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EFFECTS OF SUPPLEMENTAL FEEDING ON NORTHERN BOBWHITE POPULATIONS IN SOUTH TEXAS

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ABSTRACT

During 1985–87, the effects of supplemental feeding on northern bobwhite (*Colinus virginianus*) populations were studied on 4 paired sites, representing a cross-section of soils, vegetation, and hunting pressure in south Texas. Whole milo was provided from late fall–March. Feeding increased winter survival of birds on deep sand sites (225–245%), but not on red sandy loam or clay sites. Feeding did not improve reproductive success on any of the study sites. Most birds collected had milo in their crops and there was a tendency to find birds close to feeders more often than at random points. The study demonstrated that supplemental feeding can increase survival if food is limiting, however, data suggested feeding was not effective when habitat structure was inappropriate, or when food was not limiting.

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Key words: *Colinus virginianus*, northern bobwhite, reproduction, supplemental feeding, survival, Texas

INTRODUCTION

Northern bobwhite management efforts are theoretically directed at limiting factors. It is difficult to determine the limiting factor or factors in specific situations, so management techniques have tended to be copied from other areas that have successful programs. Technique suitability is rarely evaluated for new situations. Feeding of a high-energy supplement in autumn-winter is 1 tool in northern bobwhite management that has gained acceptance in south Texas with little scientific evidence that it increased density by improving productivity, or survival.

Supplemental feeding of northern bobwhites has been tested in several areas. Frye (1954) found that Florida population densities increased with supplemental feeding when natural foods were limiting. Conversely, populations were not increased with the use of supplemental feed in Alabama (Keeler 1959). Robel et al. (1974) reported that birds having access to food plots had greater accumulated body fat compared to birds not having access to food plots during late winter in Kansas. Lehmann (1984:16, 276) suggested that northern bobwhite benefited from feeding in south Texas, but predators also were attracted to feeders. Guthery (1986:48–59) also suggested that supplemental feeding could benefit northern bobwhite reproduction and survival if habitat structure was of sufficient quality and the feeding program was correctly handled. DeMaso et al. (1998), working in Oklahoma, found that supplemental feeding did not have an effect on annual mortality, but did affect the distribution of cause-specific northern bobwhite mortality. Townsend, et al. (1999) noted that winter weather in Oklahoma was not a predictor of use of feeders by northern bobwhite. In 2 of 3 years, they also found winter survival was greater on areas with supplemental feed compared with non-fed areas, however, the opposite was found for the third year.

Our objective was to monitor northern bobwhite responses to fall feeding of a high-energy supplement in south Texas. Specifically, we looked at the effects of supplemental feeding on northern bobwhite winter survival, winter-spring population age structure, fall-winter distribution, and predator activity at feeders.

STUDY AREAS

Eight study sites (260 ha each) were selected and paired; one of each pair was a treatment (feeding) site and the other was a control (non-fed) site. Three study-site pairs were in south Texas, 35 km south of Hebbronville centrally located in Jim Hogg County. A fourth study-site pair was in the Gulf Prairies and Marshes (Gould 1975) on the Welder Wildlife Foundation Refuge, about 18 km north of Sinton, in San Patricio County. Annual precipitation at the Welder location averaged about 80 cm. The south Texas areas received about 50 cm of rainfall annually.

Study-site pairs were selected based on geographic proximity and similarity of current and past grazing management, range condition classes (United States Department of Agriculture 1976), quail harvest rates,

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precipitation patterns, and vegetation types. Study sites were centrally located in pastures to reduce potential effects of northern bobwhite ingress and egress.

Vegetation, soil types, grazing pressure, and hunting activity were similar on study sites and the surrounding areas (Doerr 1988). Doerr (1988) noted that vegetation structure was similar on paired areas except for site III during fall 1986. The control site III was in better range condition compared to the fed site III. The increased grass cover on control site III accounted for a higher vertical screening (vegetation profile board; Nudds 1977). Site IV had significantly greater percent screening at all strata heights compared to the other sites (I, II, and III) (Doerr 1988). Site II had the lowest percent screening compared to the other sites.

Paired Sites I

The first paired sites were located on the H. C. Weil's Palangana Ranch in Jim Hogg County and a 0.3-km buffer of similar habitat separated sites. Soils were dominated by deep sands in the Nueces and Saritas soil series, although inclusions of sandy loam of the Delmita series comprised <20% of each study site. Mesquite (*Prosopis glandulosa*) mottes with brazil (*Condalia obtusifolia*), lime-prickly ash (*Zanthoxylum fagara*), lantana (*Lantana horrida*), and granjeno (*Celtis pallida*) were common woody species and comprised 10% of the vegetation cover of the study sites. Important herbaceous species associated with the mesquite mottes included ground cherry (*Physalis viscosa*), dichanthelium (*Dichanthelium* spp.), bristlegrass (*Setaria* spp.), and panicgrasses (*Panicum* spp.). Open areas (90% of sites) were dominated by perennial horsemint (*Monarda* spp.), milkpea (*Galactia* spp.), three-awn (*Aristida* spp.), thinseed paspalum (*Paspalum setaceum*), panicum, and seacoast bluestem (*Schizachryium scoparium*). Other plants included partridgepea (*Cassia fasciculata*), cowpen daisy (*Verbesina enceloides*), and spurges (Euphorbiaceae).

Grazing management consisted of a cow-calf operation with year-long continuous grazing at 8 ha/animal unit (AU). This was changed to a 2-herd 3-pasture system at 10 ha/AU during the study. Northern bobwhite harvest rates were similar on both sites (about 20% of autumn densities) as was hunting pressure (about 20 hunter hours/site).

Paired Sites II

The second paired sites were on the A. Weil's Sombrero Ranch in Jim Hogg County. A 0.6-km buffer of similar habitat separated the sites. Soils were predominately sandy loams of the Delmita series, with inclusions of Nueces and Saritas soils. Woody vegetation consisted of catclaw acacia (*Acacia greggii*), brazil, granjeno, and mesquite. Brush composed 20% of the vegetation cover on the sites. Common grasses included three-awn, panicgrass, thinseed paspalum, seacoast bluestem, fringed signalgrass (*Brachiaria ciliatissima*), red lovegrass (*E. oxylepis*), hairy grama (*Bouteloua hirsuta*), and sideoats *grama (B. curtipendula*). Forbs included partridgepea, perrenial horsemint, milkpea, cowpen daisy, croton, yellow wood-sorrel (*Oxalys dillenii*), tephrosia (*Tephrosia* spp.), senna (*Senna* spp.), pepperweed (*Lepidium* spp.), bladderpod (*Lesquerella* spp.), and flax (*Linum rigida*).

Grazing management, throughout the study, consisted of a cow-calf operation with year-long, continuous grazing at 8 ha/AU. Northern bobwhite harvest rates were <10% of autumn densities and hunting pressure was <15 hunter hours/site during the study.

Paired Sites III

The third paired sites were on the W. W. Jones' Alta Vista Ranch in Jim Hogg County. Soils were deep sands of the Nueces and Saritas soil series. This study area was not established until the second field season (autumn 1986 through winter 1987). Vegetation was similar to site I. The primary difference in vegetation composition between the 2 areas was that site III had a greater percent cover of seacoast bluestem, tanglehead (*Heteropogon contortus*), crinkleawn (*Trachypogon secundus*), and American balsamscale (*Elyonurus tripsacoides*).

Livestock management was a cow-calf operation with a year-long, continuous grazing system at 12 ha/AU. Northern bobwhite harvest rates were equal on the paired sites at 20–30% prior to the 1986–87 hunting season. Harvest during the 1986–87 season was about 19% on the control site and 37% on the fed site.

Paired Sites IV

The fourth paired sites were on the Welder Wildlife Foundation in San Patricio County and study sites were contiguous. Soil on this area was Victoria clay. Brush species included mesquite, agarito (*Berberis trifoliata*), huisache, hackberry (*Celtis* spp.), lime pricklyash, blackbrush (*A. rigidula*), granjeno, and Texas persimmon (*Diospyros texana*). Common grasses included gramagrasses, common bermudagrass (*Cynodon dactylon*), vine mesquite (*P. obtusum*), meadow dropseed (*Sporobolus asper*), Texas wintergrass (*Stipa leucotricha*), and tridens (*Tridens* spp.). Forbs included western ragweed (*Ambrosia psilostachya*), Leavenworth vetch (*Vicia leavenworthii*), upright prairie coneflower (*Ratibida columnaris*), frogfruit (*Phyla* spp.), yellow wood-sorrel, croton, bladderpod, pepperweed, mallows, and primrose (*Oenthera* spp.).

The sites were part of a cow-calf operation on a 3-month, 4-pasture, 3-herd, deferred-rotation system. The control area was moderately stocked (2.8 ha/AU) and the treated area was lightly stocked (5.7 ha/AU). Both sites were in good range condition. There was no hunting pressure on these sites.

METHODS

Feeders

Sixteen feeders were set in a 4 × 4 grid, 0.3 km apart on each fed site. Feeders also were 0.3 km from study site borders to reduce potential ingress-egress from the surrounding land. Initially, feeders consisted of a 208-l plastic drum placed on a 1.2-mm plywood board, and wired between 2 metal fence posts. Six, 8-mm holes were drilled into the sides of each feeder about 6 cm above the bottom. These feeders were replaced prior to the 1986–87 field season with 19-l plastic buckets hung 2–4 cm above the soil surface from existing brush. Feeders hung from brush were less susceptible to loss of feed due to red harvester ants (*Pogonomyrmex barbatus*), and the large plastic drums were more difficult to fill than were the plastic buckets. Feed flow holes were drilled 2–3 cm above the bottom of the containers. Feeders were filled with 15 kg of whole milo and monitored twice weekly from 1 September 1985 through 31 March 1986 and from 25 November 1986 through 31 March 1987. Whole milo is a high carbohydrate (70–80%), low protein (12%), and low fat (1–4%) supplement (Nestler et al. 1944). The high carbohydrate content makes milo an excellent energy source. It provides 100% of minimum protein requirements of non-breeding adult northern bobwhites and 52% of breeding female northern bobwhite protein requirements (Nestler et al. 1944).

Population Attributes

Northern bobwhite population densities were estimated using line transects (Guthery 1987). Four, 1.2-km transects spaced at 0.3-km intervals were established on each study site. Between 20 and 45 km of transects were walked on each study site in the autumn and late winter through early spring (Mar) during the first or last 3 hours of daylight. Numbers of birds flushed, right-angle distance between transect line and each flush point, and transect length were estimated. Effective strip width, group size, and population density were calculated using a Kelker estimator (Gates 1979).

Trapping was conducted on sites I and II and the fed site III during both field seasons and on the unfed site III during the second field season. Sixteen to 32 traps were used on each site. Trap locations were prebaited for 3–5 days. Trapping was conducted once a month from September through March the first field season and limited to a 15-day trap session in November and March the second field season. An effort was made to trap and mark 100 individual quail at each site during both years. Birds were banded with uniquely numbered aluminum leg bands supplied by Texas Parks and Wildlife. Age, sex, location, and date of capture of each individual were recorded. These data were used to determine age and sex ratios and an index of relative survival (numbers recaptured and/or harvested/number initially banded). Data also were used the second year to provide a second index of bird density on the study sites using a Schumacher-Eschmeyer (Schumacher and Eschmeyer 1943) estimator.

Crop Analysis

Crops of birds obtained from hunters at site III were examined for presence or absence of supplemental feed and native foods. We did not have access to hunters at sites I and II. Date and time of collection were noted for each bird.

Observation Data

Feeders were visited 0.5 hour before to 2 hours after sunrise and 2 hours before sunset to 0.5 hour after sunset to determine if northern bobwhites or raptors were at or near feeders. A similar number of random points were visited on both treatments and served as controls. Feeders were visited 5 times/month and random points were visited 1–2 times/month from November through February. Presence or absence of northern bobwhites and raptors were recorded. The visual presence of northern bobwhites at feeders (within 30 m) was assumed to be an indicator of feed use by the birds.

Scent Stations

Terrestrial predator activity was monitored using modified scent stations (Linhart and Knowlton 1975). Eight scent stations spaced 0.3 km apart were operated for 2 consecutive nights on each study site. Each station consisted of a 2-m diameter, cleared circular area. Soil in the area was sifted and leveled. A scent capsule was staked in the center of the area. Carmine's Canine Lure was used as an attractant. Species and number of animals were recorded in the morning. These data were reported as animal visitations/night/station.

Statistical Analyses

Differences in grazing pressure, vegetation, soils, and hunting pressure between study sites preclude the use of statistical analysis to differentiate between treatment effects and experimental error when comparing treatment effects between study sites. Therefore, statistical analysis related to northern bobwhite and predator responses are descriptive.

A 95% confidence interval (Schumacher and Eschmeyer 1943, Chapman 1948) was used to detect differences in northern bobwhite densities between fed and control sites. Differences between northern bobwhite density estimates from trap data also were determined using 95% confidence intervals. Frequencies of bands returned were compared between paired study-sites using Chi-square tests.

Data related to northern bobwhite and raptor presence on fed and random points were pooled by month for each site and analyzed using Chi-square tests (Snedecor and Cochran 1967:250–252). Data related to presence of grain in crops were not pooled, and were analyzed using Chi-square tests.

RESULTS

Northern Bobwhite Population Attributes

Initial densities were similar on paired sites (Table 1). Northern bobwhite densities were greater on fed sites compared to control sites on deep sand study areas (sites I and III) during subsequent spring sample

Table 1. Seasonal densities of northern bobwhites (D = number/ha) and standard errors as affected by supplemental feeding on 4 south Texas study areas, 1985–87.

Area	Fall 1985		Winter 1985		Spring 1986		Fall 1986		Spring 1987	
Treatment	D[a]	SE	D	SE	D	SE	D	SE	D	SE
Site I										
control	1.49	0.36	0.77	0.25	0.30A	0.25	1.95	0.73	0.35A	0.45
fed	1.59	0.60	1.40	0.71	1.10B	0.35	2.31	0.81	1.10B	0.42
Site II										
control	1.92	0.61	2.54	0.71	1.85	0.78	2.05	0.29	0.95	0.38
fed	1.89	0.66	2.28	0.75	2.10	0.90	1.92	0.33	0.89	0.50
Site III										
control[b]					0.64	0.56	1.64	0.51	0.56	0.41
fed	1.79	0.62	0.70	0.38	1.11	0.49	2.56	0.53	0.69	0.56
Site IV										
control	0.25	0.85	0.20	0.92	0.25	0.87	0.52	0.74	0.36	0.93
fed	0.25	0.87	0.31	0.96	0.29	0.82	0.25	0.85	0.40	0.89

[a] Densities followed by different letters in columns by study areas differ ($P < 0.05$).
[b] Study site added spring 1986.

periods, but not in autumn 1986. Densities were not different on the fed sites II and IV compared to the respective control sites during subsequent sample periods. Fall 1986 population estimates based on trap data were supportive of estimates from transect data (Fig. 1). No marked northern bobwhites were observed or harvested off sites from which they were originally trapped.

Densities were greatest in the autumn and declined 50–76% during winter and early spring. The greatest population reductions were seen on sites I and III (Table 1). Population reductions ranging between 3 and 53% were seen on sites II and IV. Site IV on the Gulf Prairies and Marshes had the lowest population densities compared to all other study areas (Table 1). Northern bobwhite densities on the south Texas areas (sites I, II, and III) were at comparable levels in the autumn. Densities on site II were generally greater than those on the deep sand areas (sites I and III).

Winter survival was not greater on fed sites compared to paired control sites, except on site I (Tables 2 and 3). Survival, based on estimated densities, ranged between 17 and 97% (Table 2). Survival on the

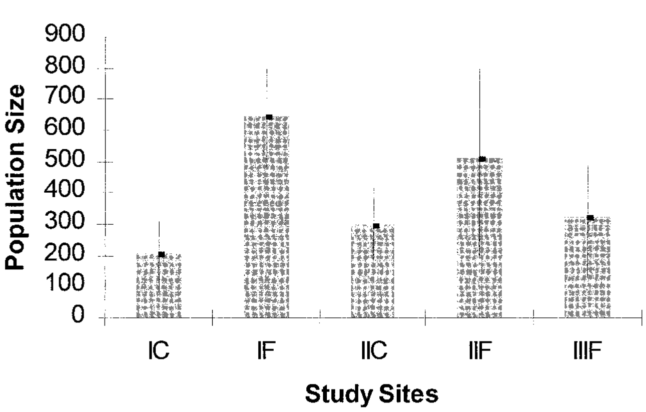

Fig. 1. Population estimates (Schumacher-Eschmeyer) of northern bobwhites and 95% confidence intervals on Site I with (IF) and without feeders (IC), Site II with (IIF) and without feeders (IIC), and Site III with feeders (IIIF).

fed site I was over twice the survival found on the control site. Survival based on band returns during the second field season yielded similar results. Band returns were similar between the control and fed sites II and returns on the fed site I were double those on the control area (Table 3).

Juvenile-to-adult ratios (Table 4), as a measure of reproductive success, were similar between paired fed and control sites, and varied between 1:1.7 and 1:2.6. Juvenile-to-adult-female ratios followed the same pattern, varying from 1:6.4 to 1:8.0.

Feed Usage

Percent of birds using supplemental feed varied by month and time of day. Between 45 and 70% of birds shot on fed areas during the second field season had supplement in the crops (Table 5). The percent of crops with supplement increased over time. A greater ($P < 0.05$) percent of northern bobwhite crops collected in the afternoon had some supplement present compared to bird crops collected in the morning during November and December 1987 (Table 6). The percent of crops with milo present was similar ($P > 0.25$) between morning and evening samples in January and February 1987. The percent of northern bobwhite crops having no food (native or supplement) was greater ($P < 0.05$) in morning compared to afternoon (Table 7).

Table 2. Percent northern bobwhite survival and increase on 3 south Texas study areas based on comparison of spring and fall population estimates from flush transect data, 1985–87.

Area	Treatment	Winter 1985 survival	% Spring to fall increase	Winter 1986 survival
Site I	Control	20.1	650.0	18.0
Site I	Fed	69.2	210.0	47.6
Site II	Control	72.8	110.8	46.3
Site II	Fed	92.1	91.4	46.4
Site III	Control[a]		256.3	34.2
Site III	Fed	62.0	230.6	27.0

[a] Site not established until spring 1986.

Table 3. Indices of survival on 5 south Texas study sites based on band returns from birds banded in 1985–86 and re-trapped or harvested in 1986–87 and birds banded in fall 1986 and re-trapped in spring 1987.

	Site I		Site II		Site III
Index	Fed	Control	Fed	Control	Fed
Banded 1985	54	46	58	60	112
Re-trapped 1986–87	12B[a]	3A	6A	3A	9A
% bands re-trapped	22.2	6.5	10.3	5.0	8.0
Banded fall 1986	133	102	110	100	100
Re-trapped spring 1987	36B	16A	9A	8A	6A
% bands retrapped	27.1	15.7	7.3	9.0	6.0

[a] Number followed by different letters in rows differ ($P < 0.10$).

The percent of times that birds were flushed near feeders (≤ 30 m) was greater compared to the percent of times birds were flushed at random locations on fed and control sites, except on site I (Table 8).

Predation

Indices of predator activity and depredation were similar between paired sites. Scent-station visitations ranged between 0.56 and 1.55 animals/station/night. Raptor sighting on transects averaged 0.21 birds/km on fed areas and 0.24 birds/km on control areas. There was no difference ($P < 0.05$) between the number of perched predators observed at feeders (21 of 2,500 observations) compared to observation points on control areas (2 of 500 observations).

DISCUSSION

If supplemental feeding was an effective tool in this study, then increases in northern bobwhite density on fed sites compared to unfed sites should be related to increased reproductive success or survival. If supplemental feeding did not increase population densities, then either food supply indices should be adequate or some other habitat factor should be documented as limiting the population.

Paired Site I

Density calculations showed about twice the density on the fed area compared to the control area. High use of supplemental feed by birds on the fed area and increased autumn-to-spring survival of birds on the fed site compared to the control site suggested that supplemental feeding increased population numbers. Similarly, the increased use (more northern bobwhites at feeders) of supplemental feed over time, the increased use of supplemental feed during morning feeding periods over time, and the slight increase in the percent of birds with no food (native or supplemental) in crops indicated that native foods became limited as the winter progressed.

The similarity of northern bobwhite age ratios on the fed and control sites and the similarity or reduced spring-to-autumn population increase suggested that supplementing winter food supplies with a high energy-low protein ration did not improve reproductive success. Perrin (1965) hypothesized that a restricted food supply would delay egg laying and clutch size, and that early nest initiation would increase survival of young. Work by Dijkstra et al. (1982) on kestrels (*Falco tinnunculus*) and Kallander (1974) supported the hypothesis that laying date and clutch size were affected by increased food supply. Yom-Tov (1974) reported increased breeding success of carrion crows (*Corvus corone*) having access to supplemental feed compared to crows without access to supplemental feed. Similar findings were reported by Hogstedt (1981) regarding black-billed magpies (*Pica pica*) and by Pattee (1977) studying wild turkeys (*Meleagris gallopavo*). Wilbur et al. (1974) felt that supplemental feeding might have improved California condor (*Gymnogyps californius*) breeding success. These studies supplied a complete ration supplement. Also, the supplement was supplied during the breeding and brooding periods.

Guthery (1986:59) suggested that an appropriately executed feeding program could enhance breeding success of northern bobwhites. This type of program includes supplying a whole ration supplement throughout breeding and brooding. The supplement provided to northern bobwhites in our study was low in protein

Table 4. Age ratios (juveniles/adult) in autumn 1986 through spring 1987 based on trap data and harvest data on the south Texas study sites I, II, and III.

	Site I		Site II		Site II	
Age ratio	Control (125)[a]	Fed (263)	Control (131)	Fed (153)	Control (269)[b]	Fed (194)
J : A[c]	2.3	2.3	2.7	1.7	2.6	1.9
J : A female	7.3	7.4	7.4	8.0	6.7	6.4

[a] Number of birds trapped.
[b] Number of birds harvested.
[c] J = juvenile and A = adult.

Table 5. Number (n) and percent (%) of crops with supplemental feed present and absent in November–February from fed site III, winter 1986–87.

	With feed[a]		Without feed	
Month	n[a]	%	n	%
November	66AB	49	70	51
December	56A	46	67	54
January	281BC	59	196	41
February	26C	70	11	30

[a] Number of crops with supplemental feed followed by different letters differ ($P < 0.05$).

Table 6. Number (*n*) and percent (%) of crops with supplemental feed present and absent from fed site III by time of day, winter 1986–87.

Period	Time of collection	Crops with feed[a] *n*	%	Crops without feed *n*	%
Nov–Dec	Morning	46A	37	78	63
	Evening	91B	60	62	40
Jan–Feb	Morning	147A	62	92	38
	Evening	160A	58	115	42

[a] Number of crops with supplement feed followed by different letters during same date differ ($P < 0.05$).

Table 7. Number (*n*) and percent (%) of crops having no native or supplemental feed present in mornings and evenings from fed site III, winter 1986–87.

Period	Time of collection	Crops with feed[a] *n*	%	Crops without feed *n*	%
Nov–Dec	Morning	38B	24	124	76
	Evening	10A	6	153	94
Jan–Fed	Morning	64B	21	239	79
	Evening	35A	11	275	89

[a] Number of crops with feed followed by different letters differ ($P < 0.05$).

and was available only during the beginning of the breeding season. A diet composed of whole milo does not meet minimum protein or phosphorous requirements of northern bobwhite (Nestler et al. 1944). Protein has been suggested as an important supplemental nutrient for improving northern bobwhite productivity (Guthery 1986:53). However, Wood et al. (1986) found that south Texas northern bobwhites were able to meet minimum reproductive protein requirements, but not minimum phosphorous requirements by using native foods. The study by Wood et al. (1986) was not designed to determine if native food supplies limited populations or nutrient plane. Their study only addressed whether existing northern bobwhites were able to meet nutrient requirements. The data strongly suggested that protein was not limiting, but that phosphorous may have been limiting. Therefore, the use of a whole-milo supplement in winter and early spring may not have met the necessary assumptions of supplying the appropriate nutrient at the appropriate time to improve reproduction.

Paired Site II

Northern bobwhite density, reproductive success, age ratios, and survival were not different between the fed and control sites. These population indices suggest that factors other than food may have limited population densities.

More conclusive evidence that food may not have been limiting on site II was the occurrence of birds at feeders. Birds were found more consistently at feeders compared to random locations on site II, but birds did not use feeders as consistently as birds on site I.

Paired Site III

Northern bobwhite density on the fed site was greater compared to density on the control site in spring 1986. It cannot be conclusively stated that feeding was the source of population differences and hence survival, during winter 1985, because pre-treatment data were unavailable.

Bird survival was similar between the fed and control site in winter 1986. This might be due to differential hunting pressure between the control and fed site. Harvest pressure (number of birds shot/estimated autumn population) was similar between the study sites in winter 1985, but in winter 1986 harvest pressure was 37% on the fed site, and 19% on the control site. Number of hunter hours was nearly twice as high on the fed site compared to the control site in winter 1986. Nearly doubling hunting mortality on the fed site compared to the control site may have reduced overall winter survival in 1986. Hunting mortality may not be completely compensatory with other sources of mortality. Roseberry and Klimstra (1984:40) reported data from Illinois that hunting mortality was intermediate between being additive and compensatory. If hunting mortality during our study was additive, the larger harvest on the fed site decreased survival and contributed to the similarity in winter survival for the fed and control sites in 1986.

Paired Site IV

Northern bobwhite densities on the fed site were not different from densities on the control site. Food-producing forb densities and cover were generally greater than found on the other paired sites (Doerr 1988) suggesting that food production may not have been limiting. Also, the probability of locating birds at feeders compared to random locations was not different. The low bird densities on site IV compared to the other sites indicated that some component of the environment not measured by our study was restricting bird densities.

Site IV was surrounded by a coyote-resistant fence and few coyotes were present inside the study area.

Table 8. Number (*n*) and percent (%) of observations at feeder and random locations having northern bobwhite present and absent on 4 south Texas study areas, fall–winter 1985–86 and 1986–87.

Area	Treatment	Birds present[a] *n*	%	Birds absent *n*	%
Site I	Fed-feeder	109C	18.2	491	81.8
	Fed-random	4A	4.0	96	96.0
	Control	6A	3.0	194	97.0
Site II	Fed-feeder	66B	11.0	534	89.0
	Fed-random	8B	8.0	92	92.0
	Control	3A	1.5	197	98.5
Site III	Fed-feeder	128C	21.3	472	78.7
	Fed-random	5A	5.0	95	95.0
	Control	1A	1.0	99	99.0
Site IV	Fed-feeder	2A	2.0	98	98.0
	Fed-random	0A	0.0	100	100.0
	Control	0A	0.0	100	100.0

[a] Different letters following number of visits with birds differ ($P < 0.10$).

Scent-station activity suggested that other mammalian predator activity was no greater compared to activity on Sites I, II, and III. Fewer raptors were observed on site IV compared to the other study areas. Therefore, depredation is discounted as an important reason for reduced populations on site IV.

Wilson (1984) felt that herbaceous vegetation on the Welder Wildlife Foundation Refuge was too thick for optimum northern bobwhite densities. Furthermore, Bareiss (1985) reported that a majority of random locations on the Welder Refuge were unsuitable for northern bobwhites. Doerr and Silvy (1987) also noted that habitat structure was limiting populations on site IV. Also Doerr and Silvy (1987) found that northern bobwhite densities on a study area adjacent to site IV were greater compared to densities on site IV. Moreover, they reported that herbaceous structure of the vegetation on adjacent sites was lower compared to structure on site IV. Doerr and Silvy (1987) concluded that a negative relationship existed between northern bobwhite densities and nest cover, and percent vegetation screening.

MANAGEMENT IMPLICATIONS

The variable population responses to supplemental feeding demonstrate that food supply is only 1 of several environmental factors in a complex system. Winter feeding of a high-energy supplement can improve survival if food is limiting. This study also demonstrated that feeding can increase the probability of locating birds. However, supplemental feeding cannot compensate for limitations in habitat structure or high hunting pressure. Therefore, management objectives and habitat status should be assessed prior to implementation of any feeding program.

Supplemental feeding with whole milo appears to increase survival of birds on deep sand range sites in south Texas. However, this increased survival did not result in increased densities the following fall.

Whole milo was not effective for increasing northern bobwhite density or survival on clay soils of the Gulf Coast Prairies and Marshes or on red sandy loams of south Texas. Plant communities on the Gulf Coast Prairies and Marshes are highly productive due to high soil fertility, length of growing season, and abundant rainfall. Northern bobwhites are closely related to lower successional stages. Therefore, maintaining lower successional stages over a portion of their range will probably be of greater benefit for northern bobwhites than simply supplying an additional food source. Supplemental feeding on red sandy loam range sites in south Texas may be more complex. Guthery (1986: 130) suggested that enhanceing native foods and rejuvenating habitat structure may be synergistic. Therefore, manipulating both habitat structure and native feed on these range sites may be required to achieve a satisfactory northern bobwhite population response.

Whole milo supplied from winter through early spring did not increase reproductive success. If the objective of a feeding program is to improve reproductive success, then a total ration supplied through the breeding and brooding seasons may be more appropriate. Supplemental feeding did not improve reproductive success of bobwhites on any of the study sites. Young bobwhite chicks feed almost exclusively on insects (Roseberry and Klimstra 1984:87). Supplemental feeding does not produce more insects for chicks, therefore, one would not expect supplemental feeding to increase reproductive success if insects were limiting within an area. No matter how much supplemental feeding increases adult bobwhite survival and body condition, if insects are limiting, supplemental feeding will not increase bobwhite numbers for the fall hunt. Therefore, a fifth assumption that could be added to Doerr's (1988) list for bobwhite supplemental feeding; supplemental feeding should benefit all segments (young as well as adults) of the population.

Winter feeding appears to improve the consistency of locating birds on deep sand and red sandy loam range sites of south Texas. Feeding does not appear to improve opportunities for locating birds when populations are low. Also, feeding did not increase predator activity, nor was there a greater probability to see predators at feeders compared to locations without feeders. DeMaso et al. (1999) and Townsend et al. (1999) also noted that northern bobwhites using feeders were not predisposed to hunter harvest or predators.

No single management tool will produce consistent results with northern bobwhite populations because of the matrix of environmental factors that influence a population. Knowledge concerning the status of key environmental factors can improve predictions regarding the effects a management tool may have on a population. Doerr and Silvy (1987) felt that an understanding of northern bobwhite management objectives and knowledge of the status of the habitat and population were essential to gain benefits from a feeding operation. This study demonstrates that the effects of feeding on northern bobwhite populations are variable because of the confounding interactions of environmental factors. Variability in efficacy of supplemental feeding and the associated costs need to be considered and compared to potential risks and benefits of other management tools before managers implement such a program.

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