Supplemental feed use by free-ranging white-tailed deer in southern Texas

Marc L. Bartoskewitz, David G. Hewitt, John S. Pitts, and Fred C. Bryant

Abstract Providing pelleted supplemental feed to free-ranging white-tailed deer (*Odocoileus virginianus*) is an increasingly common management practice in Texas and across the southeastern United States. Despite its prevalence, the proportion of a deer herd that consumes supplemental feed and the effects on antler size and body mass are unknown. We mixed markers (chlortetracycline during summer and chromic oxide during winter) into pelleted feed offered on 3 ranches and used data from harvested deer to assess the effect of deer sex, age, and distance from a feeder on the likelihood that a deer consumed feed. We also assessed the effect of feed consumption on antler size and body mass. Patterns of feed use varied by ranch, but a greater proportion of male deer used supplemental feed than female deer, older males tended to use feed more than young males, and the likelihood of a deer using feed was negatively related to distance between harvest location and the nearest feeder. On one ranch, antler size was 14% greater in males that consumed feed, but significant effects were not noted on other ranches. Male body mass at time of harvest was increased 12–23% by feed use in summer and winter. Female body mass at time of harvest was greater only in females 2.5 years of age that had eaten feed during summer. Feed use during summer did not influence female body mass at other ages ($P>0.181$), and body mass was not affected by feed use during winter ($P=0.484$). Our results suggest that supplemental feeding programs benefit males more than females. If managers wish to provide supplemental feed to females, higher feeder densities (>1 feeder/164 ha) and free-choice feeders should be considered.

Key words chromium, nutrition, *Odocoileus virginianus*, supplemental feed, tetracycline, Texas, white-tailed deer

Survival and productive processes of cervids are related to nutrient intake (Verme 1969, Hobbs 1989, Cook et al. 2000), and if forage resources are limiting, providing supplemental feed is a management alternative. Intentional provision of supplemental feed for cervids in North America, primarily to increase winter survival, dates back at least to the early 1900s, (Carhart 1943, Baker and Hobbs 1985, Smith 2001). Cervid management is becoming more intensive (McBryde 1995), especially on private land where leasing of hunting rights can be an important source of income and provision of feed increases lease prices (Baen 1997). Currently supplemental feed is provided for many purposes, including increasing reproductive rates, population density, body mass, antler size, and survival (Lewis and Rongstad 1998, Smith 2001). Supplemental feed also may be provided to alter cervid movements or distribution, to make animals more visible for recreational purposes, or to reduce damage to agricultural crops or other resources (Smith 2001, Conover 2002). The ability of supplemental feeding

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programs to meet their objectives is partially dependent on the proportion of the target population that consumes feed.

Southern Texas is a semi-arid rangeland in which nutritionally based carrying capacity for white-tailed deer (*Odocoileus virginianus*) is positively related to precipitation (Strickland 1998). Annual precipitation is highly variable, and dry periods are common (Norwine and Bingham 1985). Summer is particularly dry, and forage resources often are poor (Meyer et al. 1984) when females are raising fawns and males are growing antlers. For these reasons and because of the high proportion of private land, supplemental feeding is common (Thigpen et al. 1990). However, the proportion of the deer population using supplemental feed is unknown, and effects on deer productivity are unclear. Our objectives were to 1) estimate the proportion of free-ranging white-tailed deer using supplemental feed; 2) determine the effect of a deer's gender, age, and distance between harvest location and the nearest feeder on the likelihood that a deer had consumed feed; and 3) estimate the effect of supplemental feed on antler size and body mass of white-tailed deer.

Study area

Research was conducted on 3 ranches in south Texas. Ranch A, located in Aransas County 8 km off the coast of Rockport, Texas in the Gulf Prairies and Marshes region (Hatch and Pluhar 1993), encompassed 4,452 ha of area usable by livestock and wildlife. Although not enclosed by a deer-proof fence, it was a barrier island and surrounded by water. Ranch A had 13 barrel feeders (1/342 ha) that provided feed ad libitum. On average, Ranch A fed approximately 23 kg of pelleted feed/day/feeder during summer and 11 kg/day/feeder during winter. Ranch A had 1 deer/10 ha and a ratio of 1 male to 1.5 females. Harvest of male deer consisted of mature bucks and yearlings with small antlers. Female deer were harvested opportunistically. Annual precipitation averaged 89 cm (National Climatic Data Center 2000) in Rockport. Vegetation consisted of tallgrasses, sedges (*Carex* spp.), bluestems (*Schizachyrium* spp.), and dropseeds (*Sporobolus* spp.) in sandy soils, while cordgrass (*Spartina patens*) and saltgrass (*Distichlis spicata*) were the dominant grass species in the saline coastal lowlands. A variety of forbs such as snoutbeans (*Rhynchosia* spp.), partridge pea (*Chamaecrista fasciculata*), butterfly pea (*Centrosema virginianum*), ground cherry (*Physalis* spp.), and several *Compositae* spp. occurred in sandy soils.

Feeder and buck. A higher proportion of male white-tailed deer used supplemental feed compared to females.

Ranch B was a 3,238-ha deer-hunting lease in Jim Wells and Kleberg counties 20 km west of Kingsville, Texas, within the Gulf Prairies and Marshes and South Texas Plains regions (Hatch and Pluhar 1993). A 1.2-m-high net wire fence surrounded the lease, with highways on 2 sides. Ranch B had 8 feeders (1/405 ha) that released approximately 3.7 kg of pelleted feed/day/feeder during summer and winter. Helicopter population surveys indicated that Ranch B had 1 deer/8 ha and a ratio of 1 male to 2 females. Harvest of male deer consisted of mature bucks, although the harvest was small. Female deer were harvested opportunistically. Average annual rainfall was 70 cm (National Climatic Data Center 2000) in Kingsville. Herbaceous vegetation was similar to that on Ranch A; however, shrub communities were more dominant and diverse. Browse species included spiny hackberry (*Celtis pallida*), guayacan (*Guajacum angustifolium*), honey mesquite (*Prosopis glandulosa*), and lime prickly ash (*Zanthoxylum fagara*).

Ranch C was located in Duval County 13 km north of Freer, Texas, within the South Texas Plains region (Hatch and Pluhar 1993). We used a 5,260-ha portion of the ranch that was partially enclosed by a 2.4-m-high net wire fence. The area contained 32 feeders (1/164 ha) that dispensed approximately 4.5 kg of pelleted feed/day/feeder during summer. Average pelleted feed provided during winter was not calculated. Helicopter population surveys estimated the deer population at 1 deer/7 ha and a ratio of 1 male to 0.9 females. Harvest of male deer consisted of mature bucks and younger deer with small antlers. Female deer were harvested opportunistically. Annual rainfall averaged 63 cm (National Climatic Data Center 2000) in Freer. Vegetation consisted of mixed shrubs dominated by honey mesquite, spiny hackberry, guajillo (*Acacia berlandieri*), and lime-prickly ash.

Pelleted supplemental feed was fed at all 3 sites for >5 years before the study. The specific pelleted feed used during our study had been provided for 1-2 years prior to the beginning of the study.

Methods

Estimating summer feed use

To mark the teeth and bones of deer that ate supplemental feed during summer, we mixed a pelleted commercial deer feed (processed grain byproducts, soybean hulls, plant protein products, grain products, cane molasses, and vitamin and mineral supplements; Table 1) with aureomycin 90 chlortetracycline at a concentration of 660 mg/kg (Van Brackle et al. 1995) before the pelleting process. We shipped feed containing chlortetracycline to each ranch and fed deer via feeders for 2 weeks each month from July-September 1999; we provided feed without chlortetracycline in the intervening 2 weeks. Marked feed was offered in 2-week intervals to reduce feed costs and potential effects of the chlortetracycline antibiotic. Because deer would be marked with a 660-mg dose of chlortetracycline (Van Brackle et al. 1995), it was not necessary to offer the feed continuously.

We collected mandibles and metacarpal bones from all hunter-harvested white-tailed deer for chlortetracycline analysis on each ranch from 1 October 1999-31 January 2000. We froze samples at -20°C for later analysis. We cut a 2.5-cm section of mandible using a bandsaw and shipped samples to Matson's Laboratories (Milltown, Montana, USA) where teeth were cross-sectioned to a thickness of 100 microns and mounted on slides for examination under an ultraviolet light microscope for yellow fluorescence of chlortetracycline. Metacarpal bones were used for analysis when a tooth was not available.

Table 1. Nutrient content of supplemental feed offered on 3 southern Texas ranches from July 1999–January 2000.

Nutrient	Concentration
Calcium (%)	1.25–1.75
Phosphorus (%)	>0.95
Sodium chloride (%)	0.20–0.70
Potassium (%)	>1.30
Crude protein (%)	18.5
Crude fiber (%)	<20.50
Crude fat (%)	>2.00
Gross energy (kcal × g^{-1})	4.51
Digestible energy (kcal × g^{-1})	3.18

Estimating winter feed use

To determine which deer ate feed during winter, we mixed the same type of pelleted feed used during summer with 40 ppm chromic oxide (Cr_2O_3) before the pelleting process. Chromic oxide was used instead of chlortetracycline as a marker during winter so that we could distinguish summer and winter feed use in harvested deer. We chose this concentration of chromium to ensure that fecal chromium concentrations would be elevated above background concentrations even if deer diets contained only 20% supplemental feed. We provided chromium-laced feed on all 3 ranches from 1 October 1999-31 January 2000.

We determined background fecal chromium concentrations by collecting fresh fecal samples from the field on each ranch before initiation of the chromium feed. We froze samples at -20°C, then sent them to MoorMan's laboratory (Quincy, Illinois, USA) and analyzed them using atomic absorption spectroscopy. Background fecal chromium concentrations were <6 ppm ($\bar{x}$=2.48; 95% CI=2.33 to 2.62; n=34), which was the concentration we chose to distinguish between deer that had not eaten supplemental feed (fecal Cr <6 ppm) from those that had (fecal Cr >6 ppm). We collected feces from the colon of hunter-harvested deer on each ranch and froze samples at -20°C for later analysis.

All harvested deer were weighed (field-dressed mass, only viscera removed) by ranch personnel and then aged by a single observer using tooth replacement and wear (Severinghaus 1949). We determined Universal Transverse Mercator coordinates of every feeder and harvest location using a Global Positioning System. We measured antler characteristics using the Boone & Crockett (B&C) Club scoring system (Boone and Crockett Club 1995).

Statistical methods

We used logistic regression analysis (Stokes et al. 1995) to evaluate the effect of deer gender, deer age (1.5, 2.5, 3.5, ≥4.5), and distance between harvest location and the nearest feeder on the likelihood that deer had eaten supplemental feed. Each ranch was analyzed separately because ranches differed in many attributes that could impact feed use (e.g., feeder density, feeder type, natural forage base), and preliminary analyses showed intractable higher-order interactions involving ranch. Furthermore, we did not conduct logistic regression analyses for Ranch B because of the low sample size of males and the low percent of female deer using supplemental feed (Figure 1). We used Akaike's Information Criterion coefficients (AIC_c), corrected for sample size (Burnham and Anderson 1998), to choose the model best supported by the data. Because deer age, gender, and distance between harvest location and the nearest feeder were hypothesized to affect deer use of supplemental feed, and because interactions among these factors were biologically feasible, we considered models with AGE, SEX, DISTANCE, and all possible interactions in the logistic regression. If a model with third-order interactions was the best model, we conducted a follow-up analysis for each gender separately. We conducted separate analyses for summer and winter feed consumption. Ninety-five percent Wald confidence intervals were presented with odds ratios.

We attempted a 3-way ANOVA (PROC GLM; SAS Institute, 1996) to compare antler size (gross B&C score) of males using feed and males not using feed during summer with RANCH, AGE, FEEDUSE (0=no feed use detected; 1=feed use detected), and all possible interactions as independent variables. We did not include Ranch B in the analysis because of the low number of males harvested. Because of a significant RANCH*AGE interaction ($F_{3,113}=3.79$, $P=0.012$), we analyzed ranches A and C separately with AGE, FEEDUSE, and AGE*FEEDUSE as main effects. We used the LSMEANS statement (SAS Institute 1996) to estimate the effect of feed use on antler size, averaged across ages.

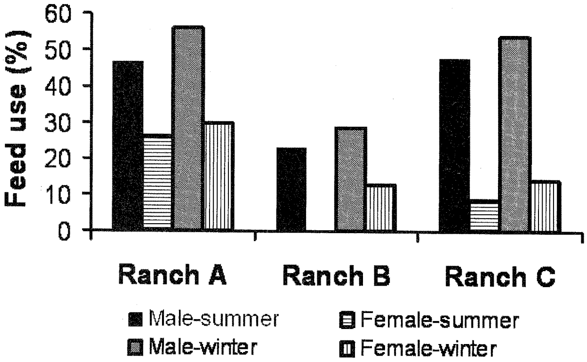

Figure 1. Percent of male and female white-tailed deer that consumed supplemental feed during summer 1999 and winter 1999–2000 on 3 ranches in southern Texas.

We used a 3-way factorial ANOVA to evaluate the effect of feed use on female body mass. Separate analyses were conducted for feed use in summer and winter with body mass as the dependent variable and RANCH, FEEDUSE, AGE, and all possible interactions as independent variables. We did not include Ranch B in the analysis because of the low percent of females that consumed feed. The LSMEANS statement in SAS (SAS Institute 1996) was used to estimate the effect of feed use on body mass when interactions were detected. We conducted a similar analysis for effects of feed use on male body mass. Analysis of male body mass was limited to Ranches A and C because of the small number of males harvested on Ranch B, and each ranch was analyzed separately because of a RANCH*FEEDUSE interaction for summer feed use ($F_{1,132}=6.06$, $P=0.015$) and a RANCH*AGE interaction for winter feed use ($F_{3,118}=2.69$, $P=0.049$). We used the LSMEANS statement (SAS Institute 1996) to estimate the effect of feed use on body mass, averaged across ages. Statistical tests were considered significant at $P<0.05$, although tests with $0.05<P<0.1$ are discussed. Type III sum of squares were used in ANOVA. Interactions are reported only if $P<0.05$. Means are given with standard errors.

Results

We obtained data from 82 males and 52 females harvested from Ranch A, 17 males and 82 females harvested from Ranch B, and 78 males and 62 females harvested from Ranch C. Supplemental feed use during summer ranged among ranches from 23–48% for harvested males and 0–27% for harvested females (Figure 1). Feed use by harvested males during winter ranged among ranches from 29–56%, while feed use was 13–30% for harvested females (Figure 1). The percent of deer harvested ≤1 km from a feeder ranged from 49% on Ranch B to 93% on Ranch C (Figure 2). Percent of deer harvested <100 m from a feeder ranged from 5% on Ranch B to 13% on Ranch C. Ranch A had the largest proportion of deer harvested >2 km from a feeder.

Summer use of supplemental feed

The model with AGE, SEX, DISTANCE, and AGE*SEX had the lowest AIC_c value (Tables 2, 3) in determining the probability of feed use by deer on Ranch A. The odds of feed use by males was 3.3 (CI =1.2–9.4) times greater than females at 3.5 years of age and 11.1 (CI=2.5–50.2) at ≥4.5 years of age

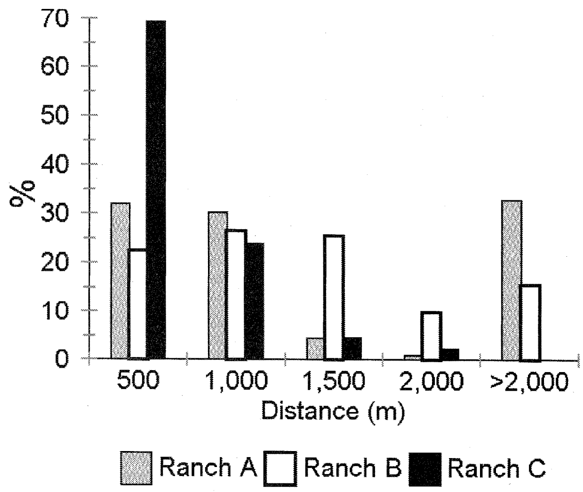

Figure 2. Percent of white-tailed deer harvested in 500-m intervals from a feeder (feeder nearest harvest location) on each of 3 ranches in southern Texas, during the 1999–2000 hunting season.

(Figure 3). The likelihood of feed use by deer ≤2.5 years old did not differ between males and females. With every km decrease between a harvest location and a feeder, the odds that deer consumed feed increased by a factor of 1.9 (CI=1.3-2.6).

We analyzed each sex separately for Ranch C because the model AGE, SEX, DISTANCE and all possible interactions had the lowest AIC_c value (Table 2). No model matched data well for females (relative likelihood of top two models=1.08, 95% CI of odds ratios of all variables in all models contained 1) probably because of the low number of females consuming feed (n=4). The model with the lowest AIC_c for males was AGE, DISTANCE, AGE*DISTANCE (Tables 2, 3), although most odds ratios from this model had low precision. The odds of feed use by older males were greater than younger males when harvested near feeders. Another way of interpreting the interaction is that the odds of males having used feed when harvested 1 km from a feeder compared to the odds of a deer the same age harvested at a feeder ranged from 10.9 (CI= 0.1-1131) for yearling deer, to 0.04 (CI = 0.003-0.53) for 3.5-year-old deer, and 0.0026 (CI= 0.0001-0.10) for ≥4.5-year-old deer.

Winter use of supplemental feed

The AGE, SEX, DISTANCE, and AGE*SEX model (Tables 2, 3) had the lowest AIC_c value for Ranch A during winter. The odds that males used feed relative to females increased from 10.1 (CI=2.6-37.9) at 3.5-years-old to 31.7 (CI=4.9-204.5) at ≥4.5-years-old (Figure 3). Confidence intervals for sex odds ratios at 1.5 and 2.5 years old contained 1. With every km decrease between a harvest location and a feeder, the odds that deer consumed feed increased by a factor of 4.3 (CI=2.4-8.0).

The model with SEX and AGE as independent variables had the lowest AIC_c for feed use during winter on Ranch C, but was essentially the same as the models containing SEX only, DISTANCE and

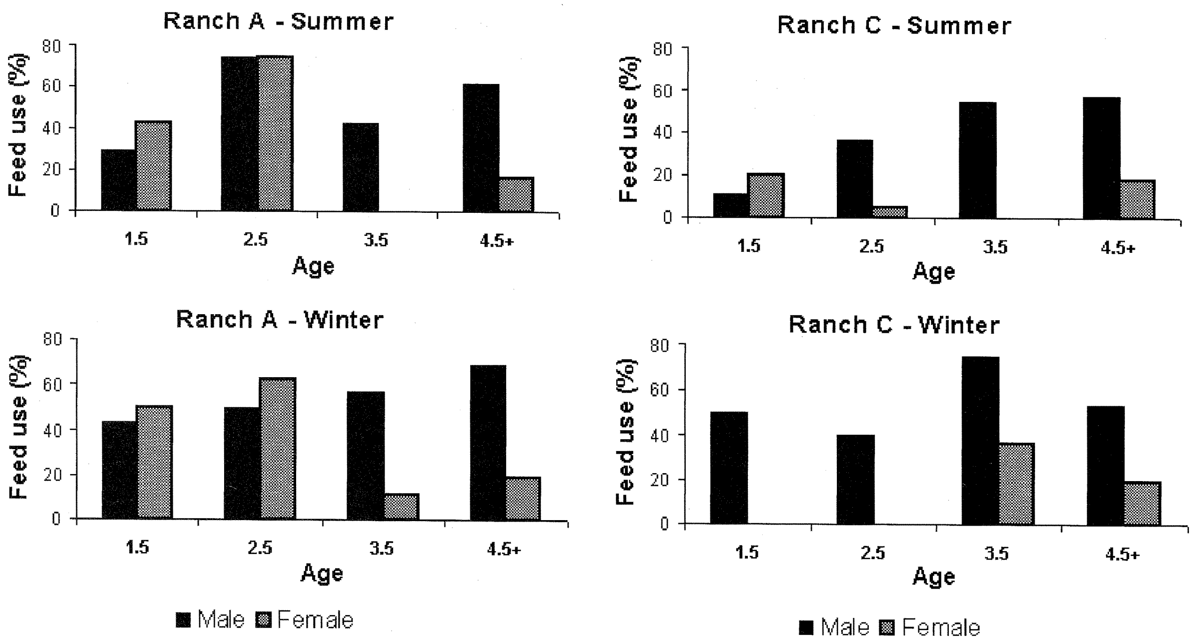

Figure 3. Percent of white-tailed deer that had consumed supplemental feed during summer 1999 and winter 1999–2000, by sex and age class (years of age), on 2 ranches in southern Texas.

Table 2. Logistic regression models with AIC_c simple differences (Δ_i) < 10 from the 18 models compared to predict use of supplemental feed by free-ranging white-tailed deer on 2 ranches in southern Texas during July–September 1999 (summer) and October 1999–January 2000 (winter).

Season		Ranch A				Ranch C			
Model[a]	K[b]	AIC_c	Δ_i	w_i	−2 Log L	AIC_c	Δ_i	w_i	−2 Log L
Summer									
FULL MODEL	8	131.13	5.79	0.02	113.65	103.78	0.00	0.33	86.45
AGE SEX DIST AGESEX DISTAGE DISTSEX	7	128.81	3.47	0.08	113.67	108.48	4.69	0.03	93.45
AGE SEX DIST AGESEX DISTAGE	6	126.58	1.24	0.23	113.73	106.36	2.58	0.09	93.60
AGE SEX DIST AGESEX DISTSEX	6	127.44	2.09	0.15	114.59	108.38	4.60	0.03	95.62
AGE SEX DIST DISTAGE DISTSEX	6	134.58	9.24	0.00	121.73	106.93	3.14	0.07	94.17
AGE SEX DIST AGESEX	5	125.34	0.00	0.43	114.74	107.27	3.48	0.06	96.73
AGE SEX DIST DISTAGE	5	132.69	7.34	0.01	122.09	104.91	1.13	0.19	94.37
AGE SEX DIST DISTSEX	5	134.29	8.95	0.00	123.69	107.34	3.55	0.06	96.79
AGE DIST SEX	4	132.28	6.94	0.01	123.88	105.93	2.15	0.11	97.58
AGE DIST DISTAGE	4	133.98	8.63	0.01	125.58				
AGE DIST	3	133.41	8.07	0.01	127.18				
DIST SEX DISTSEX	4	133.11	7.77	0.01	124.71	111.19	7.41	0.01	102.84
DIST SEX	3	131.08	5.73	0.02	124.84	110.19	6.40	0.01	103.98
DIST	2	131.99	6.65	0.02	127.87				
Summer[c]									
DIST AGE DISTAGE	4					69.52	0.00	0.88	60.83
DIST AGE	3					73.68	4.16	0.11	67.27
DIST	2					78.68	9.16	0.01	74.48
AGE	2					84.44	14.92	0.00	80.24
Winter									
FULL MODEL	8	95.54	5.06	0.03	78.11	116.39	7.58	0.00	98.77
AGE SEX DIST AGESEX DISTAGE DISTSEX	7	94.06	3.59	0.06	78.97	114.09	5.28	0.01	98.85
AGE SEX DIST AGESEX DISTAGE	6	92.60	2.12	0.13	79.78	112.01	3.19	0.03	99.08
AGE SEX DIST AGESEX DISTSEX	6	91.85	1.38	0.18	79.04	111.78	2.97	0.03	98.86
AGE SEX DIST DISTAGE DISTSEX	6	95.93	5.46	0.02	83.12	113.33	4.51	0.02	100.40
AGE SEX DIST AGESEX	5	90.48	0.00	0.36	79.90	109.76	0.94	0.09	99.10
AGE SEX DIST DISTAGE	5	95.81	5.34	0.03	85.23	111.11	2.30	0.05	100.46
AGE SEX DIST DISTSEX	5	94.57	4.09	0.05	83.99	111.07	2.25	0.05	100.41
AGE DIST SEX	4	94.73	4.25	0.04	86.35	108.91	0.10	0.14	100.48
DIST SEX DISTSEX	4	94.61	4.14	0.05	86.23	111.05	2.24	0.05	102.62
DIST SEX	3	94.14	3.67	0.06	87.92	108.89	0.08	0.14	102.64
AGE SEX AGESEX	4					109.77	0.95	0.09	101.34
AGE SEX	3					108.81	0.00	0.15	102.56
SEX	2					108.89	0.08	0.14	104.76

[a] Variables were AGE (1.5, 2.5, 3.5, ≥4.5 years of age), SEX (0 = female and 1 = male), DIST (distance in km between a deer's harvest location and the nearest feeder).

[b] K = number of parameters in the model, including the intercept. AIC_c = Akaike Information Criterion, corrected for sample size. w_i = Akaike weights, calculated with all 18 models tested, even those not shown in the table.

[c] Models for males only because of AGE*SEX*DIST interaction when both genders were in the model.

SEX, and AGE, SEX, DISTANCE (Tables 2, 3). Because SEX is the one variable common to all these models, the greater use of supplemental feed by males compared to females (Figure 3) is the important factor in all these models. The odds of males using feed was 8.6 (CI=3.1–24.1) times that of females in the model with SEX and AGE. In the other models, the odds ratio ranged from 7.9 (CI=2.8–22.4) to 8.9 (CI=3.2–24.7).

Effects of feed use

Antler size of males that consumed feed during summer on Ranch A increased an average of 27.8± 12.9 cm ($F_{1,50}$=4.83, P=0.033; Figure 4) over males

Table 3. Coefficients and standard errors for parameters in logistic regression models with the lowest AIC_C, and percent concordance for each model, used to predict use of supplemental feed by free-ranging white-tailed deer on 2 ranches in southern Texas during July–September 1999 (summer) and October 1999–January 2000 (winter).

	Ranch A				Ranch C			
	Summer		Winter		Summer[a]		Winter	
Model Parameter[b]	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	2.597	1.261	2.530	1.346	−5.168	2.011	−3.022	0.877
AGE	−0.761	0.371	−0.487	0.379	1.755	0.556	0.323	0.22
SEX	−2.998	1.4	−1.719	1.565	c		2.151	0.526
DISTANCE	−0.620	0.169	−1.471	0.309	6.554	3.903		
AGE*SEX	1.201	0.42	1.15	0.475				
AGE*DISTANCE					−2.776	1.127		
Percent concordance	79.7		92.2		84.9		72.2	

[a] Model applies to males only because a significant AGE*SEX*DISTANCE interaction required males and females to be analyzed separately and no model matched the data well for females.

[b] Units for parameters were AGE, 1.5, 2.5, 3.5, ≥4.5 years of age; SEX, 0 = female and 1 = male; DISTANCE between a deer's harvest location and the nearest feeder in km.

[c] Blank cells indicate that parameter or interaction was not in the model with the lowest AIC_C score.

that did not consume feed. We excluded the 2.5-year-old age class from this analysis because all males of that age consumed feed during summer. There was evidence of an AGE*FEEDUSE interaction ($F_{2,50}=2.41$, $P=0.101$; Figure 4), suggesting that most of the effect came from 3.5-year-old deer, which had 67.3±30.6 cm increase in antler size when consuming feed. Feed use did not affect antler size in males on Ranch C ($F_{1,61}=2.15$, $P=0.147$, Figure 4).

There was an AGE*FEEDUSE interaction ($F_{2,84}=2.95$, $P=0.058$) in the effect of feed use on female body mass. Body mass was 11.1±5.70 kg greater in 2.5-year-old females that used feed during summer than females that did not. Feed use during summer did not influence female body mass at other ages ($P>0.181$). Body mass of females was not affected by feed use during winter ($F_{1,80}=0.50$, $P=0.484$). Averaging across ages, males on Ranch A that consumed feed during summer and males that consumed feed during winter weighed 4.7±1.8 kg ($F_{1,69}=6.90$, $P=0.011$) and 7.5±2.1 kg ($F_{1,72}=12.74$, $P<0.001$) more, respectively, than males that had not consumed feed (Figure 5). We excluded the 2.5-year-old age class from the summer analysis because all males of that age had consumed feed during summer. On Ranch C males that consumed feed during summer were 11.0±2.6 kg heavier ($F_{1,61}=19.5$, $P<0.001$) and males that consumed feed during winter were 6.4±2.4 kg heavier ($F_{1,46}=7.71$; $P=0.008$; Figure 5) than males that had not consumed feed.

Discussion

The goal of many southern Texas deer management programs that provide pelleted feed is to increase fawn production of females and body and antler size of males. If supplemental feed is to increase productivity at the population scale, a large portion of the deer herd must consume feed. Our results indicate that the proportion of female deer using feed is low and fawn production may not increase dramatically as a result of feeding programs. The proportion of males that consumed feed was greater than that of females and was >50% in males ≥4.5 years old during summer when antlers were growing. Thus, a large enough proportion of mature males may be consuming feed to influence antler size, assuming deer eat enough feed to improve their nutritional status and forage resources are poor quality relative to supplemental feed. These prerequisites appeared to have been met on Ranch A, where males that consumed feed had larger antlers than males that had not. Ozoga and Verme (1982) reported increased antler size with supplemental feeding of an enclosed white-tailed deer herd. However, Schultz and Johnson (1992) found no increases in antler development of free-ranging white-tailed deer using mineral licks. These differing results suggest that benefits of supplemental feed vary with location and type of supplement.

The lack of a consistent effect of feed use on body mass of females may have been due to the low feed use by females on all ranches. Furthermore, females may not increase body mass with supplementation if additional nutrients are used to support increased reproductive effort, such as larger litter mass or greater milk production. Differences between the sexes in the effect of feed use on body mass may occur because reproductive fitness of male cervids is likely to benefit more than females

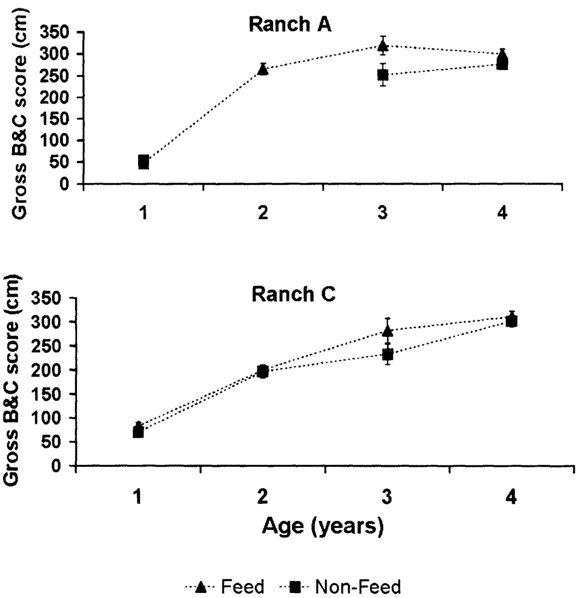

Figure 4. Mean (SE) antler size (Boone and Crockett Score [B&C score]) by age class (years of age) for male white-tailed deer that consumed supplemental feed during summer and that had not consumed feed on 2 ranches in southern Texas, 1999. Points in which SE bars are not visible either had small SE or were based on antler size of one deer (1 point).

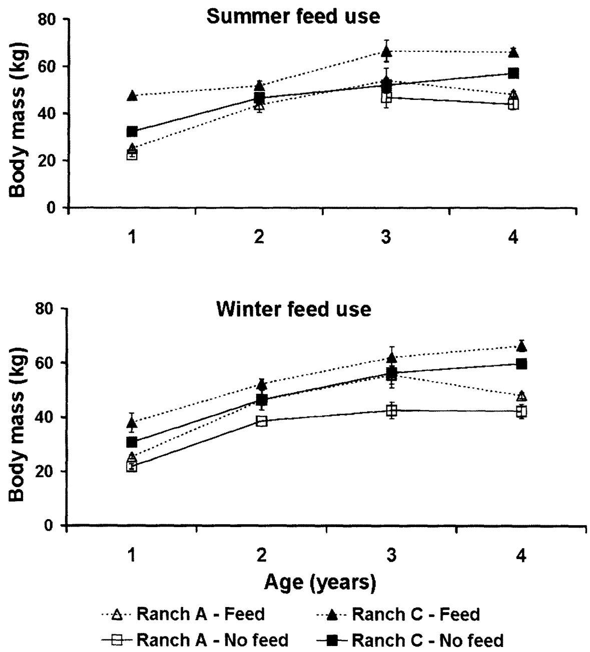

Figure 5. Mean (SE) body mass by age class (years of age) for male white-tailed deer that consumed supplemental feed during summer (top) and winter (bottom) and not consumed feed on 2 ranches in southern Texas, 1999. Points in which SE bars are not visible either had small SE or were based on weights of one deer (2 points).

from use of excess nutrients to increase body mass. Our results support reports by Ozoga and Verme (1982) and Johnson et al. (1987) that showed increased body mass of males using pelleted feed and food plots, respectively. The former study also found increased body mass of females, a finding that differs from our study. Johnson and Dancak (1993) and Schultz and Johnson (1992) showed no increases in deer body mass in areas with food plots or mineral licks, respectively. These varying results again suggest that the effect of supplementation varies with location and type of supplement.

Our objective was to estimate the proportion of a deer herd that consumed supplemental feed, and we obtained our sample using hunter-harvested deer. Because of the large number of female deer harvested on these ranches, there was little selection for individual females in the harvest. Males with medium and large antlers were harvested as trophies on these ranches, and mature males with small antlers were often harvested to free resources and breeding opportunities for larger males. Thus, there was not selection solely for large- or small-antlered mature males. Yearling male deer with small antlers were more likely to be harvested on these ranches than yearlings with large antlers. If antler size in yearling deer is increased through the use of supplemental feed, there was potential for selection against yearling deer that use supplemental feed. Thus, additional study may be warranted to assess our finding that older males appear more likely to use supplemental feed than younger males.

Differences between male and female use of supplemental feed may be partially explained by dominance hierarchies (Ozoga and Verme 1982). Males are generally dominant over females (Hirth 1977, Townsend and Bailey 1981) and are more likely to win interactions at feeding sites (Ozoga 1972, Schenbeck 1975, Grenier et al. 1999). The increase in feed use with age in males also suggests that dominance interactions at feeders were important. At feeding sites, large males dominate smaller males, and adult females may displace yearling males (Schenbeck 1975). Although we did not measure behavioral interactions, greater use of feed by adult males is consistent with the hypothesis that social interactions contributed to patterns of feed use we observed. It is inconsistent with the hypothesis that differences in nutrient requirements caused the patterns we observed because lactating female deer would be expected to have the highest nutrient requirements during summer

Social interactions at feeding sites may influence which animals in a deer herd are able to gain access to supplemental feed.

(Robbins 1993, Parker et al. 1999) and intake rate of male deer typically declines during the rut (Parker et al. 1999), which occurred from late October to late December in our study areas (Williams et al. 1995). Competition at feeding sites would be expected to be lower when feed is available ad libitum because subordinate deer would be able to consume feed when dominant deer were not present. Competition should also be decreased by increased feeder density, but the density of feeders necessary is unknown. A low density of feeders was cited as the reason supplemental feed use was lower than predicted during winter in Ontario (Schmitz 1990).

Distance of harvest location from the nearest feeder was a significant variable in predicting the likelihood that deer had consumed feed. With the exception of yearling males on Ranch C during summer, the likelihood of feed use declined as deer were harvested farther from feeders. Because yearling males in southern Texas may disperse 2–14 km from their natal ranges during rut (McCoy 2001), yearling males may be harvested at sites different from sites used during summer before dispersal. This may be one reason yearling male deer on Ranch C did not show a strong relationship between distance from a feeder and probability of feed use.

One implication of distance being an important factor in predicting supplemental feed use by free ranging white-tailed deer is that a greater density of feeders should decrease the average distance between the harvest location and feeder and thus should increase the proportion of the population that consumes feed. Using the logistic model for Ranch A during summer (Table 3) and decreasing the distance between harvest location and the nearest feeder from 1 to 0.25 km increased the probability of a 3.5-year-old male consuming feed from 0.63 to 0.73 and increased the probability of a 3.5-year-old female consuming feed from 0.33 to 0.43. During winter the same change in distance between a deer's harvest location and the nearest feeder increased the males' probability of consuming feed from 0.84 to 0.94 and the females' probability from 0.34 to 0.61. However, the probability of feed use when DISTANCE was 0 km approached 1.0 (0.86–0.98) only for males >4.5 years of age and males of all ages during winter on Ranch A. Even at high feeder densities, there may be a portion of a free-ranging deer population that is unlikely to use pelleted feed. This is consistent with observations of biologists managing free-ranging deer herds who routinely see deer during census and hunting activities that were not observed or photographed at feeders.

Interactions among RANCH and other variables in several of our analyses suggest that results of a feeding program in one location may be a poor predictor of supplemental feed effects in another location (Tarr and Pekins 2002). Ranches in our study varied in feeder density, type of feeder, rainfall, and possibly forage resources. Ranch A had the poorest forage resources because the sandy soils supported little shrub cover and forbs were abundant for only a short time after rainfall, which was infrequent. Ranch B had better forage resources than Ranch C because of higher average rainfall and more productive soils. Poorer natural forages, moderate feeder density, and feeders in which food was available ad libitum meant that positive effects of feeding were most likely to be seen on Ranch A, which appeared to be the case. We were unable to draw conclusions about the importance of each of these factors on the proportion of deer that used feed and the effects of feed on productive processes because these factors were confounded.

Supplemental feeding of white-tailed deer is becoming more prevalent throughout the white-tailed deer's range. As interest in supplemental feeding increases, there will be pressure to increase the efficiency of feed-delivery systems. Our data suggest that under various combinations of forage quality, feeder type, and feeder density, <60% of males and ≤30% of females used supplemental feed. If this pattern of feed use is representative, managers may reasonably expect supplemental feed to benefit a portion of mature males, but should not expect large increases in fawn production because female use of feed is low. We found evidence that supplemental feed can increase antler size and male body mass. These results will help managers set realistic expectations for a supplemental feeding program and may help guide refinements in feed delivery systems.

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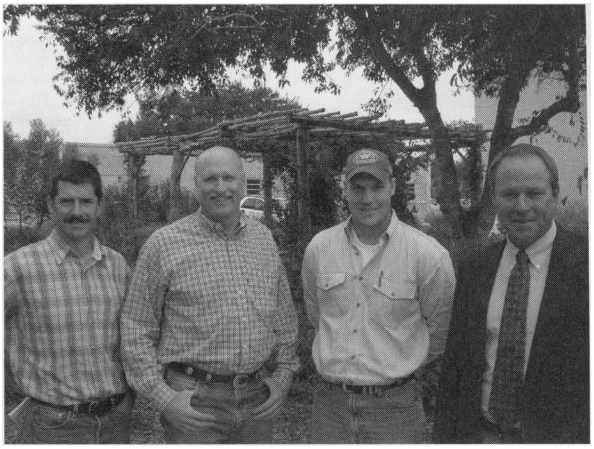

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