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ANTLERS OF WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS*) FROM INSULAR AND MAINLAND FLORIDA

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Abstract.—We analyzed antler characteristics of the Florida Key deer (*Odocoileus virginianus clavium*) and white-tailed deer from the adjacent Everglades (*O. v. seminolus*). Antler length, antler beam diameter, number of points, and whole body mass of Everglades deer were greater ($P < 0.03$) than those of Key deer in all age-classes. Antler measurements and whole body mass increased ($P \leq 0.0001$) with age in both populations. Antler growth in deer of the Everglades was similar to that reported for other white-tailed deer of the eastern U.S., in which greatest increase in antler size occurred between one and two years of age. For Key deer, greatest increase in antler size between age-classes was delayed one year. Antlers of Key deer do not approach the size of antlers of even yearlings of more northerly white-tailed deer until Key deer are about three years of age. Antlers of deer from the Florida Keys and Everglades became relatively larger ($P \leq 0.0003$) with age.

Brisbin and Lenarz (1984) compared body measurements between insular and mainland populations of white-tailed deer; however, few studies have documented antler characteristics of insular deer or have compared antlers of insular and adjacent mainland white-tailed deer. Of several theories concerning antler function, foremost is that they serve in inter-male competition (Goss 1983). Morphology of deer antlers is influenced by genetic make-up, environmental factors, and age of the animal (Scribner et al. 1989).

The endangered Florida Key deer occupy a group of islands from 8 to 2,400 ha in area located southwest of Miami (Hardin et al. 1984). Antler characteristics of Key deer are of interest because Key deer are the smallest subspecies of white-tailed deer in North America (Hardin et al. 1984), and they live in a subtropical environment at the southernmost region of the conterminous U.S. Key deer have been isolated from most diseases, major predators (Klimstra et al. 1981), and conspecifics

of the Everglades since rising of ocean levels some 4000 years ago (Hoffmeister 1974). Genetic isolation and differing environments for deer of the Keys and Everglades may have resulted in divergence of antler characteristics. Our objectives were to determine relationships of absolute and relative antler size with age and location for deer of the Florida Keys and Everglades.

METHODS

Data were recorded at time of necropsy of 501 male Key deer ≥ 1 year of age from 1968 to 1989. Mortalities were mainly a result of collisions with vehicles. Most skulls were cataloged and deposited in the research collection of the Cooperative Wildlife Research Laboratory, Southern Illinois University at Carbondale. Whole body mass and quantitative antler data were recorded when carcass condition allowed. Total number of points ≥ 2.5 cm were counted (spike bucks had two points); beam length was measured from burr to tip on the outside edge of the antler (Smith et al. 1983). Beam diameter was measured 2.5 cm above the burr (Roseberry and Klimstra 1975) with a dial caliper. Values for analyses of beam length and diameter represent an average from the two antlers of individuals. If one antler of a pair was broken, length of the intact antler was included in analyses. Deer were aged according to Severinghaus (1949). Ages of those from 1968 through 1985 were estimated by four deer biologists at an "aging bee," while the others were aged when necropsied. Stage of antler growth (i.e., polished, recently cast, or in velvet) at time of death was analyzed to determine chronology of the antler cycle. Except for description of antler chronology, only non-growing (polished) antlers ($n = 217$) were included in analyses.

Data from 601 male white-tailed deer were collected 1978-1989 at hunter check-stations in the Everglades and Francis S. Taylor Wildlife Management Area (Broward, Dade, and Palm Beach counties) of the south Florida mainland. Taxonomic status of deer from the Everglades has been uncertain (Layne 1974). According to Baker (1984), deer of south Florida are *O. v. seminolus*. Methods of data collection were similar to those used for Key deer, but only dressed weights were recorded. To allow comparisons with Key deer, regression relationships (R. W. Ellis, pers. comm.) based on previous studies of these deer were used to estimate whole body mass from dressed weights. The equation for yearlings was $Y = 3.158 + 1.355X$ ($n = 40$, $R^2 = 0.961$), for 2-year-olds was $Y = 8.067 + 1.284X$ ($n = 29$, $R^2 = 0.953$), and for 3-year olds was $Y = 14.208 + 1.196X$ ($n = 10$, $R^2 = 0.903$). Chronology of antler development could not be determined for mainland deer because data were collected mainly when antlers were polished (September - December). Data from Everglades deer may be biased if hunters selected for larger deer. However, potential for this bias was reduced by accounting for age in analyses.

Data for Key deer were collected over a longer period (1968-1989) than those available for mainland deer (1978-1989). Therefore, we adjusted the Key deer data to prevent potential biases associated with differences in years of collection. To adjust the Key deer data set, t-tests were used to compare means of whole body mass and antler measurements in each age-class, between time periods 1968-1977 and 1978-1989. When a variable differed ($P \leq 0.05$) between times, only data from 1978-1989 (time of collection for mainland deer) were included in analyses for that variable.

One-way ANOVAs for unbalanced designs were used to test for age effects on whole body mass, antler length, and beam diameter within deer of the keys (age-classes 1, 2, 3, 4, 5, and 6+ years) and mainland (age-classes 1, 2, and 3 years). Tukey's studentized range tests were used to distinguish differences among means. We used two-way ANOVA to determine if significant interactions occurred between location and age (age-classes 1, 2, and 3). We did not interpret the main effects from the two-way analyses because by using

one-way ANOVAs described above, we were able to test for age effects using all age-classes of Key deer, whereas in the two-way we used only ages represented for both locations. T-tests were used to compare means of antler measurements and whole body mass between locations within age-classes 1, 2, and 3 years.

Transformations of data for total points failed to correct problems of non-normality and heteroscedasticity, so we used methods for analyzing counts of deer in several total points categories. We used log-linear analyses within each location for comparing distributions of point values across ages (analog of one-way ANOVAs for other variables described above), and another log-linear analysis for testing significance of interaction across age and locations (analog of two-way ANOVA described above). Log-linear analyses were also used within each age-class to determine if distribution of points varied by location (analog of t-test). Three categories for number of points were identified: two points (spikes), 3-4 points (forks), and ≥ 5 points.

We examined relative (proportional) antler size using antler beam diameter in relation to whole body mass. Beam diameter was used because it was highly correlated with antler volume in wild (Rogers and Baker 1965) and confined (McCullough 1982) populations of white-tailed deer. Therefore, of variables considered in this study, beam diameter may best represent the actual size (volume) of antlers. We used ANCOVAs with whole body mass as the covariate to test for differences in relative antler size among ages for each population. A third ANCOVA, with body mass and age-class (1, 2, and 3) as covariates, was used to test for differences in relative antler size between deer of the Keys and Everglades.

RESULTS

Whole body mass of yearlings ($P = 0.0491$) and antler length of 2-year olds ($P = 0.0442$) differed between the time periods 1968-1977 and 1978-1989 for Key deer. For these age-specific variables, data for Key deer were adjusted to facilitate comparisons with data from mainland deer by including only the samples from the latter time period.

Key deer with polished antlers were collected from late August through March, with a mean of 25 November (SD = 51 days). Based on mortality data and observations of live Key deer, some males shed their antlers as early as late February or as late as April. The mean date for male deer showing no antlers was 7 April (SD = 20 days). The period of antler growth ranged from mid-March through late August, with a mean of 7 June (SD = 34 days).

We analyzed beam diameter to test for asymmetry between the two antlers of individual Key deer. Of 48 racks, 13 had larger diameters on the right, 16 had larger diameters on the left, and 19 had diameters the same on both sides. Therefore, asymmetry between the two antlers of individuals was common. However, on a population basis, a paired t-test indicated no difference ($t = 0.18$, $P = 0.8608$) between left and right antlers. Analyses of antler measurements of other white-tailed deer populations showed similar results (McCullough 1982, Smith et al. 1983). We did not test for asymmetry of antlers in Everglades deer because available data represented mean values of the two antlers, rather than individual values.

The different measurements of antler size of deer from both the Florida Keys and mainland were highly inter-correlated (Table 1). Relationships of whole body mass with antler measurements, and beam diameter with antler length for deer of mainland Florida were highly significant but weaker ($P \leq 0.05$, z -tests for two independent r 's) than those for Key deer.

Whole body mass, antler length, and beam diameter of both Key deer and mainland deer increased with age (Table 2). For Key deer, statistical differences were not shown for any measurement between ages one and two, but were shown for antler length between ages two and three. Greatest increase in antler size for consecutive age-classes of Key deer occurred between the ages of two and three for beam diameter and length. For deer of mainland Florida, greatest increase between consecutive age-classes occurred between ages one and two for all variables (Table 2). These differences in growth patterns resulted in significant location by age interactions (Table 2) for antler length and whole body mass.

Number of antler points increased ($P \leq 0.0001$) with age in deer of the Keys and mainland (Table 3). Deer of the mainland showed greater ($P < 0.03$) numbers of points than Key deer in all age-classes. The ratio of racks with greater than two points to two points for yearling Key deer (0.16) and Everglades deer (1.13) showed that yearling bucks from the Everglades were about seven times more likely than Key deer to have racks with greater than two points (Table 3). A significant interaction

Table 1. Correlation coefficients (n in parentheses) for the relationships of age-class (one, two, or three years), whole body mass, and antler characteristics in deer from the Florida Keys and mainland. All r -values are significant ($P \leq 0.0001$, except beam diameter and age in Key deer, $P = 0.0093$).

	Antler length	Beam diameter	Body mass	Age
Florida Keys				
Total points	0.77 (71)	0.88 (17)	0.71 (91)*	0.47 (127)
Antler length		0.97 (12)*	0.84 (51)**	0.54 (71)
Beam diameter			0.94 (10)*	0.61 (17)
Body mass				0.34 (102)
Florida mainland				
Total points	0.81 (445)	0.78 (444)	0.57 (434)*	0.38 (455)
Antler length		0.86 (507)*	0.66 (491)**	0.44 (513)
Beam diameter			0.67 (489)*	0.43 (511)
Body mass				0.40 (572)

* $P \leq 0.05$ for $H_0: r_{\text{Florida Keys}} = r_{\text{Florida Mainland}}$

** $P \leq 0.01$ for $H_0: r_{\text{Florida Keys}} = r_{\text{Florida Mainland}}$

for location and age was not detectable ($P = 0.3159$), suggesting that the rate of increase in points with age did not differ between deer of the Keys and mainland.

Means for whole body mass, antler length, and beam diameter of Everglades deer were greater than those of Key deer in all age-classes ($P 0.02$ for all t-tests). Deer from the Everglades, on average, had antlers 1.56-3.07 times longer with beam diameters 1.28-1.4 times larger than antlers of Key deer (Table 2). Everglades deer averaged 1.61-1.73 times the body mass of Key deer. Antlers of Key deer do not approach the size of antlers of even yearlings of more northerly (South Florida, South Carolina, Illinois, Michigan) white-tailed deer until Key deer are about three years of age (Fig. 1). Antlers of deer from mainland Florida were smaller than those of more northerly deer, with differences being greatest for 3-year olds (Fig. 1).

Relative antler size, expressed as antler beam diameter adjusted for effects of whole body mass (Fig. 2), increased with age in Key deer ($F = 7.0$, $P = 0.0003$) and Everglades deer ($F = 17.8$, $P \leq 0.0001$). Relative antler size did not differ ($F = 0.21$, $P = 0.6506$) between Keys and Everglades deer.

Table 2. Whole body mass and antler measurements [$\bar{x} \pm \text{SE} (n)$] for male deer with polished antlers. Means within columns for the two locations are not different ($P \leq 0.05$) when followed by the same letter.

Location age (years)	Whole body mass (kg)	Antler length (cm)	Beam diameter (mm)
Florida Keys			
1	27.2 \pm 1.2 (30)A	7.9 \pm 0.9 (39)A	13 \pm 1 (7)A
2	28.6 \pm 1.0 (34)AB	8.2 \pm 1.5 (12)A	15 \pm 1 (4)AB
3	32.8 \pm 1.1 (38)BC	18.2 \pm 2.0 (20)	18 \pm 2 (6)AC
4	35.5 \pm 1.3 (20)CD	26.5 \pm 2.2 (10)B	19 \pm 1 (8)BC
5	36.4 \pm 1.0 (23)CE	28.7 \pm 1.9 (11)B	20 \pm 1 (12)C
6+	41.1 \pm 2.0 (16)DE	31.9 \pm 0.9 (11)B	22 \pm 1 (11)C
<i>F</i> (age)	15.7	45.8	9.6
<i>P</i>	0.0001	0.0001	0.0001
Florida mainland			
1	43.8 \pm 0.4 (332)A	17.6 \pm 0.5 (284)A	17 \pm 0.3 (281)A
2	49.6 \pm 0.5 (205)B	25.2 \pm 0.6 (192)B	21 \pm 0.3 (193)B
3	53.2 \pm 1.0 (35)C	28.4 \pm 1.4 (37)B	23 \pm 0.9 (37)C
<i>F</i> (age)	56.8	66.9	60.0
<i>P</i>	0.0001	0.0001	0.0001
<i>F</i> (location by age)	2.9	3.8	0.5
<i>P</i>	0.0545	0.0238	0.5011

Table 3. Proportions of antler racks containing 2, 3-4, and ≥ 5 points.

Location age (years)	Antler points			Total racks
	2	3-5	≥ 5	
Florida Keys				
1	0.86	0.08	0.06	48
2	0.72	0.13	0.15	39
3	0.30	0.30	0.40	40
4	0.10	0.15	0.75	20
5	0	0.10	0.90	30
6+	0	0.21	0.79	24
Florida mainland				
1	0.47	0.28	0.25	247
2	0.18	0.28	0.54	175
3	0.12	0.15	0.73	33

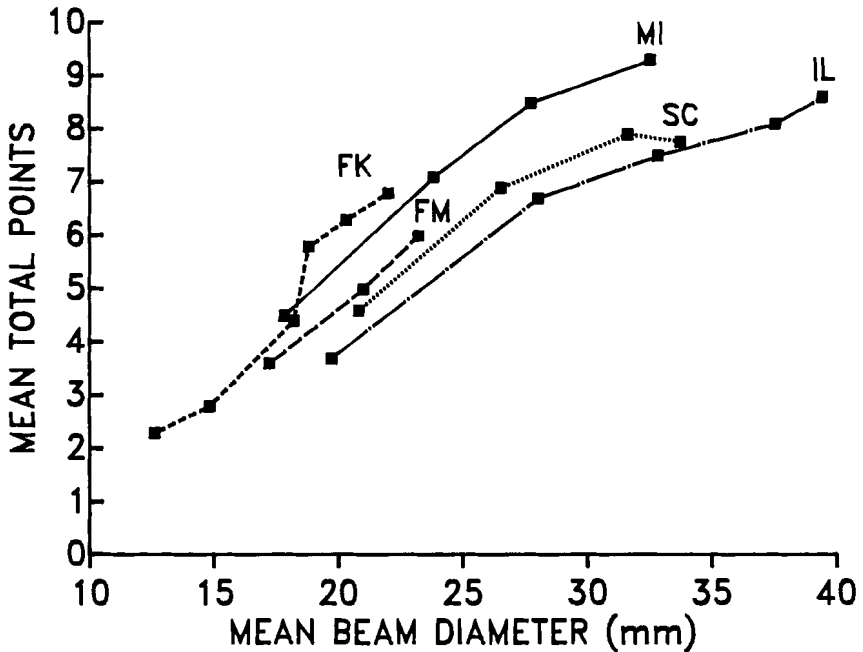


Figure 1. Age-specific antler characteristics (by age-class) of yearling and older white-tailed deer from the eastern U.S. Data for the Florida Keys (FK) and the Everglades of Florida mainland (FM) are from this study. Data from Michigan (MI) are from McCullough (1982), South Carolina (SC) are from Smith et al. (1983), and Illinois (IL) are from Roseberry and Klimstra (1975).

DISCUSSION

Chronology of antler development for Key deer was generally similar to that of other white-tailed deer populations in the southeastern U.S. Growth of antlers in deer of the Everglades occurs about the same time as for Key deer, but Everglades deer shed antlers earlier (late Nov. to Jan., Loveless 1959). White-tailed deer of Blackbeard Island, Georgia also cast antlers as early as November (Osborne 1976). The antler cycle of deer in Mississippi was similar to that of Key deer, showing an identical mean date (7 April) of antler casting (Jacobson and Griffin 1983).

Correlations of body mass with antler measurements and beam diameter with antler length were stronger for deer of the Keys than Everglades. This may be a result of less variation in physical attributes

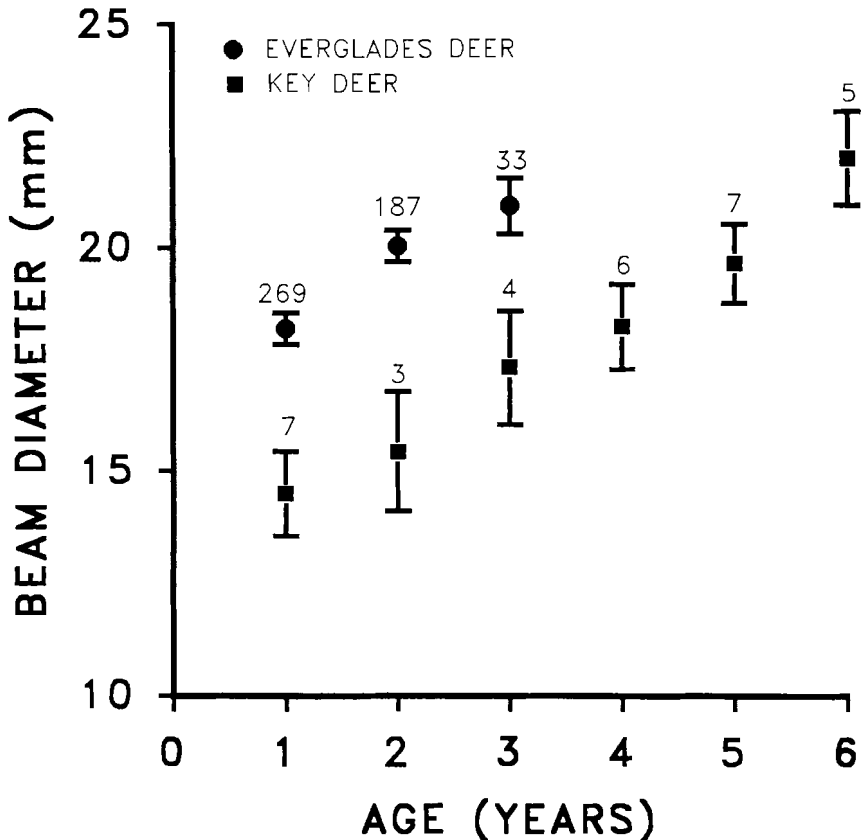


Figure 2. Means (\pm SE) of antler beam diameter, adjusted through ANCOVA for each population, to remove effects of whole body mass. Sample sizes are above error bars.

of Key deer due to small (250-300) population size (gene pool) and associated inbreeding due to confinement to islands.

Greatest increase between consecutive age-classes for means of antler measurements was later in Key deer than for deer of mainland Florida (this study), Michigan (McCullough 1982), Illinois (Roseberry and Klimstra 1975), and South Carolina (Smith et al. 1983), all of which showed greatest increases in antler characters between age-classes one and two (Fig. 1). Female Key deer reflect a similar pattern; they attain peak productivity later in life than other white-tailed deer of North America (Folk and Klimstra 1991). These delays in maturation for male and female Key deer may be associated with a deficiency of nutrients such as phosphorus (Widowski 1977) and/or other limiting aspects of their island environment.

Antler beam diameter, number of points, and body mass increase with latitude in white-tailed deer of North America (Smith et al. 1983, Baker 1984). Artiodactyls on islands are usually smaller than those on adjacent mainland (Foster 1964, Lomolino 1985). Our findings for deer from the Florida Keys and Everglades are consistent with these patterns. However, data presented for the George Reserve deer herd of Michigan (Fig. 1) represent an obvious departure. We would predict that the Michigan curve would be to the right of the other curves, but instead, these deer exhibit relatively small beam diameters. McCullough (1982) suggested that the uniqueness of antlers in these confined deer may be a result of the founder principle because the herd's source was based on only two males.

Greater mean numbers of points in Key deer for beam diameters 18-22 mm (Fig. 1) are probably a function of age in combination with their relatively small antlers. Key deer attain their maximum number of points at diameters shown by more northerly deer at much younger ages.

Proportionally larger antler size with age in deer of the Florida Keys and Everglades is not surprising because such positive intraspecific allometry (Gould 1966) is common for deer (Goss 1983).

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