Physiological Condition of Female White-tailed Deer in a Nutrient-deficient Habitat Type

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Abstract - Physiological and morphological indices are useful for determining condition of *Odocoileus virginianus* (White-tailed Deer; hereafter deer) and are important for deer management. However, information about deer condition in nutrient-deficient habitat types is sparse. Pocosins have a low nutritional plane and are characterized by deep, acidic, peat soils with a dense shrub layer that provides little or no hard and soft mast. In July 2008 and March 2009, we collected a total of 60 female deer (30 from each period) from a 31,565-ha pocosin forest managed intensively for *Pinus taeda* (Loblolly Pine) in coastal North Carolina. We recorded whole weight, eviscerated weight, spleen and adrenal gland weights, and kidney fat index (KFI). Abomasal parasite counts (APC) and femur marrow fat index (MFI) were determined post-collection in the laboratory, and blood samples were analyzed for packed cell volume and standard serum chemistries. Serum chemistries were within expected ranges, with the exception of elevated potassium concentrations. The KFI and MFI were within levels reported in the literature, and APC levels did not indicate heavy parasite loads. Spleen (t_{58} = 0.69, P = 0.492) and adrenal gland weights (t_{58} = 1.46, P = 0.151) were similar between periods. Our results provide baseline physiological data for deer in a nutrient-deficient habitat type. Though managers need to consider nutritional plane of particular habitat types, our results indicate that deer can achieve normal body weights and maintain body condition in nutrient-deficient sites.

Introduction

Physiological analyses of *Odocoileus virginianus* Zimmermann (White-tailed Deer; hereafter deer) based on blood-serum parameters and body-condition indicators (e.g., kidney fat, femur marrow fat) have been used to evaluate health and condition. Serum chemistry results have been reported from South Dakota (Hippensteel 2000, Osborn 1994), Minnesota (Seal and Erickson 1969, Seal et al. 1978), Michigan (Johnson et al. 1968), Oklahoma (DeLiberto et al. 1989), Kansas (Klinger et al. 1986), Missouri (Tumbleson et al. 1968), Texas (Blankenship and Varner 1977, Kie et al. 1983, Waid and Warren 1984, White and Cook 1974), and Maryland (Wilber and Robinson 1958), and body condition results have been reported from Manitoba (Ransom 1965), South Dakota (Hippensteel 2000, Osborn 1994), Oklahoma (DeLiberto et al. 1989), Texas (Kie et al. 1983, Waid

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and Warren 1984), and South Carolina (Finger et al. 1981, Johns et al. 1984). However, physiological data for deer in the Southeast are lacking.

As Quality Deer Management (QDM) has grown in popularity, interest in individual-level health parameters (e.g., kidney fat, body weight, parasite load) has increased. Although deer management has focused typically on population-level parameters (e.g., relative density, sex ratios), individual-level health parameters can be used by state agencies, private managers, and hunters to assess the success of management strategies. Thus, an understanding of physiological condition of deer across their range is warranted. Further, nutritionally deficient habitat types are of interest because few studies have examined deer health at sites where nutritional plane is low. Hence, the objectives of our study were to establish baseline physiological values and determine the relative health of female deer in a nutritionally deficient habitat type during the 2 most stressful time periods for deer.

Study Area

We conducted our study at Hofmann Forest, which is owned and managed by the North Carolina State Natural Resources Foundation. Hofmann Forest is a 31,565-ha tract of contiguous pocosin intensively managed for *Pinus taeda* L. (Loblolly Pine) production in the Coastal Plain of North Carolina (Jones and Onslow counties). Pocosins are characterized by deep, acidic, nutrient-deficient sandy or peat soils (Richardson et al. 1981). Typical pocosins are fire adapted (15- to 20-year disturbance interval), have temporary surface water (but may flood for long periods), and maintain a high water table (Christensen et al. 1981, Richardson et al. 1981). During the study, Hofmann Forest contained 28% natural pocosin, 52% pine plantation, 10% clearcut, and 2% agriculture (e.g., corn, soybeans, wheat). In the natural areas, dominant vegetation included *Pinus serotina* Michaux (Pond Pine) and a dense shrub layer comprised of *Cyrilla racemiflora* L. (Titi), *Magnolia virginiana* L. (Sweetbay), *Persea borbonia* (L.) Spreng. (Redbay), *Ilex glabra* (L.) A. Gray (Inkberry), and *Smilax* spp. (Greenbriar) (Christensen et al. 1981, Richardson et al. 1981). Also, the pine plantations contained the dense shrub layer characteristic of the natural areas. Pocosins provide little or no hard mast, and soft mast is limited. Thus, deer are largely dependent upon browse (Hazel et al. 1978). At their natural climax stage, pocosins represent a low browse resource with many plants unpalatable and containing low crude protein and phosphorus, which could affect body maintenance of deer (Smith et al. 1956).

During the study, 9 hunt clubs were active on Hofmann Forest, and their hunting areas ranged in size from about 445 to 5460 ha. Deer were hunted predominately using dogs, and harvest records maintained by hunt clubs from 2001 through 2006 indicated a male-biased harvest. On average, hunters harvested antlered males 74% of the time, and the total deer harvest averaged 430 deer/year during this time period. Deer harvest was stable throughout and showed no indication of decline. The North Carolina Wildlife Resources Commission

(NCWRC) estimated the deer density in the two-county area including Hofmann Forest was between 6 and 17 deer/km^2, with the lower density in pocosins and the higher density in the agricultural areas outside of Hofmann Forest (R. Norville, NCWRC, Kinston, NC, pers. comm.).

Methods

We shot female deer in the head with high-powered rifles at night in July 2008 and March 2009. Collections corresponded with the 2 most stressful time periods for female deer in the southern portion of the range (i.e., late summer, during lactation and late winter, before spring green-up). Within minutes of collapse, we collected blood via cardiac puncture and stored blood samples on ice until centrifuged for serum separation, usually within 6 hours of collection. Serum samples were placed on ice, frozen, and later analyzed by Antech Diagnostics (on an Olympus AU5400, Melville, NY) for glucose, urea nitrogen (BUN), creatinine, total protein, albumin, total bilirubin, alkaline phosphatase (ALP), alanine aminotransferase (ALT), aspartate aminotransferase (AST), cholesterol, calcium, phosphorus, sodium, potassium, chloride, albumin/globulin ratio, BUN/creatinine ratio, globulin, and creatine kinase (CK). We measured packed cell volume (PCV) of whole blood in the field using a hematocrit centrifuge.

We recorded total body weight and collected kidneys with all perirenal fat, spleens, adrenal glands, fetuses (in March), and the right femur (Hippensteel 2000, Osborn 1994). Eviscerated weights were recorded after all internal organs, the lower jaw, and the right femur were removed. For abomasal parasite counts (APC), we randomly selected a deer from the first 6 processed in each time period, then systematically sampled every 6th deer to obtain a total of 5 deer, which was the number suggested by Eve and Kellogg (1977). Each abomasum was removed from the digestive tract and stored on ice until processed (Eve and Kellogg 1977) by the North Carolina State University College of Veterinary Medicine.

We determined fat reserves using total perirenal fat (KFI: relative to naked kidney weight; Monson et al. 1974) and femur marrow fat (FMI) using a 2–3 gram sample of marrow from the center third of a cut femur combined with a 2:1 chloroform:methanol solution in the laboratory (Verme and Holland 1973). We recorded spleen and paired adrenal gland weights (Hippensteel 2000, Osborn 1994) and estimated ages of collected deer by tooth replacement and wear (Severinghaus 1949) to separate deer into 2 classes: <1.5 years and >1.5 years. The younger class represented deer that were fawns during the previous breeding season (relative to our collection periods) and were not likely to have bred, while the older class represented deer that would have been of breeding age in the previous fall breeding season.

We evaluated fecundity and breeding season dates by noting lactation status in July and recording the number and lengths of fetuses collected in March. We determined reproductive rate from fetal counts (Hesselton and Sauer 1973) and estimated conception date using a commercially available fetal-aging scale (Quality Deer Management Association, Bogart, GA; based upon Hamilton et al.

1985). We determined lactation rate by dividing the number of lactating females by the number of females collected. All research activities were approved by the NCWRC and the North Carolina State University Institutional Animal Care and Use Committee (08-082-O).

We defined population health as the combination of the overall condition of each individual deer (including body weight, fat levels, and serum chemistries) and the reproductive data from the herd. We used the combination of physiological and reproductive metrics to avoid basing our health assessment on just 1 health parameter. Analyses were primarily descriptive, which facilitated qualitative comparison to the literature and veterinary reference values. Values falling within reported ranges (e.g., DeLiberto et al. 1989, Johns et al. 1984, Kie et al. 1983) were accepted as normal. In such cases, we did not test for seasonal differences because we did not want to confuse statistical significance with biological significance. However, for metrics with potential biological significance and few reference values (i.e., spleen and paired adrenal gland weights), we compared seasonal means with *t*-tests ($\alpha = .05$) in SYSTAT 10 (Systat Software, Chicago, IL).

Results

We collected 30 female deer in July 2008 and 30 in March 2009 with ten <1.5 years old and three <1.5 years old in July and March, respectively. Serum chemistry results were obtained for all deer except 1 in the March collection; chemistries were normal in both seasons, with the exception of high potassium

Table 1. Serum chemistries of female White-tailed Deer collected at Hofmann Forest, NC, July 2008 and March 2009.

	July (n = 30)			March (n = 29)		
Chemistry (units)	$\bar{x}$	SD	Range	$\bar{x}$	SD	Range
Total protein (g/dL)	7.3	0.44	6.4–8.2	6.3	0.44	5.3–7.0
Albumin (g/dL)	2.5	0.22	2.1–3.0	2.8	0.24	2.3–3.3
Globulin (g/dL)	4.8	0.36	3.9–5.3	3.5	0.38	2.7–4.4
Albumin:globulin ratio	0.5	0.07	0.4–0.6	0.8	0.11	0.5–1.0
Aspartate aminotransferase (U/L)	90	21.5	62–157	87	31.1	47–166
Alanine aminotransferase (U/L)	42	7.6	30–64	29	6.9	11–43
Alkaline phosphatase (U/L)	119	53.5	47–267	71	31.4	24–152
Total bilirubin (mg/dL)	0.2	0.06	0.1–0.3	0.3	0.15	0.1–1.0
Urea nitrogen (mg/dL)	17	6.4	6–33	19	6.3	7–35
Creatinine (mg/dL)	1.1	0.20	0.7–1.6	1.3	0.21	1.0–1.9
Blood urea nitrogen:creatinine ratio	17	6.7	5–31	14	5.3	5–29
Phosphorus (mg/dL)	12.6	1.85	8.9–15.5	9.7	1.65	5.6–13.2
Glucose (mg/dL)	194	75.9	85–333	200	90.2	74–409
Calcium (mg/dL)	10.1	0.65	8.8–11.6	9.6	0.54	8.7–10.9
Sodium (mEq/L)	151	6.2	142–171	144	4.5	139–158
Potassium (mEq/L)	9.7	1.65	5.8–12.0	8.9	1.34	6.5–11.9
Chloride (mEq/L)	107	3.8	101–119	101	2.4	97–105
Cholesterol (mg/dL)	45	7.1	31–58	45	8.6	29–65
Creatine kinase (U/L)	327	335	80–1883	194	142	63–739

values (Table 1). Total KFI and MFI were appropriately low given the nutritionally stressful periods in which we collected deer (Table 2). Total and eviscerated body weights were comparable to deer in the region (K. Huffman, Hofmann Forest Wildlife Manager, Deppe, NC, pers. comm.; Table 2). Mean spleen (t_{58} = 0.77, P = 0.444) and paired adrenal gland (t_{58} = 1.85, P = 0.070) weights (standardized by eviscerated body weight) were similar between sampling periods (Table 2).

Mean PCV was 45% (SD = 5.6; range = 38–63; n = 28) in July and 53% (SD = 6.6; range = 39–70; n = 30) in March. Mean abomasal parasite counts were low in both seasons, with 440 and 580 worms/L of abomasal content in July and March, respectively. Three genera were identified (*Ostertagia*, *Trichostrongylus*, *Skrjabinagia*), though most worms were *Ostertagia* spp. (possibly *O. mossi*).

In July, lactation rate was 50% (75% excluding the 10 deer <1.5 years old). In March, reproductive rate was 1.5 fetuses/female (1.7 fetuses/female excluding the 3 deer <1.5 years old), and we collected 7 singletons, 16 sets of twins, and 2 sets of triplets. Of the 5 non-gestating females, 3 were <1.5 years old, 1 was old (estimated age >8 years), and the other was estimated at 2 years of age. Estimated conception dates ranged from mid-October to mid-December.

Discussion

Serum chemistry results were consistent with the published literature, with the exception of high potassium values. High potassium values have been reported in free-ranging cervids (e.g., Kie et al. 1983, White and Cook 1974, Wilber and Robinson 1958). However, why deer experience higher than expected potassium concentrations and how they tolerate levels that would have adverse consequences in other mammals is not clear (Stringer et al. 2011).

Seasonal variation in fat indices has been described for deer in the southeastern United States (Johns et al. 1984), with peak fat reserves occurring in winter (DeLiberto et al. 1989, Finger et al. 1981, Stockle et al. 1978, Waid and Warren 1984). However, our sampling periods were not designed to capture peak reserves. Rather, our sampling periods reflect the most stressful periods encountered by female deer in pocosins. Forage limitations before spring green-up (March) and during the late-summer stress period (July), coupled with the physiological demands of reproduction (gestation in March and lactation in July)

Table 2. Body parameters of female White-tailed Deer collected at Hofmann Forest, NC, July 2008 and March 2009.

	July (n = 30)			March (n = 30)		
Parameter (units)	$\bar{x}$	SD	Range	$\bar{x}$	SD	Range
Kidney fat index (%)	25.2	25.79	3.0–116.6	32.4	26.62	2.8–110.6
Marrow fat index (%)	33.8	27.00	2.1–85.4	78.5	53.44	10.0–204.2
Spleen weight (g/kg)[A]	8.22	1.78	5.18–13.72	7.87	1.73	5.2–14.43
Adrenals weight (g/kg)[A]	0.15	0.048	0.04–0.26	0.13	0.037	0.07–0.25
Whole body weight (kg)	39.8	6.75	27.2–54.5	39.4	7.99	22.2–50.8
Eviscerated weight (kg)	27.9	4.49	20.4–40.9	28.1	4.92	17.3–36.8

[A]Gram weights standardized by kg of eviscerated body weight.

could require mobilization of stored fat. Further, in the Southeast, hard mast provides a critical energy and fat source in fall, which yields highest fat deposition in winter. However, it is possible that deer in pocosins simply cannot deposit copious amounts of fat due to unavailability of hard mast. Our total KFI and MFI were comparable to values reported from South Carolina (Johns et al. 1984) and Texas (Kie et al. 1983, Waid and Warren 1984) but lower than those reported from northern regions (DeLiberto et al. 1989, Hippensteel 2000, Osborn 1994). We believe the KFI and MFI values we observed appear to confirm that large fat reserves might not be necessary for White-tailed Deer survival in the southern range (Finger et al. 1981).

Spleen (Aiton 1938, Hippensteel 2000, Osborn 1994) and paired adrenal gland weights (Hippensteel 2000, Osborn 1994, Welch 1962) were greater (≈60–110% and ≈7–75%, respectively) than those reported in other studies. Increased spleen and adrenal gland weights have been linked to increased stress levels resulting from social stress caused by high population density (Aiton 1938, Christian 1959, Christian and Davis 1964, Christian et al. 1960). However, few studies of White-tailed Deer physiology (e.g., Aiton 1938, Hippensteel 2000, Osborn 1994, Welch 1962) have reported spleen or adrenal glands weights, so regional comparisons are difficult. Without data from other seasons and hormone concentrations, we cannot determine if the weights we observed in July and March were normal (but simply higher than other published values) or elevated due to stress. Thus, our results establish baseline values for these metrics, but further study is required to adequately determine the seasonal relationship of these values to deer physiological condition.

Mean PCV from both seasons did not indicate anemia, supporting our assertion that APC levels in our study were not pathogenic. According to Eve and Kellogg (1977), our APC values indicate a low probability of deer overpopulation relative to habitat quality. Although seasonal variation has been documented (Baker and Anderson 1975, Eve and Kellogg 1977, Moore and Garner 1980), our APC values are consistent with data available from the Southeast (Demarais et al. 1983, Monschein 1977), suggesting our parasite numbers are unlikely to have an adverse impact on overall health. Additionally, we did not detect *Haemonchus contortus*, a large stomach worm, which has been implicated as a major pathogen for White-tailed Deer, particularly in the Coastal Plain of the Southeast (Davidson et al. 1980, Prestwood et al. 1973).

Lactation and reproductive rates determined in this study indicate adequate productivity spanning 2 separate breeding seasons. The high reproductive rate and prevalence of twins and triplets suggest the productivity of the population is higher than might be expected from a nutritionally deficient habitat type. Conception dates spanned 2 months, which could be explained by hunter bias toward harvesting males. Fewer breeding males could contribute to females not being bred in their first estrus of the breeding season. The lactation rate in July was 75% (excluding the 10 deer <1.5 years old), but some females may have lost fawns due to predation or malnutrition. *Canis latrans* Say (Coyote) have been increasingly implicated in fawn mortality in the Southeast (Kilgo et al. 2010), and Coyotes were present at Hofmann Forest and seen or heard commonly. However, our study did not evaluate predation mortality on fawns. Further, though our study did not quantify recruitment, there was no local evidence to suggest inadequate reproduction or recruitment.

Considering that pocosin soil and vegetation are nutrient-deficient and our collections occurred during the 2 most nutritionally stressful time periods for female deer, we believe that deer from pocosins are finding adequate nutrition and the habitat type is not necessarily deficient from a deer health perspective. It is possible that deer benefit from herbaceous forages that become more available after silvicultural practices (e.g., clearcutting and thinning). Herbaceous forages typically are more nutritious and digestible than browse, but the extent of this benefit is unknown. Furthermore, agriculture is prevalent around the boundary of Hofmann Forest, but many deer do not have access to agricultural areas to supplement their diet. Though our reproductive results, combined with the other physiological parameters, do not suggest that deer are nutritionally constrained by overpopulation, we speculate that deer condition could be dramatically lowered if population density was allowed to increase, thereby limiting access to required forage.

Though pocosins are characteristically described as nutrient-deficient, our results indicate that deer are obtaining adequate nutrition, which implies that land managers must consider deer health on the natural nutritional plane of any habitat type before establishing management strategies that are meant to improve deer health. We are not suggesting managers need complete necropsies to evaluate the condition of every individual deer at a site, but continued use of informative metrics (e.g., kidney fat, body weight, parasite load) are easily available from hunter-harvested deer. Combined with population-level metrics (e.g., sex ratio, density), individual-level metrics can be important indicators of deer condition even on low productivity sites with poor soils. Thus, state agencies and deer managers should benefit from deer physiological data as hunters and private land managers become increasingly focused on evaluating the health of deer under QDM-type programs in varying habitat conditions throughout the White-tailed Deer range.

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