Wildlife Session

Using Condition Indicators to Evaluate Habitat Quality for White-tailed Deer

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Abstract: We examined the usefulness of condition profiles, incorporating postmortem morphologic, physiologic, and dietary indices from fall-harvested deer and seasonal fecal indices of diet quality, for evaluating differences in habitat quality between adjacent populations of white-tailed deer (*Odocoileus virginianus*). This study was conducted on East Range (4.5% of 12,000 ha cultivated) and West Range (0.8% of 18,000 ha cultivated), Fort Sill Military Reservation, southwestern Oklahoma, from November 1987 to August 1989. Analysis of postmortem blood and digesta samples revealed that deer collected from East Range consumed higher quality diets than deer from West Range, where cultivation was lower. Seasonal analyses of fecal nitrogen and cell-wall constituents supported observed differences in postmortem samples. Our study indicates that morphological indices were not sensitive to the apparent differences in habitat quality between the 2 ranges. However, physiological and dietary indices may provide wildlife managers a practical and sensitive means for early detection of changes in habitat quality.

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Numerous techniques for directly assessing the condition of white-tailed deer and indirectly assessing the nutritional quality of their range have been developed (Brown 1984). Internal and external morphological measurements (Kie et al. 1983), physiological indices (Seal et al. 1978*a*, Warren et al. 1981), as well as a variety of hematological parameters (Rosen and Bischoff 1952) have been suggested for assessing the condition of deer. Indices for assessing recent nutritional history of deer include analyses of nutrient or plant cellular components of rumen contents (Kirkpatrick et al. 1969) and feces (Leslie and Starkey 1985).

Although a number of indices have been suggested to assess condition of white-tailed deer, few examples of their practical application in the management of wild populations exist in the literature. This study was initiated to test the hypothesis that condition profiles of white-tailed deer that incorporate corollary comparisons of morphologic, physiologic, and nutritional indices (Waid and Warren 1984) are sensitive to differences in habitat quality. We tested this hypothesis by comparing 2 adjacent white-tailed deer herds in southwestern Oklahoma using fall-harvested animals and seasonal changes in fecal constituents. Comparing past harvest records and annual survey data for both herds revealed apparent differences in herd density and reproduction, possibly due to differences in habitat quality. Financial and logistical support for this research were provided by Fort Sill Military Reservation, Department of Zoology, Oklahoma State University, and the National Science Foundation (BSR-8657043).

Methods

This study was conducted on Fort Sill Military Reservation (FSMR) located in the Central Rolling Red Plains and Central Rolling Red Prairies Land Resource Areas (Gray and Galloway 1969) of southwestern Oklahoma. We used condition profiles to compare habitat quality between 2 adjacent white-tailed deer populations on East Range and West Range, FSMR. East Range is dominated by rolling tall-grass prairie with 1 well developed stream bottom. West Range has a more diverse landscape ranging from rugged granite outcrops to tall-grass prairie with intermittent stream bottoms. Soil types also differ between East Range (Zaneis and Lucien-Zaneis-Vernon series) and West Range (Foard and Granite series). Approximately 4.5% of the total area is cultivated on East Range (fields average 9.0 ha), compared with 0.8% on West Range (7.5 ha). Cultivated fields are uniformly distributed on East Range, but are concentrated along east and south boundaries on West Range. Agricultural crops produced on both ranges include alfalfa (*Medicago sativa*), milo (*Sorghum bicolor*), and winter wheat (*Triticum aestivum*). Although the 2 ranges are adjacent to each other, there are no apparent transitional movements by deer between ranges (Dinkines 1990). The ranges are separated by numerous obstacles including a 4-lane highway bordered by a 6-foot hogwire fence, base housing, army barracks, a golf course, and several other man-made structures.

Minimum density of deer on East Range was estimated at 3.33 deer/km^2 in 1987 and 3.75 deer/km^2 in 1988 compared to 2.50 deer/km^2 in both 1987 and 1988 on West Range (G. G. Stout, unpubl. rep., Ft. Sill Deer Herd Analysis 1989). The mean fawn:doe ratio for the period 1982–1988 was 0.78 on East Range and 0.60 on West Range.

Morphological and Physiological Indices

Check station records for white-tailed deer harvested from East Range and West Range in November and December from 1984 to 1988 were used to evaluate differences in gross morphology between the 2 populations. Hunters were instructed to return non-eviscerated carcasses to the check station as soon as possible after death (determined to be <2 hours) during the 1987 and 1988 harvest. Age class, live weight, eviscerated carcass weight, antler characteristics of males (total number of points >2.54 cm long and main beam circumference measured 2.54 cm above the burr), and selected organ weights (cervical thymus gland and spleen) were recorded for deer harvested in 1987 and 1988.

Postmortem blood samples were obtained from the superior vena cava of hunter-harvested in the 0.5- to 6.5-year age class. Serum samples were analyzed on an Ektachem-700 Analyzer (Eastman Kodak Co., Rochester, N.Y. 27705) at the Fort Sill Medical Diagnostic Laboratory. Postmortem serum samples are not appropriate for the analysis of many serum constituents. To ascertain which constituents remained reasonably stable after death, we used analysis of variance to compare blood serum profiles of live-caught deer with postmortem samples (Dinkines 1990). Only postmortem blood urea nitrogen (BUN), creatinine (C), BUN/C ratio, and triglycerides did not differ ($P < 0.05$) between live and postmortem samples and, thus, were used to assess physiological condition of harvested deer from East Range and West Range.

Diet Quality Indices

Differences in the quality of vegetation in the diet of white-tailed deer from East Range and West Range were evaluated using both hunter-harvested animals and seasonal collections of feces. A minimum of 15 fresh fecal pellet groups were collected from random locations on both East Range and West Range in fall (October), winter (February), spring (May), and summer (August), 1987 to 1989. Additionally, postmortem samples of feces from the rectum and contents of the rumen were obtained from deer harvested in the fall from each study area. Fecal and rumen samples were oven-dried at 50 C, blended in a high-speed blender, and ground to pass through a 1-mm mesh screen. Subsamples of each fecal group or rumen sample were analyzed for concentrations of nitrogen (Kjeldahl method) and fiber content (Neutral detergent fiber, NDF; acid detergent fiber, ADF) (Goering and Van Soest 1970), and nitrogen in the ADF fraction as an index of insoluble nitrogen content (Wofford et al. 1985).

Data Analysis

To account for the effects of age on morphological variables, we used analysis of covariance with age class (for antler measurements and body weights) or eviscerated carcass weight (for organ weights) as a covariate to test the main and interactive effects of sex and habitat (East Range vs. West Range) for adult deer (≥1.5-year age class). Differences in morphological indices of fawns were tested for main factor effects of sex and habitat using 2-way analysis of variance. For dependent dietary and physiological variables, the main and interactive effects of season, year, sex, and habitat were examined using 4-way analysis of variance. Protected multiple comparisons (LSD) were used when significant differences ($P < 0.05$) were present. Pearson correlation coefficients were used to examine relationships among physiological and dietary variables. The Statistical Analysis System (SAS) was used for all data analyses (SAS Inst. Inc. 1982).

Results and Discussion

Morphological and Physiological Indices

Body weight and antler characteristics were recorded for 515 white-tailed deer harvested from 1984 to 1988 (East Range 108 females, 149 males; West Range 61 females, 197 males). Males were heavier than females, and all deer continued to increase in both live weight ($r = 0.77$) and eviscerated carcass weight ($r = 0.77$) with age ($P < 0.01$). Live weights ($\bar{x} = 50.6 \pm 1.2$ (SE) kg) and eviscerated carcass weights (37.6 ± 0.5 kg) did not differ ($P > 0.10$) between deer herds.

Although body weights have been suggested as a useful measure of deer condition, they tend to be variable with respect to season, age, and sex (Kie 1988). Body weights also are less sensitive to acute dietary changes compared to long-term nutritional restriction (Holter and Hayes 1977, Warren et al. 1981). Body weight indices would be more sensitive for assessing condition among fawns because of their relative growth demands (Holter and Hayes 1977, Seal et al. 1978*a*). However, no differences ($P > 0.10$) in live weights or eviscerated carcass weights were detected between ranges for male or female fawns. We also observed no differences ($P > 0.10$) in spleen or thymus gland weights, number of antler points ($P > 0.07$), or main beam circumference ($P > 0.10$) in adult deer.

Standard blood chemistry profiles were computed for a total of 59 postmortem blood samples obtained from hunter-harvested deer. No age or year differences ($P > 0.10$) were found in postmortem concentrations of BUN, C, triglycerides, and BUN/C ratio. We observed differences ($P < 0.05$) in concentrations of BUN, C, and the BUN/C ratio between deer herds (Fig. 1). Overall, concentration of BUN averaged 25.0 ± 1.5 mg/dl for East Range and 16.6 ± 1.4 mg/dl for West Range, and was not influenced by sex. Creatinine concentrations differed ($P < 0.05$) between areas and interacted ($P < 0.05$) with sex; concentrations were lower in males harvested from East Range (1.68 ± 0.14 mg/dl) than from West Range (2.52 ± 0.22 mg/dl). The BUN/C ratio of deer was greater on East Range (16.51 ± 1.82) than West Range (7.11 ± 0.55) and also differed ($P < 0.05$) with respect to sex. No difference ($P > 0.10$) in the concentration of triglycerides was observed between deer herds.

Serum chemistry parameters are attractive indices for assessing condition because they reflect recent nutritional history (Seal 1977). Serum concentrations of BUN in our study were similar to values recently reported for deer from south-central Oklahoma in the fall (DeLiberto et al. 1989). Postmortem blood profiles of deer on FSMR suggested that nutritional quality of habitat on East Range was better than on West Range. Positive relationships between recent protein intake and concentration of BUN or the BUN/C ratio have been demonstrated by several investigators (Bahnak et al. 1979, Warren et al. 1981). Seal et al. (1978*b*) found that BUN values were useful in detecting differences among habitats of white-tailed deer in Minnesota. Differences in habitat quality between deer herds on FSMR are probably more related to protein than energy availability as suggested by serum chemistry profiles that reflected significant differences in BUN, but similar concen-

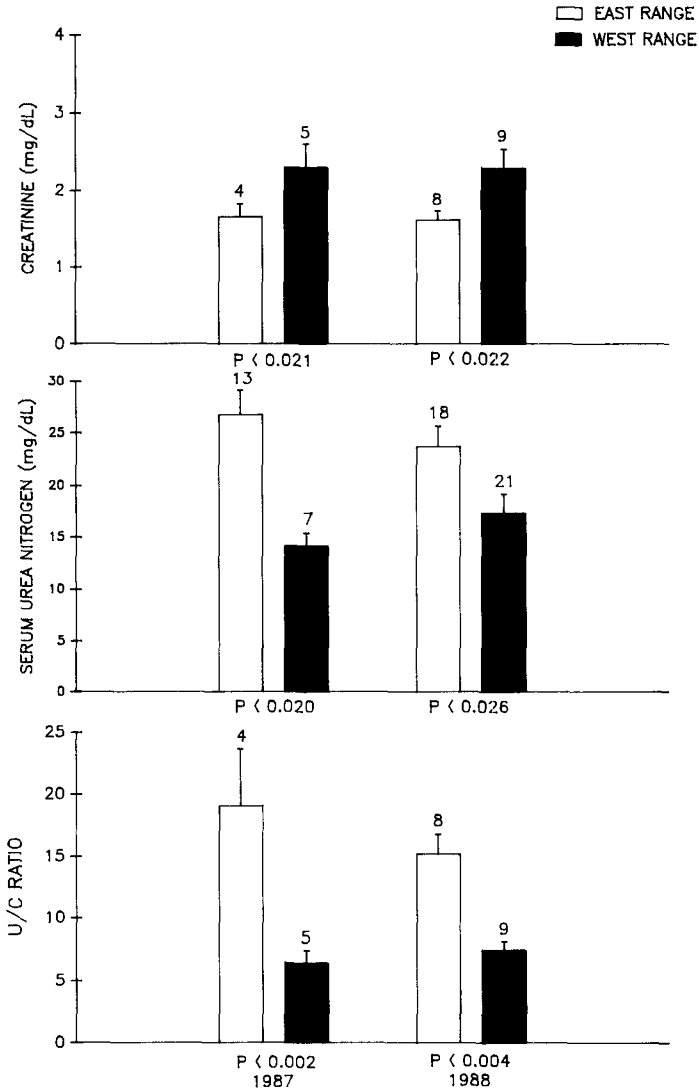

Figure 1. Mean (± SE) concentrations of urea nitrogen, creatinine, and urea/creatinine ratios in blood serum obtained from white-tailed deer harvested from East Range and West Range, Fort Sill Military Reservation, Oklahoma, November to December 1987 and 1988.

trations of triglycerides (an indicator of energy status) (Trustwell 1975, Seal and Hoskinson 1978*c*).

Diet Quality Indices

We obtained postmortem rumen contents and fecal samples from 36 harvested deer on East Range and 38 from West Range during fall 1987 and 1988. No significant ($P > 0.10$) year effects were observed for concentrations of nitrogen, NDF, or ADF in either postmortem rumen contents or fecal samples. Concentrations of nitrogen and ADF in rumen and fecal samples, and NDF in rumen samples, differed between East Range and West Range deer herds (Table 1). We also found higher levels of insoluble nitrogen in feces from West Range than East Range, but no difference for rumen contents (Table 1).

There were no relationships ($P > 0.10$) between age class and postmortem dietary indices measured in this study. We observed that concentration of nitrogen in feces correlated inversely with ADF levels in feces ($P < 0.01$, $r = -0.62$) and positively with nitrogen ($P < 0.01$, $r = 0.35$) and insoluble nitrogen ($P < 0.03$, $r = 0.28$) levels in rumen contents. ADF concentration of feces correlated inversely with nitrogen ($P < 0.01$, $r = -0.32$) and positively with ADF ($P < 0.01$, $r = 0.43$) concentrations in rumen contents. Nitrogen concentration of rumen contents was correlated inversely with ADF content in rumen contents ($P < 0.01$, $r = -0.40$), but not feces ($P > 0.05$, $r = 0.06$).

Nitrogen concentration of rumen contents has been used to estimate dietary crude protein intake in deer (Klein 1962, Kirkpatrick et al. 1969), despite the fact that levels are often higher than in the diet (Klein 1962) as a result of endogenous sources. Several investigators have demonstrated that rumen crude protein levels fluctuate seasonally in response to changes in forage quality (Kopf et al. 1984, Waid and Warren 1984). The inverse relationship observed between nitrogen and ADF in rumen contents suggests that forage digestibility increases with increased crude

Table 1. Diet quality indices for hunter-harvested white-tailed deer differing between East ($N = 36$) and West Range ($N = 38$), Fort Sill Military Reservation, Oklahoma, in November and December 1987 and 1988.

Index (% dry wt.)	East range $\bar{x}$	East range SE	West range $\bar{x}$	West range SE	P
Feces					
Nitrogen	2.49	0.09	2.11	0.72	0.01
Acid detergent fiber	38.95	1.30	46.59	1.01	0.01
Insoluble nitrogen	0.50	0.02	0.61	0.03	0.04
Rumen					
Nitrogen	3.73	0.17	2.80	0.09	0.01
Neutral detergent fiber	56.63	1.14	64.56	1.39	0.01
Acid detergent fiber	33.16	0.96	41.65	1.43	0.01
Insoluble nitrogen	0.43	0.03	0.50	0.03	0.13

protein. The positive relationship between feces and rumen digesta for nitrogen is in agreement with other studies demonstrating a strong relationship between diet and fecal nitrogen levels (Klein 1962, Kirkpatrick et al. 1969).

Insoluble nitrogen content determined in this study is thought to reflect the amount of fiber-bound, cell-wall protein. Wofford et al. (1985) reported fiber-bound nitrogen in excess of 1.00% may indicate high levels of dietary tannins or phenolics which makes predictions of dietary nitrogen from fecal nitrogen unreliable. Since the insoluble nitrogen concentration was below 1.00% for both East Range and West Range, we suspect that the concentration of nitrogen in feces reflects a difference in diet quality and not a problem with insoluble phenolics.

The use of feces to index seasonal changes in dietary quality has received considerable attention from biologists because obtaining rumen contents requires the sacrifice of animals. Concentration of nitrogen in feces is positively related to both digestibility (Holloway et al. 1981) and protein content (Leslie and Starkey 1985) of the diet. However, few reported studies have attempted to use fecal indices to determine differences in habitat quality among white-tailed deer populations (Jenks et al. 1989).

Differences in seasonal fecal indices between deer herds on FSMR were similar to those observed for postmortem serum and diet quality profiles. Concentration of nitrogen in fecal pellet groups showed significant ($P < 0.01$) seasonal and annual fluctuations (Fig. 2). Mean seasonal concentrations of nitrogen for the 2 years combined varied from a low of 1.99 ± 0.05% in winter to 2.70 ± 0.09% in spring. Multiple range tests indicated that concentrations of nitrogen in feces were not different ($P > 0.05$) between summer and spring; all other comparisons were significant ($P < 0.05$). Annual mean concentration of fecal nitrogen was greater ($P < 0.05$) in 1988 (2.50 ± 0.05%) than 1987 (2.25 ± 0.06%). Fecal nitrogen concentrations averaged about 18% greater ($P < 0.01$) on East Range than West Range, and there was an interaction ($P < 0.05$) with season. Differences in nitrogen concentration of feces between deer herds were most pronounced in summer and fall.

Concentration of ADF in feces also showed significant ($P < 0.01$) seasonal and annual effects (Fig. 2). Concentrations of ADF were lower ($P < 0.05$) in fall (42.09 ± 0.9%) compared with winter (49.7 ± 0.8%), spring (49.9 ± 1.2%), and summer (46.9 ± 0.7%), and greater ($P < 0.05$) in 1988 (47.9 ± 0.9%) than 1987 (46.6 ± 0.7%). There also was a difference ($P < 0.01$) between deer herds and deer herd by season interaction ($P < 0.05$). Concentrations of ADF were greater ($P < 0.05$) on West Range (overall, 49.1 ± 0.7) than East Range (45.2 ± 0.8%) for all seasons except winter. Concentrations of ADF were inversely correlated ($P < 0.01$, $r = -0.41$) with nitrogen in feces, and showed a slight correlation ($P < 0.01$, $r = 0.23$) with insoluble nitrogen.

Concentration of insoluble nitrogen in feces showed seasonal and annual fluctuations ($P < 0.01$) (Fig. 2). Insoluble nitrogen levels were highest ($P < 0.02$) in spring (1.0 ± 0.03%) compared with summer (0.9 ± 0.03%), fall (0.5 ± 0.03%), and winter (0.5 ± 0.02%). Annual mean concentration of insoluble nitrogen was greater ($P < 0.01$) in 1988 (0.81 ± 0.02%) than 1987 (0.69 ± 0.02%). The

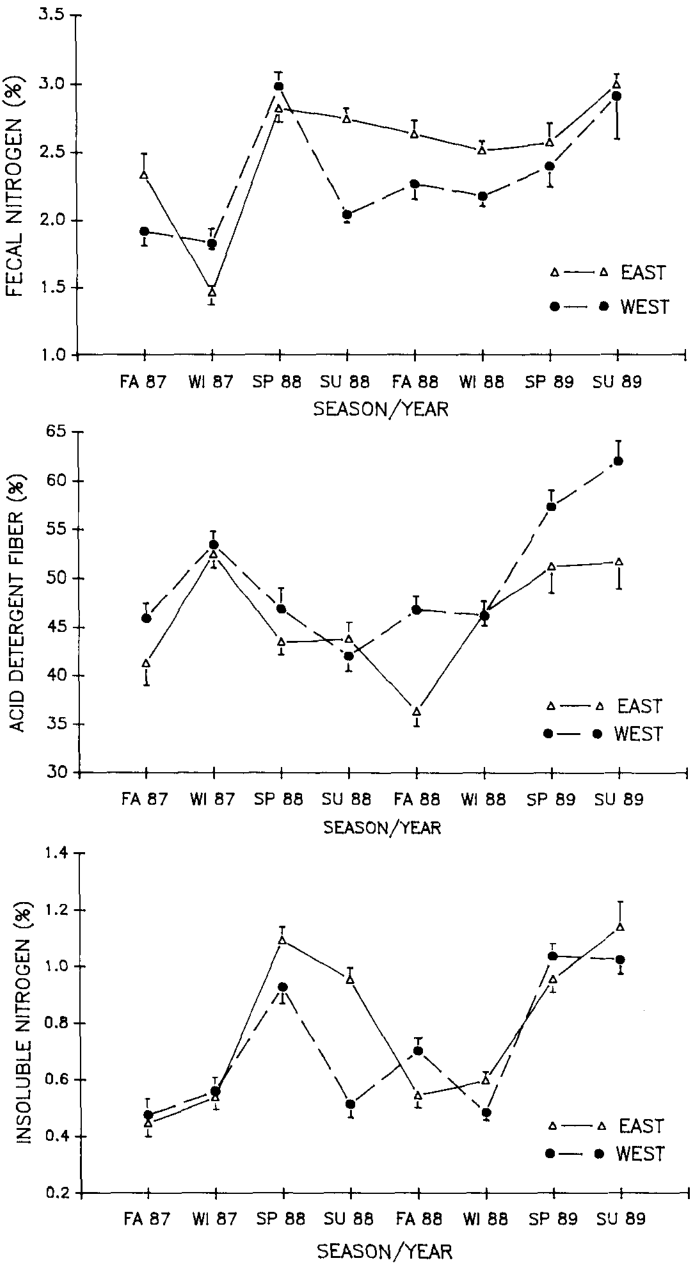

Figure 2. Seasonal variations in concentrations (%) of nitrogen, acid detergent fiber, and insoluble nitrogen in fecal samples collected from East Range and West Range, Fort Sill Military Reservation, Oklahoma, from fall 1987 to summer 1989. Values represent mean ± standard error of minimal sample size 15.

concentration of nitrogen in fecal samples was correlated ($P < 0.01$, $r = 0.48$) with insoluble nitrogen. Differences between East Range and West Range were similar to those observed for nitrogen; insoluble nitrogen was greater ($P < 0.01$) on East Range (0.74 ± 0.03%) than West Range (0.69 ± 0.03%).

Management Implications

Our study on FSMR demonstrates the feasibility and utility of using condition profiles incorporating morphologic, physiologic, and dietary quality indices for assessing or comparing habitat quality among white-tailed deer herds occupying similar habitats. Small sample sizes usually make interpretation of a single index of habitat quality difficult and risky (Kie 1988). Myriad intrinsic and extrinsic variables unrelated to habitat quality can potentially mask differences in an index that might otherwise be attributable to habitat quality. As a result, single variable models for assessing differences in habitat quality or comparing populations that occupy dissimilar habitats or have disparate diet selection should be avoided. Condition profiles for assessing habitat quality between 2 or more populations inhabiting similar habitats that are based on a variety of indices should provide more sensitivity in the presence of interfering variables.

Both physiologic and diet quality indices supported our conclusions that the nutritional quality of habitat on East Range was higher than on West Range. A plausible explanation for this difference is the greater amount and distribution of cultivated fields available on East Range compared to West Range. Although differences in diet quality were detected between herds, no differences were observed in morphology. Apparently, East Range and West Range are both providing deer adequate nutrients for morphologic maintenance and development. Differences in density and fawn-to-doe ratios between deer herds on FSMR suggest that nutritional conditions of the habitat influenced population dynamics (nutrient-demanding recruitment) but not morphology.

Our study also suggests that useful physiologic and dietary quality information can be derived postmortem from hunter-harvested white-tailed deer. In particular, serum BUN levels, which have been widely used to assess protein intake in deer, remain stable up to 2 hours after death. Rumen contents and fecal samples from hunter-harvested deer also can provide useful information on diet quality for the fall season. Changes in diet quality during other seasons can be monitored by periodic profiling of nutrient and cellular constituents in deposited feces, at relatively low cost (Jenks et al. 1989).

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