

Condition and Diet Quality of White-tailed Deer in Response to Vegetation Management in Central Oklahoma

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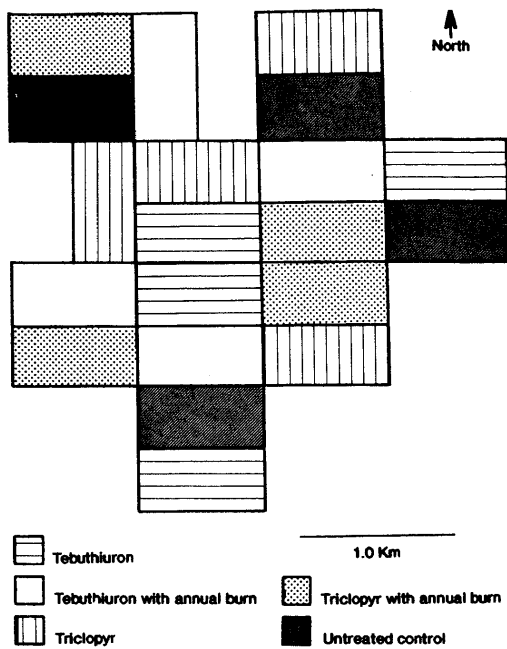
We examined the effects of woody vegetation management using herbicide and fire on condition and diet quality of white-tailed deer (*Odocoileus virginianus*) in the cross timbers of central Oklahoma. Condition of deer was assessed seasonally (1987-1989) on an area containing a mosaic of habitat types created by various brush removal treatments and on a control area not exposed to any such treatments. Five treatments were used on the Cross Timbers Experimental Range (CTER): tebuthiuron, tebuthiuron with an annual spring burn, triclopyr, triclopyr with an annual spring burn, and untreated habitat. Deer carcass weights were significantly higher on the CTER than on untreated areas; no differences were detected in any morphological or reproductive parameters examined. Concentrations of nitrogen in postmortem feces and rumen digesta of animals collected in spring were higher on untreated control than CTER study areas. Concentrations of nitrogen and acid detergent fiber in feces differed significantly among seasons and study areas, reflecting higher-quality diets on the CTER than on untreated control areas. Differences among study areas were also noted for concentrations of insoluble and soluble nitrogen in feces. Variable herbicide patterning positively influenced the quality of diets available to white-tailed deer, but had minimal influence on physical condition.

INTRODUCTION

The cross timbers land resource area is a western extension of the Ozark plateau, oak-hickory ecosystem and accounts for approximately 19 million ha of land in the central United States (1,2). Livestock production on these oak-dominated rangelands is relatively poor owing to low production of herbaceous forage (3). Brush management programs that selectively remove unwanted woody species and increase herbaceous forage production can often benefit both white-tailed deer (*Odocoileus virginianus*) and livestock (3,4). Improved cattle and deer production after removal of woody vegetation has promoted use of herbicides and fire on rangeland in the cross timbers area (5-8).

Effects on white-tailed deer of a variety of brush management strategies using herbicides and fire have been examined in a variety of habitat types. Initial improvements in browse and forb production have been demonstrated following applications of 2,4,5-T, picloram, 2,4-D, tebuthiuron, triclopyr, and glyphosate (9,10). However, behavioral and population responses of white-tailed deer to herbicide-induced vegetation changes varies considerably and appear to be dependent on habitat type (11-14). Little has been reported on nutritional and physiological responses of deer to brush management.

We initiated studies in 1987 to evaluate the impact of a brush management strategy utilizing variable herbicide patterning and prescribed burning on diet quality and condition of white-tailed deer on cross timbers rangeland in Oklahoma. Variable herbicide patterning (VHP) is a modification of the "variable rate patterning" (15) approach to brush management, where two or more dosages of a single herbicide are applied to alternating strips or blocks of vegetation to create a diversity of vegetation types. The rationale behind VHP is that because commonly used brush herbicides are readily available and vary considerably with respect to efficacy and selectivity (16), two or more herbicides may be used on alternating strips or blocks of vegetation to create a diverse mosaic of habitat types. In this study we examined seasonal changes in diet quality and physical condition of white-tailed deer exposed to variable herbicide patterning with



tebuthiuron and triclopyr used in combination with annual prescribed burning.

METHODS

Study area: Our study was conducted on the Cross Timbers Experimental Range (CTER), Payne County, Oklahoma (36°2' to 36°4' N, 97°9' to 97°11' W). The CTER, a 648-ha research area, was established in 1983 to compare vegetation, livestock, and wildlife responses to brush management. Two control sites, Ham's Lake Research Area (HLRA) and Zoological Research Area (ZRA), are located 13 and 9 km west of Stillwater, respectively. All three research areas are located in the western cross timbers forest and occupies a rugged landscape dissected by stream drainages with steep slopes. Soils of the region were described by Gray and Stahnke (17), and a pre-treatment vegetation inventory of the area was completed in 1982 (18).

Upland hardwood forest, dominated by blackjack (*Quercus marilandica*) and post oak (*Quercus stellata*), is the primary vegetation type on coarse-textured soils, although prairie is interspersed on fine-textured soils (18). Upland forest, prior to treatment, varied from an open hardwood overstory

with a productive herbaceous understory to a completely closed overstory with negligible understory production. Bottomland forest occupies a rather restricted position along drainages. Understory species were dominated by coralberry (*Symphoricarpos orbiculatus*), eastern red cedar (*Juniperus virginiana*), poison ivy (*Rhus radicans*), rough-leaf dogwood (*Cornus drummondii*), redbud (*Cercis canadensis*), and American elm (*Ulmus americana*). Dominant herbaceous vegetation included little bluestem (*Schizachyrium scoparium*), Indian grass (*Sorghastrum nutans*), western ragweed (*Ambrosia psilostachya*), and rosette panicgrass (*Panicum oligosanthos*) (18).

Variable herbicide patterning: A mosaic of five habitat types was created on the CTER by using two-herbicide patterning, in combination with or without annual prescribed burning, and interspersed with untreated habitats. The CTER was divided into 20 adjacent, fenced 32.4-ha pastures, and 4 replications each of 5 different brush treatments were randomly applied to differing pastures on the study area (Fig. 1). The 5 brush treatments included: 1) tebuthiuron (*N*-[-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-*N,N'*-dimethylurea); 2) tebuthiuron in conjunction with an annual spring burn; 3) triclopyr ([[(3,5,6-trichloro-2-pyridinyl)-oxy]acetic acid); 4) triclopyr application with an annual prescribed burn; and 5) untreated control. Each herbicide was applied aerially at a rate of 2.2 kg/ha (tebuthiuron in March and triclopyr in June 1983) and annual prescribed burning in April 1985-87. The mosaic created by variable herbicide patterning was available to all deer since fences did not hinder their movements.

Vegetation responses to tebuthiuron and triclopyr applications, with and without prescribed burning, on the CTER have been reported previously (10,19). Briefly, tebuthiuron habitats possessed little overstory, dense herbaceous cover, and little woody understory; triclopyr habitats contained little overstory with moderate amounts of herbaceous cover and a dense understory of resprouting woody species; and untreated habitats were characterized by a dense woody canopy with little herbaceous cover and moderate amounts of woody understory (10,19). Annual prescribed burning was effective at suppressing cover of eastern redcedar and improving nutritional quality of

selected herbaceous forages (20).

Evaluation of animal condition: Fecundity and general condition of deer on CTER were compared to those on ZRA in March from 1987 to 1989. Five adult does (3 collected on ZRA in 1987) were collected annually from each study area using a spotlight and a high-powered rifle. Blood samples for hematologies were obtained within 5 min of death by cardiac puncture into 3-ml Vacutainer tubes, containing EDTA-K₂ as an anticoagulant, and placed on ice. Rumens were injected with a 10% solution of mercuric chloride (HgCl₂) to stop microbial fermentation. Deer were transported to the laboratory for postmortem evaluation.

Hematocrit and hemoglobin concentration were determined within 6 h as described previously by Lochmiller et al. (21). Body weight was recorded to the nearest 0.5 kg using a standard spring scale and age was determined by tooth eruption and wear (22). Spleen, paired adrenal glands, thymus, kidneys, kidney fat, and uterus were removed, trimmed of excess fat and connective tissue, and weighed to the nearest 0.01 g. Kidney fat index was calculated as described by Rinney (23). Femur marrow fat was estimated by the oven-dry method at 50 °C (24). Fetuses were enumerated, age determined (25,26), and conception date calculated by back dating (27).

Postmortem subsamples, of digesta from the rumen (mixed prior to sampling) and feces from the rectum were obtained from each animal to assess recent dietary quality. Subsamples of rumen digesta and feces were oven dried (50°C) and ground with a Wiley-Micro mill to pass through a 1- mm mesh screen. These were analyzed for neutral detergent fiber (NDF) and acid detergent fiber (ADF) using the procedures of Goering and Van Soest (28). Concentration of total nitrogen was determined by the Kjeldahl procedure (29). Insoluble nitrogen (fiber-bound, indigestible nitrogen) was determined by analyzing for residual nitrogen after removal of acid detergent solubles (30). Concentration of soluble nitrogen was calculated as the difference between total and insoluble nitrogen concentrations.

Seasonal evaluation of dietary quality: We indirectly monitored seasonal changes in the nutritional quality of diets of whitetailed deer on each of the three study areas using fecal indices (31,32). Fecal pellet groups were collected in winter (January), spring (April), summer (July), and fall (October) from winter 1988 to summer 1989. Because deer could not be observed defecating, we collected feces that appeared fresh (33). A minimum of 15 fecal groups were collected from each study area and combined for analysis (34). Five composites (1 composite of 15 fecal groups per habitat type on the CTER) were compared to 5 composites each from the ZRA and HLRA for each season. Composited fecal samples were analyzed for total nitrogen, soluble nitrogen, insoluble nitrogen, and ADF concentrations as previously described for postmortem samples.

Statistical analysis: Differences in morphological indices of condition between study areas (CTER, ZRA) were examined by using a one-way analysis of covariance with body weight as the covariate; differences in body and carcass weight were examined using age as a covariate. Differences in indices of dietary quality (total nitrogen, soluble nitrogen, insoluble nitrogen, NDF, ADF) of postmortem rumen and fecal samples were analyzed by using a two-way analysis of variance with year and study area (CTER, ZRA) as the independent variables. If significant interactions were indicated, differences between study areas were analyzed by year for that variable. Indices of diet quality (total nitrogen, soluble nitrogen, insoluble nitrogen, ADF) from seasonal fecal collections were analyzed for differences among study areas (CTER, ZRA, HLRA) within each season using a one-way analysis of variance. Hartley's F-Max test was used to test for homogeneity of variances among study areas (35). Variables with heterogeneous variances (kidney fat index, ruminal nitrogen, and fecal insoluble nitrogen) were rank-transformed prior to analysis (36). Protected multiple comparisons (LSD) were used when analysis of variance rejected the null hypothesis that study areas were similar. The Statistical Analysis System (SAS) was used for all data analyses (37).

RESULTS

Animal collection: Twenty-six adult female deer were collected from 1987-89 from the ZRA ($n = 13$) and the CTER ($n =$

13). Brush management on the CTER had a significant ($P < 0.05$) influence on carcass weight of adult does which averaged about 2 kg heavier on the CTER than the ZRA (Table 1). Body weight and weights of uterus, adrenal glands, thymus gland, and spleen did not differ ($P > 0.05$) between CTER and ZRA. Femur fat and kidney fat indices were higher in deer collected on the CTER than ZRA, but differences were not ($P > 0.05$).

Measurements of fecundity indicated that variable herbicide patterning had no influence on reproduction of adult does (Table 1). Mean conception date, proportion of does pregnant, and number of fetuses/doe were similar between study areas.

Packed cell volume and hemoglobin concentrations averaged 43.96 and 16.12%, respectively, and were not influenced ($P > 0.05$) by brush management (Table 1). Postmortem concentrations of total nitrogen and NDF in rumen digesta showed significant ($P < 0.05$) annual fluctuations, and a significant ($P < 0.05$) interaction between year and habitat type was indicated. Total nitrogen was lower and NDF was higher ($P < 0.005$) in rumen digesta of deer collected from the CTER ($< x > = 2.52 \pm 0.23\%$, and $60.67 \pm 2.87\%$) compared to ZRA ($3.81 \pm 0.17\%$, and $48.24 \pm 1.50\%$, respectively) ($\pm N = SE$) in 1988, but not in other years. Concentrations of insoluble nitrogen in rumen digesta was significantly ($P < 0.05$) lower on the CTER than the ZRA. Concentrations of soluble nitrogen did not differ ($P > 0.05$) between study areas (Table 2).

Differences among years were not significant ($P > 0.05$) for mean concentrations of total nitrogen, ADF, or soluble nitrogen in postmortem feces (Table 2). Concentrations of total nitrogen in feces of collected deer tended to be lower ($P = 0.055$) on the CTER than the ZRA. Mean concentration of ADF was significantly ($P < 0.001$) higher on CTER than the ZRA. Brush management had no significant influence ($P > 0.05$) on soluble and insoluble nitrogen concentrations in feces (Table 2).

TABLE 2. Nutritional indexes of rumen and fecal samples taken from adult white-tailed deer on the Cross Timbers Experimental Range (CTER) and the Zoological Research Area (ZRA) in the spring of 1987-89.

Variable (x) ^a	Study area					
	CTER			ZRA		
	n	<x>	SE	n	<x>	SE
Rumen content						
Nitrogen	12	3.35	0.24	12	4.10	0.20
NDF	12	53.00	2.38	13	47.18	0.94
ADF	12	35.62	1.68	13	31.52	1.23
Insoluble N ^b	11	0.46	0.04	13	0.64	0.06
Soluble N ^b	11	3.00	0.23	13	3.46	0.19
Feces						
Nitrogen	12	2.55	0.18	13	2.94	0.21
ADF	12	48.12	1.77	13	39.02	1.58
Insoluble N ^b	13	0.54	0.02	13	0.55	0.04
Soluble N ^b	13	2.02	0.11	13	2.39	0.18

^a All values of x and SE are %.

^b N = nitrogen.

TABLE 1. Comparisons of morphological, physiological, and reproductive indices of condition in adult female white-tailed deer collected on the Cross Timbers Experimental Range (CTER) and Zoological Research Area (ZRA) in March of 1987-1989.

Variable (x)	Study area					
	CTER			ZRA		
	n	<x>	SE	n	<x>	SE
Packed cell						
volume (%)	13	45.22	1.50	13	42.63	2.16
Hemoglobin (g/dl)	8	15.16	1.92	8	17.09	0.06
Femur marrow						
fat (%)	13	72.31	6.11	13	69.98	4.71
Kidney fat (%)	13	27.22	7.49	13	17.33	2.77
Does pregnant ^a	13	100.00	--	13	92.00	--
Fetuses/doe	13	1.93	0.18	13	2.00	0.25
Body weight ^b	13	49.78	1.83	13	48.83	2.23
Carcass weight ^b	13	37.53	1.94	13	35.45	1.40
Uterus ^c	13	413.81	43.47	13	489.14	87.50
Ovaries ^b	13	1.84	0.36	13	1.54	0.16
Adrenal glands ^c	13	4.11	0.41	13	4.23	0.39
Thymus gland ^c	11	16.12	3.45	11	18.58	3.45
Spleen ^c	13	221.79	20.51	11	254.33	17.77

Units: ^a %; ^b mass in kg; ^c mass in g.

Seasonal monitoring of diet quality: Concentrations of total nitrogen, soluble nitrogen, insoluble nitrogen, and ADF in feces differed significantly ($P < 0.05$) among seasons (Fig. 2). All nitrogen parameters measured were highest in concentration in spring and lowest in winter; however concentrations of ADF were highest in winter and lowest in summer.

Differences in fecal indices of diet quality were indicated between brush-treated and untreated control study areas (Fig. 2) Concentrations of total and soluble nitrogen in feces were significantly greater ($P < 0.05$) on the CTER than both untreated control areas in fall and ZRA in winter. There were no significant differences ($P > 0.05$) in con-

centrations of insoluble nitrogen between the CTER and untreated areas for any season, but levels were higher ($P < 0.05$) on the HLRA than ZRA in spring. Concentrations of ADF in feces of deer collected from the CTER were significantly ($P < 0.05$) lower than both untreated areas in fall, but were significantly higher ($P < 0.001$) than HLRA in winter. All other seasonal comparisons between study areas were not significant ($P > 0.05$).

DISCUSSION

Variable patterning of herbicide applications created a series of different habitat types on the CTER. Herbicides were applied to reduce overstory dominance of post oak and blackjack oak. As a result of these treatments and their respective herbaceous responses, the mosaic created on the CTER was comprised of open areas containing grasses and forbs, areas with high cover and browse production, and patches of typical cross timbers habitat. McCollum et al. (20) noted that the burn treatments used on the CTER caused increased weight-gain in cattle.

Morphometric parameters such as body weight, carcass weight, kidney fat index, femur marrow fat, and metabolically active organ weights can be used to assess body condition in white-tailed deer populations (38). Kie (39) demonstrated that eviscerated carcass weight, and other morphological and physical parameters were useful indices for comparing the relative condition of white-tailed deer between high and low density populations in Texas. Similar morphometric parameters of condition were used by Hesselton and Sauer (40) to assess the relative condition of four deer herds in New York. Eviscerated carcass weight is a less variable indicator of condition than body weight and is thought to reflect protein intake on a long-term basis (41-43).

Greater carcass weights of white-tailed deer collected on the CTER suggests that variable herbicide patterning provides longterm improvements in nutrition in comparison to untreated study areas. Increased forage production was observed during the

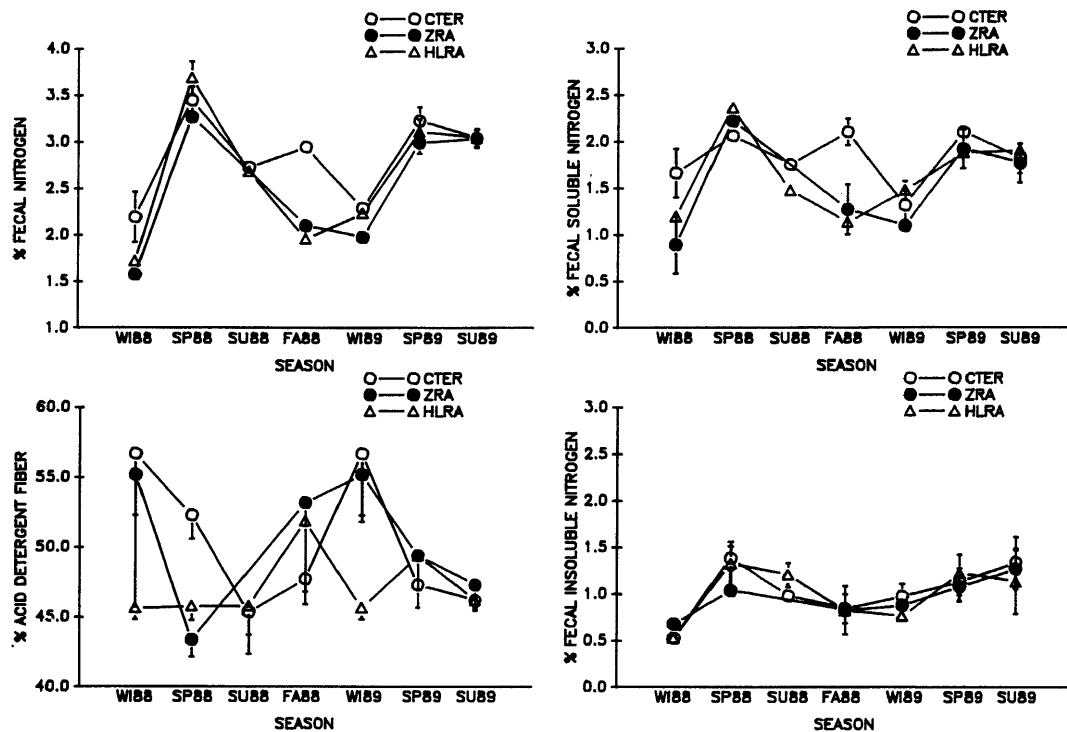


Figure 2. Concentrations of selected nutritional parameters ($\pm SE$) of feces collected seasonally from the Cross Timbers Experimental Range (CTER), Zoological Research Area (ZRA), and Ham's Lake Research Area (HLRA) from winter 1988 to summer 1989.

first two years post-treatment but declined over time (44) (Fig. 3). Tanner et al. (45) observed that white-tailed deer were often attracted to new succulent woody growth following application of herbicides in Texas. Deer density was not determined in our study.

Nutritional quality of the habitat and diets of white-tailed deer are frequently assessed indirectly by determining concentrations of selected nutrients in feces and rumen digesta. Leslie and Starky (31) found a strong correlation between dietary nitrogen and fecal nitrogen concentrations. High concentrations of nitrogen in feces (31) and ruminal nitrogen (45) are associated with a high-quality diet whereas high concentrations of fiber components are indicative of poor-quality forage (46). Kie (47) effectively used ruminal concentration of crude protein to make relative comparisons of diet quality between two populations of white-tailed deer in Texas. Ruminal concentrations of nitrogen have also been used to index range quality for sitka black-tailed deer (*Odocoileus hemionus sitkensis*) in southwest Alaska (48). Fecal soluble nitrogen is thought to reflect dietary quality because it indexes soluble nitrogen from dietary and other endogenous sources (49).

Indices of diet quality fluctuated greatly across seasons on both brush-treated and untreated study areas. Differences among seasons undoubtedly reflected changes in food habits of white-tailed deer, as demonstrated by Van Vreede (49) on cross timbers rangeland in south central Oklahoma. Diets in this region are typically dominated by woody browse and mast in fall and winter, and forbs in the spring and summer. Comparisons of fecal indices (total nitrogen, soluble nitrogen, and ADF) of diet quality indicated that nutritional conditions were relatively better on the CTER than untreated study areas in fall and winter. Digestibility and concentrations of crude protein in coralberry (*Syphoricarpus orbiculatus*), greenbriar (*Smilax* spp.), hackberry (*Celtis* spp.), blackberry (*Rubus* spp.), and elm (*Ulmus* spp.) were greater on herbicide-treated habitats than untreated areas on the CTER (50) in fall and winter. Similar improvements in the quality of browse were documented by Bogle et al. (51) following applications of tebuthiuron and fire. Improvements in the nutritional quality of diets from fall to winter could have accounted for greater eviscerated carcass weights of white-tailed deer observed on the CTER compared to untreated areas. Fecal indices indicated higher-quality diets on the CTER in fall and winter did not persist into spring and summer when diets of deer typically shift to succulent forbs (49). This observation was largely supported by postmortem fecal and rumen digesta analyses as well.

Variable herbicide patterning increased the nutritional quality of white-tailed deer diets. Although these advantages may only be manifested in long-term benefits (i.e. carcass weight), alterations to habitat by variable herbicide patterning can be used to positively influence white-tailed deer habitat. Topography, soil type, and geology of an area relative to type of patterning should be considered before herbicide application.

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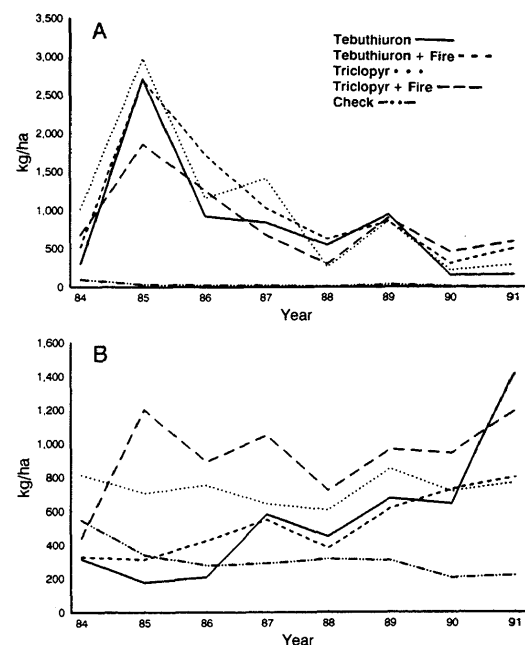


Figure 3. Annual standing crop (kg/ha) of (A) forb and (B) browse biomass on the two most dominant soil types within each experimental brush treatment on the Cross Timbers Experimental Range.

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