\pm$ SE) of 60 radio-marked bobwhite hens from 1 April to 30 June 2008 and 2009 on a private ranch in Brooks County, Texas, USA.

eters (Guthery 1997, 2002). This observation was supported by our findings in 2008, and especially 2009 (i.e., none of our radiomarked birds attempted to nest). Our hypotheses—bobwhite hens with access to PC will have higher clutch size, earlier nesting dates, fewer attempts to nest, and higher nest survival than hens with access to the CO ration—were not supported by our data. We would expect, assuming nest initiation is solely nutrition-based and the PC ration improved the bobwhite hens' nutritional status prior to reproduction (by supplementing protein needs), (1) nesting to occur earlier than in pastures supplied with CO, and (2) the PC ration would ameliorate the impact of drought conditions on the vegetation community in 2009, which should have helped some bobwhites reach reproductive condition. Increasing reproductive parameters through application of a protein-carbohydrate ration was demonstrated for bobwhites during the 1999 breeding season in Florida (W. E. Palmer, unpublished data, Tall Timbers Research Station, http://www.talltimbers.org/gb-suppfeed.html). Broadcasting milo year-round and supplementing the regimen with a complete bobwhite pelleted ration during the breeding season resulted in clutch initiation 1 month earlier and 3 times better nest productivity, despite a small sample size ($n = 15$ hens); however, these results have yet to be published in peer-reviewed literature. We observed essentially no difference in our study between feed types in any reproductive parameter measured. Nest survival was slightly (~2%) higher in PC pastures than in CO pastures, but the difference is likely not biologically significant.

Bobwhite clutch size was similar in CO pastures supplied with supplemental milo and experimental pastures supplied with the PC ration. A lack of change in clutch size is consistent with other literature documenting an average clutch size of 12–14 eggs (range = 7–28 eggs/clutch; Stoddard 1931, Simpson 1972, Klimstra and Roseberry 1975, Brennan 1999). The current theory of clutch size has evolved from consensus on 4 potential hypotheses (physiology, natural selection, food limitation, and predation mitigation) into a deluge of proximate hypotheses (Lack 1947, 1954; Cody 1966; VanderWerf 1992). There has been a general agreement on Lack's third hypothesis (1954: 22), which suggests clutch size is selected for by the largest brood size for which the parents can provide food; however, some feel this is counterintuitive. Bobwhites have precocial, nidifugous chicks (Stoddard 1931, Brennan 1999), and parental investment is more intensive during egg production and development (Winkler and Walters 1983) than during brood rearing; under this hypothesis, more available crude protein may not increase clutch size.

Annual bobwhite productivity in South Texas is more heavily influenced by weather and usable space (Guthery et al. 2001, 2002; Hernández et al. 2002, 2005) than by nutrition. Nest success is a component of annual productivity, and it is likely influenced by the same factors as annual productivity (i.e., heat loads, annual precipitation, nesting cover, escape cover, etc.). Hernández et al. (2005) found that 100% of radio-marked hens nested ($n = 15$ hens) during a wet year (93 cm annual

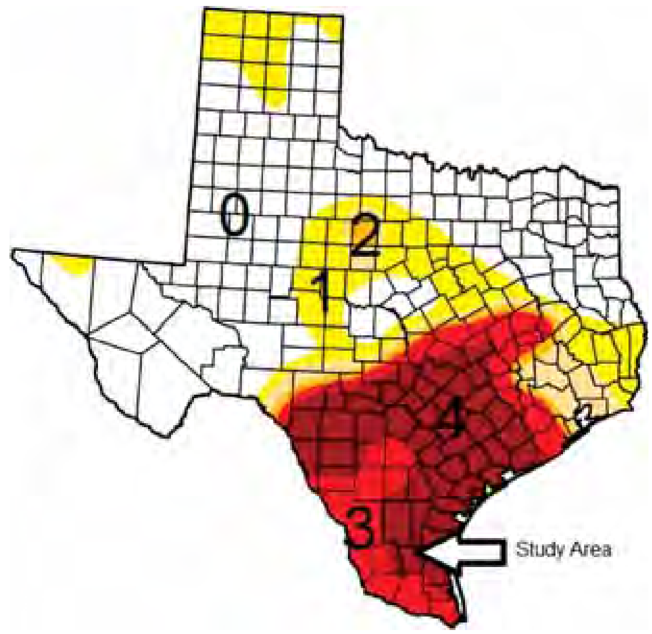

Fig. 2. Study area and severity of the 2009 Texas drought (Rosencrans 2009). The arrow points to the study area. Drought intensity ranges on a scale from 0 to 4: 0 = abnormally dry areas, 1 = moderate drought, 2 = severe drought, 3 = extreme drought, and 4 = exceptional drought.

precipitation), but during a dry year (51 cm annual precipitation) ~52% of radio-marked hens nested ($n = 19$ hens). Less precipitation occurred during our study—17% less during 2008 and 79% less during 2009—than the dry year documented by Hernández et al. (2005). However, the proportion of hens nesting in our study during 2008 was 2 times greater than the proportion of hens nesting documented by Hernández et al. (2005). Weather is strongly linked to bobwhite productivity (Kiel 1976, Giuliano et al. 1999, Guthery et al. 2002) and may have negated marginal benefit provided by the PC feed. The 2008 bobwhite nesting season length was 2 times longer than the dry year nesting season documented by Hernández et al. (2005); this is likely due to the abundant precipitation during July and August after the 2008 drought ceased. The nesting rate during the 2008 nesting season was most similar to rates documented by Hernández et al. (2005) during the dry year. The study area was in exceptional drought for all of 2009 (Fig. 2). The drought for South Texas was the worst since the historic drought of the 1950s and the worst drought in climate record history in the 3 neighboring counties (Rosencrans 2009).

Acknowledging our relatively small sample size ($n =$ 60 hens) and short study duration (2 nesting seasons), we reported one of the highest Mayfield nest success percentages (> 70%) for bobwhites. Nest success ($n =$ 793 nests) was 33% (Roseberry and Klimstra 1984) in Illinois while nest success ($n = 54$ nests) in Florida was 45% (DeVos and Mueller 1993). We cannot rule out the potential effect of predator trapping in all 4 pastures;

however, we attribute the high overall nest success to the ample amount of usable space on the study site. The vegetation community was dominated by a variety of grasses and forbs with interspersed mesquite and huisache, and was managed solely for bobwhite hunting. Simulation modeling has shown that improving habitat quality (increasing usable space) rather than increasing predator control is an effective way to increase nest success of bobwhites in South Texas (Rader et al. 2011). Nest loss to predators in our study (26%) was lower than all of the reported values (37–91%) documented by Rollins and Carroll (2001).

Hunting Parameters

Supplemental feed can facilitate hunting success by localizing coveys and increasing roadside bobwhite density (Guthery 2000, Guthery et al. 2004, Haines et al. 2004). Our hypothesis—pastures with PC ration will have more coveys moved per hour during fall hunts than pastures with the CO ration applied—was not supported by our data. Coveys moved per hour was the same between feed types in our study, suggesting the commercial pellet localizes coveys with the same efficacy as traditional grains at a much higher financial cost ($0.78 USD/kg CO ration vs. $2.22 USD/kg for the PC ration). Our estimates of mean coveys moved per hour are 4 times higher than documented by Palmer et al. (2002) and result in a covey rise about every 15 min of hunting. The large 95% confidence intervals are likely due to the low number of hunts (2) on each study area.

There are at least 3 possible reasons explaining the lack of effect in bobwhite reproduction in pastures provided with the PC ration. First, bobwhite hens may not have consumed the PC ration during either year. Anecdotal hunting data show that ~95% of all harvested bobwhites from pastures supplied with the PC ration had that ration in their crops and gizzards; however, we were unable to quantify how much feed was consumed by each hen during the breeding season. Diets of bobwhites differ between seasons (Wood et al. 1986), but we assumed bobwhite hens consume an equal proportion of PC ration in the breeding season and in the hunting season. Second, the bobwhite hens were consuming the supplemental feed, but the PC ration nutrient levels were likely poor in comparison to wild arthropods. We would have expected some sort of biologically-significant effect on nesting demographics in 2 years of drought from the supplemental PC ration. There was no effect in either year. Hens did not survive sufficiently long to nest during the 2009 nesting season. Hens likely would have remained alive throughout the season and nested during times of drought if the feed was effective. Third, the short time frame of our study (2 years) may have limited the ability of the researchers to detect potential differences between the CO and PC feed. A long-term study with a larger sample size and true replication during wet and dry years to evaluate the effects of the protein feed would allow researchers to examine whether the PC ration would provide a benefit to bobwhite populations.

MANAGEMENT IMPLICATIONS

Using the PC ration to enhance wild bobwhite reproductive parameters was ineffective based on our results. Our data did not suggest the PC ration provided no benefit to bobwhite populations over the CO ration. The additional cost of using PC ration over CO is not justified based on our results.

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APPENDIX. Feed ingredient information for a new, commercially available quail supplement (Quail Breeder 16 [denoted PC in 2008 field trial]; Quail Breeder 24 [denoted PC in 2009 field trial]) during field trials in 2008–2009 in Brooks County, Texas, USA.

	Feed type	
	Quail Breeder 16	Quail Breeder 24
Crude protein, % (min)	16.0	24.0
Lysine, % (min)	1.0	1.0
Methionine, % (min)	0.7	0.7
Crude fat, % (min)	3.0	3.0
Calcium, % (Ca) (min)	1.0	1.0
Calcium, % (Ca) (max)	1.2	1.2
Phosphorus, % (P) (min)	1.0	1.0
Salt, % (Na Cl) (min)	0.3	0.3
Salt, % (Na Cl) (max)	0.5	0.5