Physiological Evaluation of 2 White-tailed Deer Herds in Southern Florida

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Abstract: Influences of nutrition, season, area, sex, and age on physiology were estimated for 82 adult ($\geq$1 year old) white-tailed deer (*Odocoileus virginianus*) collected in the Big Cypress National Preserve (BCNP), Florida, between August 1984 and June 1986. Deer were examined for fat, kidney fat index (KFI), fecal diaminopimelic acid (DAPA), abomasal parasites (APC's), overall physical condition, in utero fecundity, and lactation. Absence of seasonal variations in fat levels and KFI values may reflect a reduced need for deer in southern Florida to store fat. Differences in DAPA concentrations, APC's, body weights, and productivity between herds suggested forage quality limited the population increase in 1 herd.

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The nutritional status of white-tailed deer affects body weight (Verme 1963), productivity (Verme 1969), fawn survival and growth (Verme 1962, 1963), and lipogenesis (Verme and Ozoga 1980), and varies by sex (Johns et al. 1980), age (Verme 1963), and season (Waid and Warren 1984). Deer are important prey for the endangered Florida panther (*Felis concolor coryi*) (Maehr et al. 1990). Panther numbers, reproductive success, and home range sizes are related to prey quantity and quality (Maehr et al. 1989). Therefore, our study sought to document the influences of habitat quality on deer in panther-occupied ranges.

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Methods

BCNP encompasses 230,000 ha in Collier, Monroe, and Dade counties, Florida, with recent, shallow, and infertile soils (Leighty et al. 1954). Approximately 80% of the mean annual rainfall of 137 cm occurs between May and October (Fernald and Patton 1984).

The 15,335-ha Bear Island Unit (BI) in northwestern BCNP has an average elevation of 4.5 m above mean sea level (MSL) and supports a mosaic of cypress (*Taxodium distichum*) domes and strands, slash pine (*Pinus elliotti*) forests, oak (*Quercus* spp.) hammocks, and prairies of saw palmetto (*Serona repens*), wiregrass (*Aristida* spp.), and other grasses in drier sites. Extensive freshwater marshes of sawgrass (*Cladium jamaicensis*), pickerelweed (*Pontederia lanceolata*), and fire flag (*Thalia geniculata*) occupy about 20% of the area (McPherson 1973). Soils are sandy, comparatively fertile, and productive (Leighty et al. 1954).

The Eastern Monument Unit (EMU) in southwestern BCNP contains about 44,390 ha, has an average elevation of 3 m MSL (Duever et al. 1985), and is dominated by small (<4 m) stunted cypress growing on thin, infertile soils. The understory is a scattered, sparse growth of sawgrass and breakrush (*Rhynchospora* spp.) (McPherson 1973). Scattered cypress domes and strands with larger trees also occur. Pine/palmetto associations are common in the central and northern portions of EMU. (McPherson 1973).

Herd Health

During August 1984–June 1986 we spotlighted and shot deer in August (summer), October (fall), March (winter), and June (spring). Each animal was weighed and aged by wear and replacement of lower teeth (Severinghaus 1949). Postmortem examination followed procedures of Nettles (1981). Fat deposits on the tail, pericardium, heart, and kidney (Stockle et al. 1978) were assigned a subjective numerical value of 0–9. Kidneys and perirenal fat were weighed to the nearest 0.1 g for calculation of KFI (Riney 1955). APC was determined for each adult animal (Eve and Kellogg 1977). A subjective overall physical condition value (range 1–12) based upon fat deposits and other conditions or abnormalities observed during necropsy was assigned each animal.

Fecal pellets were assayed for diaminopimelic acid (DAPA) to assess diet quality (Czerkawski 1974). Fecal pellets from adult deer were combined to form a single assay for each area and collection period.

Mammary glands of females were palpated and dissected to detect lactation. Because >80% of south Florida deer breed within 15 days of 10 August (Richter and Labisky 1985), analysis of in utero fecundity was limited to summer and fall-collected deer.

Data Analysis

Eight physiological variables (weight, fats, KFI, APC, and condition) were each centered and scaled to possess a sample mean of 0 and a sample variance of 1 (Rexstad et al. 1990). The principal component method of factor analysis (Johnson and Wichern 1982:361–457) with orthogonal varimax rotation (Kaiser 1958) was used to condense the physiological data array into a smaller, more usable array of independent factor scores.

Scores for each factor were assumed to arise randomly from a factorial layout of independent variables (2 sexes × 2 areas × 2 years × 4 seasons) with an age covariate. A forward selection procedure (Draper and Smith 1981:307–311) was used to build a linear ANOVA model to explain factor score variability with a minimum of interacting model effects. Starting with the simple model of 5 main effects, we added significant ($P \leq 0.05$) 2-way interactions individually to the model, then 3-way interactions, until no other interactions improved the fit of the model. Factor score means for an interacting effect in a final model were compared within levels of the other effects participating in the interaction. Factor score means were compared with the age effect fixed at its mean value. *P*-values for comparisons of season means were conservative by our use of the Bonferroni *P*-value adjustment (Johnson and Wichern 1982:197–199).

Continuity-corrected chi-square was used to compare the relative proportions of twin fetuses between areas in summer and fall-collected pregnant females. Logistic regression was used to fit pregnancy and lactation occurrence probability to linear functions of the physiological factor scores and demographic variables.

Variation among DAPA values due to effects of year, season, and area was analyzed by ANOVA. Tukey's test was used to examine differences among seasons.

Only APC data from adults with complete physiological profiles were included in analyses. Of these, only does ≥1.5 years old were included in analyses of reproductive variables. Taking logarithms of age and KFI values, and cube roots of APC values prior to analysis made distributions of these variables more symmetric (Draper and Smith 1981:225–232).

Results

Physiological Condition

Sixty-two of the 82 adult deer from which we obtained a complete physiological profile were females and 20 were males. Three factors accounted for 80% of the variation among the 8 physiological variables considered (Table 1). Fat, KFI, and condition variables were weighted heavily in Factor 1 ("fats" factor). In Factor 2 APC was identified with a high, negative loading ("APC" factor) indicating that low APC values yielded high APC factor scores. Body weight was emphasized in Factor 3 ("weight" factor) with intermediate loadings given to kidney and tail fats, KFI, and condition.

Four interactions (sex-by-age, sex-by-season, year-by-season, and year-by-area-by-sex, $P \leq 0.046$) were detected in the final ANOVA model fit to the fats factor scores ($R^2 = 0.453$). Overall, fats factor score increased with age ($P = 0.019$), but more so for male deer than for female deer ($P = 0.012$). No seasonal variation in female fat levels was detected. However, the male fat factor mean was lower in summer than in spring ($P = 0.040$, Table 2).

The final ANOVA model that was fit to the APC factor scores ($R^2 = 0.478$) included 3 interactions (sex-by-season, area-by-season, and area-by-age-by-season; ($P = \leq 0.013$). To overcome complicated interactions involving the season effect, APC factor scores in each of the August and October collection periods (Eve and Kellogg 1977, Couvillion et al. 1982) were refit to models lacking a seasonal effect ($R^2 = 0.585, N = 18$; and $R^2 = 0.419, N = 15$, respectively). In August-collected deer, the relationship between APC and age varied by area ($P = 0.014$): APC factor score increased (APC's decreased) with age among BI deer and decreased (APC's increased) among EMU deer. Among deer ≥2.5 years old, mean APC factor score was greater in BI than in EMU deer. In August, mean APC factor score was greater (APC's lower) among males than females ($P = 0.015$, Table 3). Mean APC factor

Table 1. Estimated loadings from factor analysis of physiological variables from 82 white-tailed deer collected in Big Cypress National Preserve, Florida, August 1984–June 1986.

Variable	Factor 1	Factor 2	Factor 3
Pericardial fat	0.881	0.099	0.096
Cardiac fat	0.800	0.081	0.079
Tail fat	0.622	0.032	0.589
Kidney fat	0.721	0.141	0.485
KFI	0.709	0.172	0.442
APC	−0.134	−0.979	−0.134
Body Weight	0.133	0.145	0.911
Condition Index	0.771	0.067	0.532
% variance[a]	43.22	13.15	24.04

[a]Percent of total sample variance of physiological variables due to each factor.

Table 2. Age-adjusted (to 2.5 years) fats factor score means, mean age, and unadjusted summary statistics ($\bar{x}$, SD) of fat values composite[a], KFI, and condition value[b], by sex and collection season, of 82 white-tailed deer collected in Big Cypress National Preserve, Florida, August 1984–June 1986. Within each sex grouping, factor score means followed by the same letter were not different ($P > 0.05$). Differences among mean factor scores are consistent with corresponding differences in mean physiological values for seasons with deer of comparable mean age.

		Factor score	Age	Fat values[a]		KFI		Condition[b]	
Season	N	$\bar{x}$	$\bar{x}$	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
[Female]									
Summer	16	0.551 A	3.31	3.89	1.37	43.63	35.82	6.44	1.41
Fall	12	0.466 A	2.81	4.10	1.29	38.13	24.85	6.83	1.64
Winter	16	0.259 A	3.13	3.73	1.49	23.44	22.16	5.75	1.65
Spring	18	−0.193 A	2.95	2.68	1.44	13.29	11.21	5.56	1.62
[Male]									
Summer	2	−1.565 A	3.00	1.63	0.53	11.48	0.66	4.00	1.41
Fall	3	0.610 AB	1.50	2.75	0.00	15.15	9.62	5.33	0.57
Winter	11	0.361 AB	2.55	4.23	2.11	27.91	23.83	6.73	2.20
Spring	4	1.175 B	1.16	3.25	1.40	14.39	9.44	5.75	1.50

[a]Simple average of subjective measurements of heart, pericardial, kidney, and tail fats.
[b]Subjective measurement derived from several individual characteristics.

score was less (APC's higher) among BI deer than among EMU deer collected in October ($P = 0.047$, Table 3).

Mean body weight of BI females averaged 18.9% greater than that of same aged EMU females. The final model fit to weight factor scores ($R^2 = 0.648$) included 3 interactions (season-by-year, area-by-year, and sex-by-area-by-year ($P \leq 0.012$). Weight factor score increased with age ($P < 0.001$). Among females, mean weight

Table 3. Age-adjusted (to 2.5 years) APC factor score means, and unadjusted summary statistics ($\bar{x}$, SD) of APC for 33 white-tailed deer collected in the Bear Island (BI) and Eastern Monument (EMU) units of Big Cypress National Preserve, Florida, in summer and fall seasons of 1984–1985. Means are presented by sex for summer-collected deer and by area for fall-collected deer. Differences between means within each season were significant ($P \leq 0.05$).

			Factor score	APC	
Season	Effect level	N	$\bar{x}$	$\bar{x}$	SD
Summer	Female	16	0.814	520	798
	Male	2	−1.500	1442	610
Fall	BI	7	0.696	389	529
	EMU	8	−0.351	1091	1129

factor score was greater in BI than in EMU deer in both years ($P \leq 0.015$) but among males, the same was true only in year 1 ($P < 0.001$, Table 4).

Reproduction

In summer collections, the relative proportion of twin fetuses was greater in BI (4 of 4) females than in EMU (0 of 4) females ($P = 0.034$). No difference in twinning incidence was detected between fall-collected BI (1 of 6) and EMU (0 of 8) females ($P = 0.881$). Mean fecundity rates over both seasons were 1.50 and 1.00 fetuses per pregnant female for BI and EMU, respectively. Effects of season, area, and weight factor score were related to pregnancy probability ($P \leq 0.044$). Although only the weight factor was significant, positive associations between pregnancy probability and each physiological factor covariate suggested that pregnant females were most likely in good physical condition.

Coefficients for all physiological factor covariates in the analysis of lactation occurrence were significant ($P \leq 0.021$) and negative; lactating females were in poorest physical condition.

Fecal DAPA

Mean DAPA concentration was greater in samples from BI than EMU ($R^2 = 0.750$, $N = 16$, $P = 0.013$) and in winter than in fall samples ($P < 0.05$, Table 5). DAPA was greater ($P < 0.005$) in winter than in fall in both areas. No other season mean pairs were significantly different. The DAPA mean was greater in year 2 than in year 1 ($P = 0.014$, Table 5).

Table 4. Age-adjusted (to 2.5 years) weight factor score means, and unadjusted summary statistics ($\bar{x}$, SD) of body weight (kg), abdominal fat values composite[a], KFI, and condition value[b], by sex, collection year, and study area, of 82 white-tailed deer collected in the Bear Island (BI) and Eastern Monument (EMU) units of Big Cypress National Preserve, Florida, August 1984–June 1986. Within each sex-year grouping, factor score means followed by the same letter were not different (P>0.05).

			Factor score	Body weight		Abdominal fats[a]		KFI		Condition[b]	
Year	Area	N	$\bar{x}$	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Female											
84–85	BI	15	0.378 A	38.48	5.99	2.63	1.65	37.57	41.06	5.80	1.52
	EMU	11	−0.263 B	30.95	6.38	2.32	1.33	16.32	7.21	5.00	0.45
85–86	BI	18	0.334 A	39.90	4.56	3.75	1.78	30.53	21.40	7.17	1.42
	EMU	18	−0.430 B	33.48	5.08	2.50	1.75	26.52	24.20	5.89	1.81
Male											
84–85	BI	4	1.732 A	44.55	10.84	4.25	1.94	26.28	15.36	7.00	1.83
	EMU	4	0.034 B	31.15	2.83	1.75	0.50	8.54	2.16	4.75	0.50
85–86	BI	6	1.004 A	44.65	7.72	2.25	0.61	11.02	6.29	5.17	0.41
	EMU	6	1.097 A	45.77	11.66	4.25	2.27	37.93	25.09	7.17	2.79

[a]Simple average of subjective measurements of kidney and tail fats.
[b]Subjective measurement derived from several individual characteristics.

Table 5. Summary statistics ($\bar{x}$, SD) for DAPA assay of combined fecal pellets from adult white-tailed deer from the Bear Island (BI) and Eastern Monument (EMU) Units of Big Cypress National Preserve, Florida, August 1984–June 1986. Within each effect, means followed by the same letter were not different ($P > 0.05$).

Effect	Effect level	N	$\bar{x}$	SD
Year	1984–85	8	0.724 A	0.114
	1985–86	8	0.839 B	0.117
Area	BI	8	0.840 A	0.115
	EMU	8	0.723 B	0.116
Season	Winter	4	0.885 A	0.125
	Spring	4	0.795 AB	0.113
	Summer	4	0.737 AB	0.139
	Fall	4	0.709 B	0.092

Discussion

Our data analysis approach departed from methodology familiar to most investigators of deer physiology. One may reason, as we did, that some variables, e.g., APC, are known to measure unique physiological dimensions and thus do not warrant the effort of a factor analysis. On the other hand, we suspected that other variables were closely allied in a variety of ways, and that 8 separate analyses would not yield 8 independent tests of difference. Factor analysis was an appropriate way to confirm or reject our suspicions and to suggest unforseen structures. The approach was successful (Table 1): for variables that behaved independently, no information was lost by using factor scores rather than original values (APC factor score was almost perfectly correlated with cube root of APC); for several correlated variables, information was preserved in a smaller number of surrogate factor scores; and most importantly, the factor loadings made sense to us. One may confirm that differences in mean factor scores usually agreed with differences in means of corresponding original measurements (Tables 2–4). The analysis also indicated findings beyond the scope of our paper: KFI was redundant with subjective assessments of fats and condition, and abdominal (tail and kidney) fats were allied to body weight, but thoracic (heart and pericardial) fats were not.

Inclusion of complicating model interactions was the concession we made to the realities of deer physiology dynamics. It is no surprise that, for example, seasonal variability may be inconsistent between sexes or study areas. Assuming otherwise would impose an untested, possibly unnatural restriction on the data.

Seasonal lipogenesis cycles varied by sex. Males were fattest at the onset of rut (June–July in BCNP) and significantly less so during the peak of mating (August in BCNP), a pattern reported for other deer herds (Seal et al. 1981). Unlike patterns among deer in more northern climes (Johns et al. 1980, Stockle et al. 1978), but similar to patterns among south Texas deer (Kie et al. 1983), fat stores did not vary significantly in south Florida females. A long growing season and the reduced need for fat stores may explain the negligible variability we observed in BCNP female lipogenesis cycle.

APC was an important, independent parameter in the array of physiological indices. As Davidson et al. (1982) found, physical condition and abomasal parasitism were inversely related: deer in good physical condition tended to have low APC's while those in poorer physical condition had higher APC's. Variations in physical condition by sex, age, and area coincided with inverse changes in intensities of abomasal parasitism. Male fat levels and weights were lower during rut than during other sample periods. Concomitantly, male APC's were higher than female APC's. After rut males had greater weights and fat, and APC's were equivalent to female values. During March, body weights and fat levels were low in lactating females and APC's were high. Because rapidly growing fawns demanded greater quantities of milk, maternal fat stores and body weights declined. Elevated APC's among lactating females have been noted for Texas deer (Waid et al. 1985) and livestock (Connan 1976).

EMU deer had higher numbers of abomasal parasites during August and October than BI deer, although the EMU herd density (1 deer/91 ha) was less than the BI herd density (1 deer/26 ha) (Schortemeyer and McCown 1986). The poorer soil of EMU supported fewer forage species (McCown 1988) and a reduced foraging area. The small, isolated oak hammocks and palmetto thickets may concentrate deer and facilitate the transmission of abomasal parasites.

Heavier deer are products of better nutrition (Verme 1963) and are more productive (Verme 1969). The greater incidence of twinning in BI than EMU females was influenced by the greater weight of BI females, a result most likely due to better range conditions and forage quality on BI. The mean live weight of 30.5 kg for 2.5-year-old EMU does is 1 of the lowest reported. In North America, only Key deer (*O. v. clavium*) are consistently smaller (Hesselton and Hesselton 1982).

Concentrations of DAPA, an amino acid found in the cell walls of most ruminant bacteria, fluctuate directly with digestible energy (Nelson et al. 1982). Because its ratio to total bacterial nitrogen is fairly constant, DAPA can be used as an indicator of nitrogen flow to the lower digestive tract of deer. The lower mean DAPA concentration among EMU deer confirmed a lower forage quality implied by analyses of factor scores. Lower digestible energy available in EMU forage likely contributed to lower weight and productivity among EMU females and may decrease neonate survival (Verme 1962).

Management Implications

Our results suggest that the health and productivity of EMU deer are reduced by poor forage quality. Consequently, a program to increase the quantity and quality of EMU deer forage is warranted because the small, unthrifty herd limits numbers of productive panthers in good health (Roelke 1990). The large size of the area precludes most mechanical habitat management techniques. However, prescribed fire can be used inexpensively in south Florida (Wade et al. 1980) to effectively increase the amount, availability, and mineral content of forage (Stransky and Harlow 1981). A burning program treating fire tolerant or fire climax communities on a 3- to 4-year rotation would perpetuate the benefits mentioned above. Increasing the prey base should improve the reproduction and survival of panthers in the area.

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